INCORPORATING ECONOMIC CONSIDERATIONS INTO QUANTIFICATION, ALLOCATION AND MANAGEMENT OF THE ENVIRONMENTAL WATER RESERVE

Myles Mander • David Cox • Jane Turpie • Charles Breen

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SYNTHESIS REPORT

Prepared for the
Water Research Commission

by
Myles Mander, David Cox, Jane Turpie & Charles Breen

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Institute of Natural Resources
Private Bag X01
Scottsville 3209
Tel: 033-3460796
Fax: 033-3460895
Email: inr@nu.ac.za

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EXECUTIVE SUMMARY

1 MOTIVATION

The National Water Act, No. 36 of 1998 requires that an ecological reserve is determined and set aside to promote ecological integrity. Although the Reserve is provided for in the legislation, it will become increasingly difficult to justify the allocation of a scarce resource without showing the values and benefits provided to society through maintaining or enhancing the functioning of river ecosystems.

2 AIM

The Water Research Commission provided funding for a research project that aimed to:

- evaluate the utility of a resource economics approach in contributing to the determination of the Ecological Reserve, as described in the National Water Act 36 of 1998.

It was expected that the findings of this research programme would provide a basis for a rational decision on whether or not to apply resource economics to the determination and management of the ecological reserve.

3 APPROACH

The project adopted ecological economics, with it's focus on ecosystem goods and services, as a basis for economic analysis. Importantly, the project did not focus on the value of water abstraction as this has been the focus of numerous other studies.

The project researched and developed three approaches for using economics in the reserve determination process.

- Firstly, the project identified where and how economics should be used in establishing the Ecological Reserve and its management,
- Secondly, a multi criteria decision analysis procedure was developed for integrating economic information into decision making regarding Strategic Adaptive Management, and including the ecological reserve, management classes and resource quality objectives, and
- Thirdly, developed methods for valuing river ecosystem goods and services and tested these in the Crocodile River catchment.

The project integrated its activities with the Resource Direct Measures (RDM) process associated with national catchment management initiatives in RSA.

4 THE LESSONS LEARNED IN APPLYING RESOURCE ECONOMICS

A number of lessons emerged in applying resource economics within the context of Strategic Adaptive Management including the ecological reserve, management classes and resource quality objectives.

The concept that river ecosystems supply a range of goods and services to society has proved to be a valuable approach in river management.

Generally individuals and organisations perceive the importance or role of rivers in terms of their own experiences and needs. By using the concept of rivers as suppliers of goods and services (such as recreation, fishing, fibre source, etc), stakeholders are able to develop a more complete picture of their relationship to the river and other user groups.

Recommendation

- *The WRC should develop a handbook on ecosystem goods and services*

An ecosystem services approach promotes a common understanding of the river as a source or supplier of goods and services that serves to focus management action

Experiences from the RDM process reveal that the general public, politicians, managers and scientists have limited understanding of the implications of different management classes and resource quality objectives to the supply of ecosystem services to catchment users. A focus on river goods and services (as the desired outcomes of society's management investment) can help provide a common reference point for diverse stakeholders to reach consensus in decisions regarding Management Classes (MC), the reserve and Resource Quality Objectives (RQO).

Recommendations

- *The RDM process should articulate 'resources' in terms of river ecosystem goods and services.*
- *In the application of policy, DWAF should integrate ecosystem integrity/functionality, the supply of river ecosystem goods and services, and the demand for services, in order to promote a more balanced and focussed approach to research, management and communications.*

Valuing river ecosystem goods and services is capable of generating 'orders of magnitude' estimates to inform decisions within the RDM process

In estimating the values of river ecosystem services, one is able to identify:-

- The relative values of different river ecosystem goods and services supplied,
- The magnitude of values,
- The distribution of the benefits between various sectors in society,
- The location of the user groups (or demands), and
- The river reaches where demand is significant.

The above information on values, distribution, user groups, etc, supplied by the current river condition, are able to inform decisions in establishing the management class, ecological reserve and resource quality objectives. The valuation case study (see Table 1 below) shows that river ecosystem goods and services are key role players in local and regional economies. The value of several services, are sufficient to warrant specific consideration in the RDM process and would also be critical in directing catchment management activities.

TABLE 1 : A summary of gross values of goods and services supplied by the Crocodile River ecosystems (there a numerous assumptions and limitations associated with these)

Services supplied by the Crocodile River	Benefits of services supplied	Costs associated with the Crocodile river
Fish caught by black rural households	R10.2 million per annum in cost savings	
Provision recreation fishing associated with the river	R75.7 million expenditure per annum	
Provision of flood mitigation	Cost savings of flood mitigation not calculated	R100 million damage through flooding in 2000 (1:50 year flood)
Maintenance of river banks	Cost savings not calculated	

Sediment trapping	Negligible value in this catchment	
Provision of clean and cold water to aquaculture activities	R10.7 million per annum in gross turn-over	
Exports to marine ecosystems	Contributes to a R25 million per annum prawn fishery in Mozambique	
Provision of tourism opportunities by the Crocodile river and tributaries in Kruger National Park	R19 million per annum in on-site and off-site expenditure	
Treatment of industrial and municipal waste by the Crocodile catchment	Cost savings of R2 million per annum to municipalities and industry Benefits of clean water to consumers not estimated	
Control of pests and pathogens – particularly bilharzia	Cost saving associated with greater flows and quality not estimated	R5.5 million per annum costs associated with treatment R11 million per annum costs in terms of lost productivity to households

Recommendations

- *In the implementation of RDM procedures and catchment management, DWAF should use the value of ecosystem services, distribution of benefits and location of demand, to promote informed decision making.*
- *DWAF policy should adopt resource economics as a tool for supporting its drive to attain efficiency, sustainability and equity in the use of water resources.*
- *The following goods and services should be a priority for future resource economic analysis and research investment by DWAF and WRC due to their economic significance:-*
    - *disease control,*
    - *recreation and tourism opportunities,*
    - *flood management,*
    - *exports to marine ecosystems and*
    - *natural product harvesting (animals and plants),*

The valuation of river ecosystem goods and services has proved to be a resource intensive undertaking which may not be replicable for most catchments in South Africa

Many ecosystem services proved to be complex services requiring considerable primary research to establish predictable relationships between river functionality and the quantity and quality of ecosystem goods and services supplied. There are also considerable limitations in data availability. The intensive effort required to make such assessments is likely to constrain the widespread application of resource economics in the RDM and SAM activities.

Recommendations

- *DWAF and the WRC need to develop a strategy for making critical economic information available to the RDM and catchment management process in South Africa. The project recommends two projects for implementation.*

  Project 1 – An assessment of priority ecosystem goods and services

  Develop a set of accurate values for priority goods and services including:-
  - *disease control,*
  - *recreation opportunities,*

- *flood mitigation,*
- *waste management,*
- *natural products harvesting (including plants and animals), and*
- *exports to marine systems*

Importantly these values would not be used for quantitative purposes but rather would serve to be a widely accepted indicator of potential value that could change mindsets in water use and management.

Project 2 - a strategic decision support tool

Develop a strategic decision support tool that is able to direct the RDM process within a context of limited data, towards more socially equitable and economically efficient water resource use and management. This tool could complement the preliminary and intermediate reserve determination process practiced by DWAF.

Understanding the benefits of river ecosystem services can inform stakeholders of the tradeoff's that will be made in the RDM process

By identifying the quantity, quality, users and economic value of goods and services supplied by a river, CMA's will be able to understand the distribution of benefits, and the relative importance of the goods and services to the different river user groups. In the absence of monetary data, knowledge of the distribution of benefits (who and how many people use a particular service) may be sufficient to inform trade-off's in water allocation and management.

Recommendations

- *DWAF should identify and inform stakeholders of:*
    - *the tradeoff's between the benefits and costs accruing from various allocations/management actions that are likely to result from the RDM process,*
    - *what stakeholder groups will be impacted by tradeoff's, and*
    - *what the distribution of costs and benefits will be.*
- *As DWAF policy moves towards a 'user pays' approach, information on the values and the distribution of benefits and costs associated with the use of river ecosystem goods and services, should direct policy and management interventions.*

Multi criteria decision analysis (MCDA) is a option for integrating economics into Strategic Adaptive Management and the RDM

An assessment of the RDM process revealed that there was no clear mechanism for integrating economic information into the decision making process. There are a number of steps in the Strategic Adaptive Management framework and RDM process which should include economic information. These include:

- Decisions on feasible options for supply and demand management (i.e. increasing efficiency of water use);
- Development of a catchment vision, setting of MC and RQO;
- Decisions on allocation between river reaches or quaternary catchments;
- Decisions on allocation of allocatable water resources within reaches.

With each of these decisions, there are stakeholders that will benefit, while others may have costs. The MCDA process involves evaluating or 'scoring' alternatives from different points of view (economic, ecological and social criteria) and combining these separate scores to obtain an overall ranking of alternatives which best reflects society's desires.

Recommendations

- *Economic information generated needs to be integrated by DWAF into decision making and multi criteria decision analysis should be tested as a means to integrate economic, social and ecological information within the RDM and SAM frameworks.*

Strategic decision making is necessary within the context of the RDM and catchments

Within the existing SAM framework, the RDM process is designed to take place at the level of a river reach. There are thus two possible options for making decisions at the level of individual resources (e.g. river reaches):

- Option 1 – The RDM is applied **sequentially** from mouth to source, and the constraints set at each reach. This gives automatic priority to lower reaches and estuaries, and the degree of flexibility afforded to higher reaches will be highly dependent on the natural augmentation of supplies via tributaries etc.
- Option 2 - A **strategic assessment** is made whereby all resources within a catchment are assessed together. This would attempt to promote the optimal allocation of water and water quality objectives *between its component resources.* This will still require stepwise setting of constraints from mouth to source, but will not automatically give priority to lower reaches and estuaries. It means that MC of one reach could be altered downwards to service the needs of another reach.

Recommendations

- *DWAF should adopt a strategic approach to the assessment of catchments and reaches. Major allocation decisions need to be taken at a catchment or WMA level, and need to form part of the catchment vision within SAM. This can then inform decisions with regard to setting the management class, the reserve and RQO for reaches.*

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Department of Agriculture (Mpumalanga)
Department of Health (Mpumalanga)
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Tourist lodges and B&B's
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1 BACKGROUND AND MOTIVATION

In 1995, the South African Department of Water Affairs and Forestry embarked upon a process to reformulate the national water legislation, and published a document entitled 'Discussion Document: Water Law Principles' for public comment. Amongst many other principles, this document recognised;

- ***Principle C.3***

  The quantity, quality and reliability of water required to maintain the ecological functioning on which humans depend should be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems.

- ***Principle C.4***

  The water required to meet peoples' basic domestic needs and the needs of the environment should be identified as "the Reserve" and should enjoy priority of use."

The National Water Act, No. 36 of 1998 incorporates these principles and requires that the ecological reserve is determined and set aside before subsequent allocation of resources between users. Although the Reserve is provided for in the legislation, it is believed that it will become increasingly difficult to justify the allocation of a scarce resource without showing the values and benefits (goods and services) provided to society through maintaining (or enhancing) the functioning of ecological systems within rivers.

Furthermore, the public debate which will develop around the quantification, allocation and management of the Reserve will be enhanced if a clear understanding of the range of services supplied to society by the Reserve.

2 AIM AND OBJECTIVES

The Water Research Commission provided funding for a research project that aimed to:

- evaluate the utility of a resource economics approach in contributing to the determination of the Ecological Reserve, as described in the National Water Act 36 of 1998.

It was expected that the findings of this research programme would provide a basis for a rational decision on whether or not to apply resource economics to the determination and management of the ecological reserve. It was expected that the project would also provide insight into the application of resource economics in the wider field of integrated catchment management. The key objectives of the project were:

- The development of a framework for incorporating economic criteria into the quantification, allocation and management of the ecological reserve for rivers
- The application of the framework in a case study to provide a practical example of the applicability of the approach
- The enhancement of current methodologies for establishing the environmental reserve through the incorporation of the economic value and services of water within river ecosystems

In addition to the above, a number of secondary objectives were identified, and include:

- An analysis of the policy implications of adopting the framework
- Building capacity in resource economics with particular reference to water resource management
- Building capacity in stakeholder groups to enhance awareness of the role of resource economics in water resource management
- Strengthening the national and regional (SADC) network of researchers through the sharing and exchange of information and understanding
- The development of a proposal for a collaborative regional initiative on the application of resource economics to allocation and management of water for the environment

3 METHODS APPLIED IN THE STUDY

The project had an ambitious agenda to follow given that such an approach had not been attempted before. The project took on an exploratory approach using primary and secondary research, and workshops to pursue various approaches developed.

Not all endeavors produced the anticipated outcomes with several 'dead ends' emerging which served to direct the investigation. In addition, the project attempted to integrate its activities with the Resource Direct Measures (RDM) process associated with national catchment management initiatives in RSA. As this process was in a development phase, its dynamic nature necessitated changes in the approach adopted by the project.

In anticipation of a dynamic project, the project team maintained regular documentation of the project findings and produced six issue papers at significant junctures along the way to document the progress and changes in direction. Three issue papers are included in this synthesis report as they constitute useful information for the river management community.

While the ecological reserve is a requirement for rivers, estuaries, wetlands and ground water, this project focussed on rivers to make the research task more manageable.

The project was undertaken in three phases which included:

- Conceptual development phase
- Framework development phase, and
- Testing phase

3.1 Conceptual development

The first phase of the project considered the problems associated with river ecosystem management in order to identify a useful and practical approach for application of economics. In most cases the value of rivers to society is vague while the benefits of water abstraction are explicit and quantifiable. The lack of quantifiable river ecosystem benefits and a clear understanding of the river users, precluded the identification of stakeholders and the valuation of river benefits. Consequently, the project adopted ecological economics with it's focus on ecosystem goods and services as a basis for economic analysis.

Importantly, the project did not focus on the value of water abstraction as this has been the focus of numerous other studies. The river ecosystem benefits and not the water abstraction benefits were the focus of this study. Furthermore, the study had a strong emphasis on promoting sustainable use of river services with a view to supporting the legislation requiring the establishment of an Ecological Reserve.

3.2 Frameworks developed

A framework for incorporating economics into the decisions regarding the Ecological Reserve was developed and is outlined in Issue Paper No 1, and includes:

- an approach for using economics to value river ecosystem goods and services supplied by the Ecological Reserve,
- a multi criteria decision analysis procedure for integrating economic information into decision making regarding the ecological reserve, management classes and resource quality objectives, and
- methods for valuing river ecosystem goods and services.

3.3 Testing the approaches recommended

The project tested the application of several approaches developed during conceptual phase:

- The methods for identifying and valuing ecosystem goods and services supplied by an ecological reserve (Issue paper No 1) were tested within the Crocodile River catchment and are outlined in Issue Papers No 2 and 3. Several values could not be generated due to limitations in current understanding, poor data availability and methodological problems. Several methods for valuing services where revised to deal with emerging problems. Alternatively the research needs required to address limitations in data and understanding were highlighted (see Issue Paper No 3).
- The multi criteria decision process and the integration of resource economics information in decision making (Issue Paper No 1) were not tested as conditions in the Crocodile River catchment management process were not conducive to testing the framework.

4 THE LESSONS LEARNED IN APPLYING RESOURCE ECONOMICS

A number of lessons emerged in applying resource economics within the context of quantifying and managing the ecological reserve for rivers. In addition, the lessons learned have helped inform river management initiatives of the potential use of resource economics in management practice. These lessons and their recommended application, are discussed as a summary of the research in the following section. The detailed findings of the research are documented in Issue Papers No 1, 2 and 3, and are referred to in the lessons emerging.

4.1 The concept of river ecosystem goods and services and their values are useful in process of setting the management class, the reserve and the resource quality objectives

8.1.1 An ecosystems services approach promotes a broader understanding of the benefits of rivers

The concept that river ecosystems supply a range of goods and services to society has proved to be a valuable approach in river management. Generally individuals and organisations perceive the importance or role of rivers in terms of their own experiences and needs. For example, people see rivers as:

- a source to harvest weaving and medicinal plants,
- a water surface for canoeing and rafting,
- a place to catch fish,
- a refuge or corridor for wild animals,
- a site for sand winning,
- an attractive setting to establish a tourist lodge,
- a place to picnic,
- a system which mitigates floods,
- a source of cholera and bilharzia,
- a sacred site for cultural and religious activities,
- a threat to road infrastructure due to flooding impacts,
- a source of construction timber for building materials,
- a sink to discharge effluent into, and
- a source of water for irrigation farming, industrial production and household use.

By generating a comprehensive list of ecosystem goods and services supplied to society by rivers, stakeholder groups become aware that their use is only one of many.

Furthermore, by understanding what range of goods and services the river supplies, stakeholders can identify who also relies on the river for economic, social and environmental benefits. By using the concept of rivers as suppliers of goods and services, stakeholders are able to develop a more complete picture of their relationship to the river and other user groups (See Figure 1).

Recommendations

- *The WRC should develop a handbook on ecosystem goods and services, their values and beneficiaries, for use by river management stakeholders including; DEAT, DWAF, Catchment Management Agencies (CMA), WRC, other government departments and user groups.*

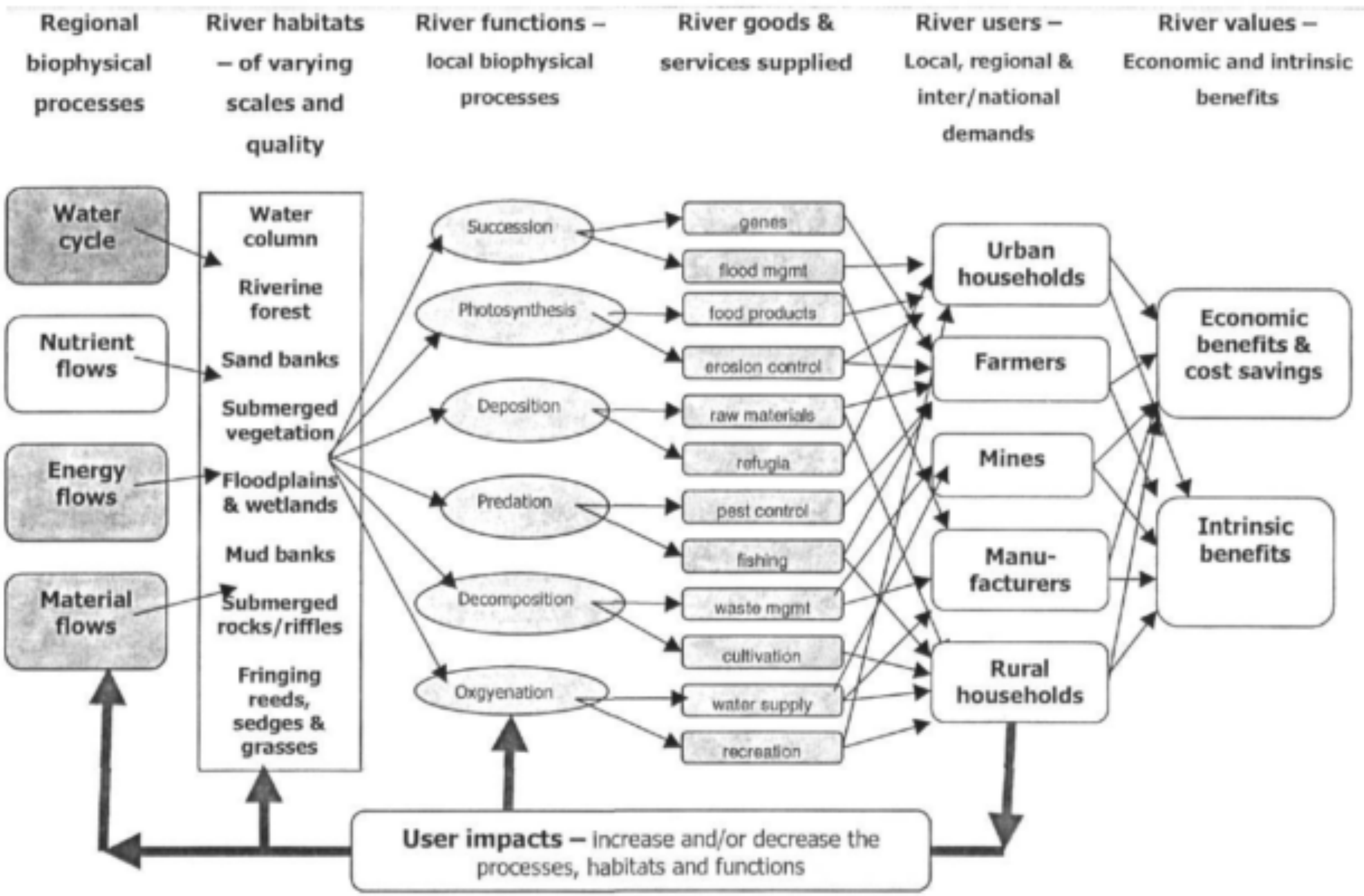

Figure 1: A model to show river management stakeholders the relationship between river ecosystems, the supply goods and services, the demands by different user groups and the benefits to users

8.1.2 An ecosystem services approach promotes a common understanding of the river as a source or supplier of goods and services can focus management action

Different stakeholder groups have different perceptions when they talk about management classes and Resource Quality Objectives (RQO). For example:

- Managers may think in terms of providing access to specific water volumes and water quality,
- Aquatic scientists may think in terms of promoting a certain level of ecosystem functional integrity,
- River users may think in terms of what benefits they can gain by using the river,
- Politicians may think of rivers as opportunities for economic growth.

Experiences from the RDM (resource directed measures) process that is progressing in South Africa, reveal that the general public and politicians have limited understanding of the implications of different management classes and resource quality objectives for their own wellbeing or society's welfare. While on the other hand managers and scientists are not clear of the implications of different management classes to the supply of river ecosystem goods and services to catchment users.

River ecosystem goods and services provide a common currency for discussion, with ecosystem functionality generating goods and service, and the use of these services generating benefits to society (see Figure 1). The driving issues for society are – will there be more or less plants to harvest, will the river be able to assimilate more or less pollutants, will there be more or less water to drink. Thus a focus on river goods and services can help provide the common reference point for diverse stakeholders to contribute to decisions about management classes, the reserve and RQO.

Recommendations

- *The RDM process should articulate 'resources' in terms of river ecosystem goods and services. For example, management classes, the reserve and RQO should be articulated in terms of the quantity and quality of river ecosystem goods and services that enables affected stakeholders to have a clear understanding of the implications of changes in the functioning of river ecosystems.*

- *In the application of policy, DWAF should integrate:-*
    - *ecosystem integrity/functionality,*
    - *the supply of river ecosystem goods and services, and*
    - *the demand for services,*

in order to promote a more balanced and focussed approach to research, management and communications.

8.1.3 Valuing river ecosystem goods and services is capable of generating 'orders of magnitude' estimates to inform decisions regarding the RDM process

The case study (see Issue Papers No 2 and 3) valued a number of goods and services supplied by the Crocodile river catchment (see Table 1). There were significant limitations in data availability, the type of data available, budgets and current understanding of the linkages between river functionality and ecosystem services supply.

Consequently, numerous assumptions had to be made in making an economic analysis thereby limiting our confidence in these estimates. However, we believe that the estimated values are indicative of the 'orders of magnitude' of current benefits and provide a useful first estimate of value.

On the other hand, the distribution of benefits was accurately identified, showing who benefited or was exposed to costs resulting from the use of river ecosystem goods and services. Furthermore, the benefits or costs were reach specific, indicating where the benefits or costs of river use are located.

In summary, in estimating values one is able to identify:-

- The relative values of different river ecosystem goods and services supplied,
- The magnitude of values,
- The distribution of the benefits between various sectors in society,
- The location of the user groups (or demands), and
- The river reaches where demand is significant.

The above information on values, distribution, user groups, etc, supplied by the current river condition, are able to inform decisions in establishing the management class, ecological reserve and resource quality objectives.

TABLE 1 : A summary of gross values of goods and services supplied by the Crocodile River ecosystems (there a numerous assumptions and limitations associated with these estimates – see Issue Papers No 2 and 3 for details)

Services supplied by the Crocodile River	**Benefits of services supplied**	**Costs associated with the Crocodile river**
Fish caught by black rural households	R10.2 million per annum in cost savings	
Provision recreation fishing associated with the river	R75.7 million expenditure per annum	
Provision of flood mitigation	Cost savings of flood mitigation not calculated	R100 million damage through flooding in 2000 (1:50 year flood)
Maintenance of river banks	Cost savings not calculated	
Sediment trapping	Negligible value in this catchment	
Provision of clean and cold water to aquaculture activities	R10.7 million per annum in gross turn-over	
Exports to marine ecosystems	Contributes to a R25 million per annum prawn fishery in Mozambique	
Provision of tourism opportunities by the Crocodile river and tributaries in Kruger National Park	R19 million per annum in on-site and off-site expenditure	
Treatment of industrial and municipal waste by the Crocodile catchment	Cost savings of R2 million per annum to municipalities and industry	

	Benefits of clean water to consumers not estimated	
Control of pests and pathogens – particularly bilharzia	Cost saving associated with greater flows and quality not estimated	R5.5 million per annum costs associated with treatment R11 million per annum costs in terms of lost productivity to households

The valuation case study shows that river ecosystem goods and services are key role players in local and regional economies. The magnitude of:

- expenditure on recreation fishing,
- costs incurred through contracting bilharzia,
- expenditure by tourists associated with the Crocodile river in KNP, and
- cost savings made by local communities in harvesting natural products,

are sufficient to warrant specific consideration in the RDM process, including setting the reserve and defining the RQO. These values would also be critical in directing catchment management activities.

Recommendations

- *In the implementation of RDM procedures and catchment management, DWAF should use the value of ecosystem services, distribution of benefits and location of demand, to promote informed decision making.*

- *DWAF policy should adopt resource economics as a tool for supporting its drive to attain efficiency, sustainability and equity in the use of water resources.*

- *The following goods and services should be a priority for future resource economic analysis and research investment by DWAF and WRC due to their economic significance:-*
    - *disease control,*
    - *recreation and tourism opportunities,*
    - *flood management,*
    - *exports to marine ecosystems and*

- *natural product harvesting (animals and plants),*

In our opinion sediment trapping and maintenance of bank stability should not be further researched from an resource economics perspective.

8.1.4 The valuation of river ecosystem goods and services has proved to be a resource intensive undertaking which may not be replicable for most catchments in South Africa.

The following ecosystem services, proved to be complex services requiring primary research to establish predictable relationships between river functionality and the quantity and quality of ecosystem goods and services supplied (see Issue Papers No 2 and 3):

- Flood mitigation,
- Tourism,
- Maintenance of bank stability,
- Waste management,
- Disease control,
- Exports to marine ecosystems, and
- Sediment trapping.

Of the above only tourism and waste management services could be valued adequately, and these required considerable investment. For example, in valuing the tourism services in Kruger National Park (see Issue Paper No 2) seventeen researchers invested three weeks each (a total of 51 weeks) in generating the essential data and making the valuation. This level of effort was not repeatable for any other services due to project budget limitations and is likely to be a common constraint for any RDM and catchment management activities in RSA.

Recommendations

- *DWAF and the WRC need to develop a strategy for making critical economic information available to the RDM and catchment management process in South Africa. The project recommends two projects for implementation.*

Project 1 – An assessment of priority ecosystem goods and services

Develop a set of accurate values for priority goods and services including:-

- *disease control,*
- *recreation opportunities,*

- *flood mitigation,*
- *waste management,*
- *natural products harvesting (including plants and animals), and*
- *exports to marine systems*

These values can then be used to inform decision making in the RDM process and in CMA's. Importantly these values would not be used for quantitative purposes but rather would serve to be a widely accepted indicator of potential value that could change mindsets in water use and management.

Project 2 - a strategic decision support tool

Develop a strategic decision support tool that is able to direct the RDM process within a context of limited data, towards more socially equitable and economically efficient water resource use and management. The tool should include:

- *user satisfaction of ecosystem goods and services demanded and*
- *scientific wisdom regarding river capabilities in supplying ecosystem goods and services.*

This tool could complement the preliminary and intermediate reserve determination process practiced by DWAF.

8.1.5 Understanding the benefits of river ecosystem services can inform stakeholders of the tradeoff's that will be made in the RDM process

The identification of goods and services supplied by rivers and the associated beneficiaries are important aspects of making management class, reserve and RQO decisions. By identifying the quantity, quality, users and economic value of goods and services supplied by a river, CMA's will be able to understand the distribution of benefits, and the relative importance of the goods and services to the different river user groups.

Importantly, it is not always necessary to know the monetary implications of trade-offs. Decision making usually includes both monetary and value judgements. In the absence of monetary data, knowledge of the distribution of benefits (who and how many people use a particular service) may be sufficient to inform a decision. Generally well organised lobbies (such as municipalities and large corporations) have been able to argue for water abstraction/effluent discharges as they are able to show what they contribute to the economy. The other user groups, usually dispersed and unorganised, have not been able quantify and therefore articulate their economic value.

This valuation exercise has helped to provide a more balanced view of the range, benefits and beneficiaries of rivers in society. For example, the costs to society of water borne parasites such as bilharzia (its vectors are closely associated to water flow) do not appear to be considered when directing river management. The case study (Issue Paper No 3) has revealed that in some schools in the Crocodile River catchment, up to 80% of pupils are infected. It is estimated that amongst adults there is an average loss of 3 days a year in absenteeism due to the disease. This is in addition to the daily debilitating effects of the disease. The costs to households and society of these impacts are substantial and the case study has highlighted these. A comparison of costs and socio-economic status of the rural communities exposed to water-borne disease, further highlights potential inequity in water allocation and inform decisions in the management of water resources.

Recommendations

- *DWAF should identify and inform stakeholders of:*
    - *the tradeoff's between the benefits and costs accruing from various allocations/management actions that are likely to result from the RDM process,*
    - *what stakeholder groups will be impacted by tradeoff's, and*
    - *what the distribution of costs and benefits will be.*

This information should be used to empower CMA's, DWAF and key stakeholders in the RDM process. Importantly, stakeholder organisations should be made aware of tradeoff's that may be made and the implications of the tradeoff's for their own wellbeing. This will provide for greater and more informed dialogue around setting management classes, the reserve and RQO.

- *As DWAF policy moves towards a 'user pays' approach, information on the values and the distribution of benefits and costs associated with the use of ecosystem goods and services will assist in directing policy and management interventions.*

4.2 A decision making framework in the Resource Directed Measures (RDM) process is necessary for integrating ecological, social and economic demands

8.2.1 Multi criteria decision analysis (MCDA) is a option for integrating economics into Strategic Adaptive Management and the RDM

An assessment of the RDM process revealed that there was no clear mechanism to integrate economic information and to make informed trade-off's in the decision making process. Consequently the project team became involved in a DWAF process of developing Strategic Adaptive Management (SAM) for catchments and subsequently developed a mechanism (a multi criteria decision analysis (MCDA)) for integrating economic information into SAM for catchments and RDM process (see Issue Paper No 1). We were however not able to test this decision making framework within the project term. However, several important lessons emerged.

There are a number of steps in the SAM framework or activities in RDM which involve making decisions (or making trade-offs) or reaching consensus among stakeholders. These include:

- Decisions on feasible options for supply and demand management (i.e. increasing efficiency of water use);
- Development of a catchment vision, setting of MC and RQO;
- Decisions on allocation between river reaches or quaternary catchments;
- Decisions on allocation of allocatable water resources within reaches.

With each of these decisions, there are stakeholders that stand to lose and others that will gain. Conventional economics reaches decisions on the basis of maximising net economic value to society by considering trade-offs in monetary terms. However, economics is not a particularly good tool in terms of solving problems of equity and sustainability, and also fails where there are values that cannot easily be translated into monetary terms.

Multi Criteria Decision Analysis (MCDA) can offer decision support in the steps above as:

- it does not require a monetary value for each benefit;
- it can include non-linear preference scales;

- it can include equity and sustainability issues specifically as criteria, or through different weighting systems, and/or through the direct input of stakeholder values in the decision-making process; and
- it can include both qualitative and quantitative inputs.

In summary, the MCDA process involves evaluating or 'scoring' alternatives from different points of view (criteria) and combining these separate scores to obtain an overall ranking of alternatives.

Recommendations

- *Economic information generated needs to be integrated by DWAF into decision making. Within the existing RDM documentation, economics may be construed as contributing to the decision in setting the environmental management class (EMC). We strongly recommend that this is not the case, and that the economic input is used within an integrative process.*

- *It is recommend that multi criteria decision analysis is considered as a means to integrate economic information into the RDM and SAM frameworks. We therefore propose that MCDA be tested by a CMA as a tool for potential application by DWAF within Strategic Adaptive Management at a national scale. As the proposed MCDA process may be complex, we further recommend that the testing be used to develop a more simple process.*

8.2.2 Strategic decision making is necessary within the context of catchments and the RDM

Within the existing SAM framework, the RDM process is designed to take place at the level of a river reach. In other words, decisions are to be taken for each component of a system that forms part of a Water Management Area (WMA). The decisions and actions taken in one component will affect, and be affected by, decisions and actions taken in other components of the system (Fig. 2).

Figure 2. Linkages between different reaches considered separately in the RDM process.

Figure 2 illustrates a simple example in which a catchment contains two river reaches, a wetland and an estuary. Considering the linkages between these, the following will have to be taken into account:

- The possible RQO for a reach will be constrained by the input requirements determined by the reserve and RQO of downstream reaches, wetlands and esturaries (or international obligations).

There are thus two possible options for making decisions at the level of individual resources (e.g. river reaches):

- Option 1 – The RDM is applied **sequentially** from mouth to source, and the constraints set at each reach. This gives automatic priority to lower reaches and estuaries, and the degree of flexibility afforded to higher reaches will be highly dependent on the natural augmentation of supplies via tributaries etc.

- Option 2 - A **strategic assessment** is made whereby all resources within a catchment are assessed together. This would attempt to promote the optimal allocation of water and water quality objectives between its component resources. This will still require stepwise setting of constraints from mouth to source, but will not automatically give priority to lower reaches and estuaries. It means that MC of one reach could be altered downwards to service the needs of another reach.

Recommendations

- *DWAF should adopt a strategic approach to the assessment of catchments and reaches. Thus at a catchment or WMA level, the following will first need to be taken into consideration in order to set the **initial constraints** in the catchment-level assessment:*
    - *Basic Human Needs*
    - *International and national legal obligations*

Following this it will be necessary to understand the existing demands for water resources within a catchment, the relative magnitude and distribution of benefits and costs, and the linkages and trade-offs operating between water resources in the catchment. Thus major allocation decisions need to be taken at a catchment or WMA level, and need to form part of the catchment vision within SAM. This can then inform decisions with regard to setting the management class, the reserve and RQO for reaches.

The implications for the RDM process is that an integrative mechanism is required to make strategic decisions about the goods and services supplied and demanded within catchments, that can integrate reach management actions for catchment scale objectives. We propose that DWAF uses a MCDA to test such an integrative approach within a CMA.

5 THE ISSUE PAPERS

5.1 A proposed framework for incorporating economic criteria into the quantification, allocation and management of the environmental reserve for rivers

5.2 The tourism value of rivers in and adjacent to Kruger National Park, and impacts of a change in river quality

5.3 The methodology used and estimates made for the value of selected ecosystem services supplied by the Crocodile River Catchment

INCORPORATING ECONOMIC CONSIDERATIONS INTO THE DETERMINATION OF THE ENVIRONMENTAL RESERVE:

Proposed framework for incorporating economic criteria into the quantification, allocation and management of the environmental reserve for rivers

Issue Paper No 1

October 2001

Prepared by
Jane Turpie, Alison Joubert, Myles Mander

Institute of Natural Resources
Private Bag X01
Scottsville 3209
Tel: 033 – 3460 796
Fax: 033 – 3460 895
Email: Ceo@nu.ac.za

In association with:
Percy FitzPatrick Institute (UCT)
Dept of Statistical Sciences (UCT)
Dept. Water Affairs and Forestry
CSIR
Botany Department (WITS)
South African National Parks

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Acronyms

CMA Catchment management agency
CMS Catchment management strategy
DFS Desired future state
DWAF Department of Water Affairs and Forestry
EMC Ecological management class
MC Management class
PES Present ecological state / status
RDM Resource directed measures
RQO Resource quality objectives
SAM Strategic adaptive management
MAR Mean annual run-off

1. THE FRAMEWORK IN WHICH ENVIRONMENTAL ECONOMICS CAN BE USED

The White Paper on water resources and the National Water Act of 1998 require the implementation of four types of regulatory activities in order to make optimal use of our country's water resources while minimizing ecological damage:

1. **resource-directed measures**, i.e. defining a desired level of protection for a water resource (the management class), and on that basis, setting clear numerical or descriptive goals for the resource quality of the resource (the Reserve and Resource Quality Objectives (RQO));
2. **source-directed controls**, i.e. controlling impacts on the water resource through the use of regulatory measures such as registration, permits, directives and prosecution, and economic incentives such as levies and fees, in order to ensure that the RQO are met;
3. **managing demand** on water resources in order to keep utilisation within the limits required for protection;
4. **monitoring** the status of the country's water resources on a continual basis, in order to ensure that the RQO are being met, and to enable us to modify programmes for resource management and impact control as and when necessary.

In order to achieve this, the country has been divided into water management areas (WMA), each of which will be managed by a Catchment Management Agency (CMA). Within these WMAs, it has been proposed to use a system of Strategic Adaptive Management (SAM), in recognition of the fact that the methods for decision making with regards to water resource allocation and management are still to be fully developed and tested (CSIR Crocodile River Workshop, 2000). Adaptive management also lends itself to development of creative strategies for achieving the national policy objectives. Within each WMA, the CMA will be involved in the development of a catchment vision and the implementation of the measures described above, as well as the development of a catchment management strategy. A framework was developed to structure the necessary steps in a SAM process and these are outlined below [see figure 1]:-

1. Strategic Balance of current and future (vision, management class and current class)
2. Components of future (reserve and resource objectives, allocation plan and resource use goals)
3. Catchment Management Strategies
4. Implementation plan
5. Operational, monitoring and implementation
6. Auditing and
7. Review and reflection.

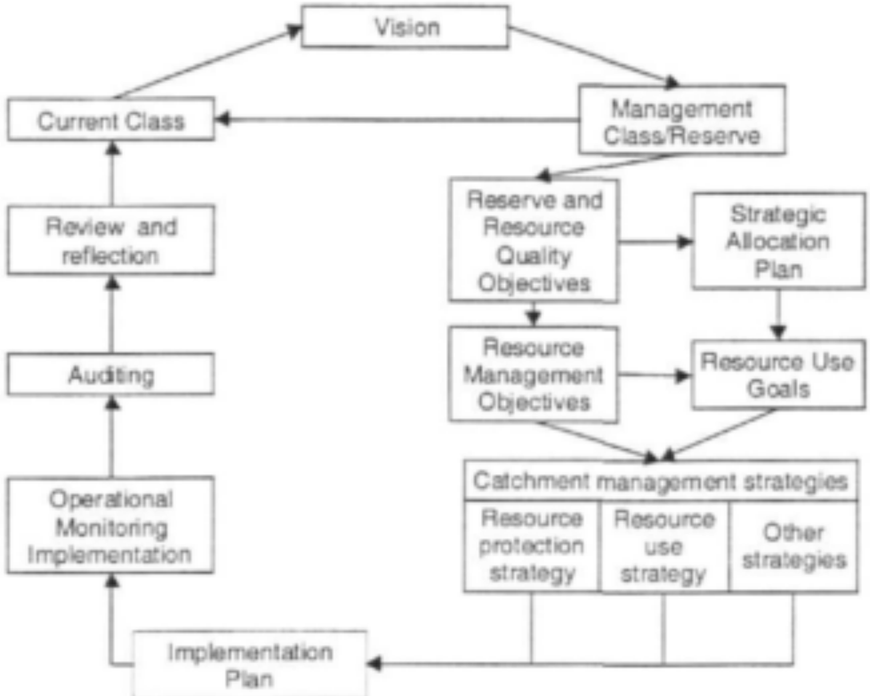

Figure 1. Proposed path of the strategic adaptive management of water resources by DWAF and CMAs, as of March 2000 [From CSIR Crocodile River 2000 Workshop]

Within the SAM framework, key decisions are taken in the first two steps. It is envisaged that multiple criteria decision-making analysis will be used to develop the vision, establish the management class, Reserve and RQO. The decision-making process will be discussed later in the document. However, environmental economics has a key role to play in informing the decisions at this early stage. It is at this point that key conflicts may arise, and therefore the trade-off's that will be made need to be clearly understood.

The so-called resource-directed measures (RDM) include the determining of RQO and Reserve of each water resource within the catchment. Water resources within a catchment include groundwater, estuaries, wetlands and river reaches. The reserve is the water quality and quantity required for the protection of basic human needs and aquatic ecosystems. For each resource, an ecological management class (EMC) will be determined on the basis of a resource's health and importance status, and the EMC will help to inform decisions regarding the management class (MC). The MC will, in turn, determine the RQO. Thus important resources will be assigned to higher MCs and will be allowed less potential perturbation than those assigned to lower MCs.

In general, the RDM has a six-step methodology which can be carried out at three levels to produce a rapid, intermediate or comprehensive determination of the Reserve (DWAF, 1999):

1. identifying significant water resources;
2. determining the ecological type;
3. determining the reference conditions;
4. determining the current resource status;
5. determining the EMC and taking other factors into consideration, the final MC and

6. setting the Reserve in quantifiable, measurable terms (on the basis of MC).

Each level of assessment (rapid, intermediate or comprehensive) involves an increasing level of complexity of data requirements and analysis. At present it is envisaged that rapid and intermediate assessments will use the EMC as the preliminary MC of a resource. This follows the precautionary principle, in that the MC cannot be set at a lower class than the EMC under conditions of partial information gleaned from short-term studies. In a comprehensive RDM procedure, it is envisaged that the MC will be set on the basis of other social and economic criteria as well as EMC, in a participative process. The MC of a resource determines the size and quality of the Reserve, and the amount of water that can be allocated (or inputs that can be tolerated).

The allocation of water to potential users will require an additional round of decision making, where economic considerations play a key role. It may transpire that the allocation decisions and decisions about the size of the reserve are interlinked, as proposed in this document. For example, recreational water users may be able to use the environmental reserve.

Within the SAM process, the development of a catchment management strategy will play a critical role in managing the supply and demand of water resources, through incorporation of source directed controls and demand management. These measures have their basis in economics, and thus economic considerations are also vital in this stage of the catchment management process.

The main aim of this discussion paper is to develop a framework for incorporating economic considerations in the determination of a catchment vision and MC with associated Reserve and RQO for directing management.

2. WHAT DO WE MEAN BY ECONOMIC CONSIDERATIONS?

Economics is essentially about the way in which **trade-offs** influence human decision-making. These tradeoffs are seen from a human welfare point of view. Tradeoffs are always made when making decisions about scarce resources, and water is a particularly scarce resource in South Africa. Thus in allocating water to one use, the opportunity to use it for another use is foregone, and the value of this other use is the opportunity cost of putting it to the first use. These tradeoffs are experienced not only in the allocation of water between such uses as irrigation, industry or domestic use, but also between the extraction of water for these purposes and leaving the water in the system. Leaving the water in the system, or maintaining its quality, has an opportunity cost in the form of lost industrial output, etc., but also generates economic value. Functioning aquatic ecosystems generate goods (natural products e.g. fish, reeds) and services (e.g. water purification, flood attenuation) whose abundance and quality is affected by the quantity and quality of water flow. Until relatively recently, the value of these ecosystem goods and services have largely been ignored in decision-making, to the detriment of ecosystems, their functioning and human wellbeing which depends on these services. The framework and methodology presented here concentrates on the incorporation of economic values associated with aquatic ecosystems into the decision processes outlined above.

In recent years, three main **policy goals** have emerged: **efficiency**, **equity** and **sustainability**. These are embodied in the motto of the current water policy: "*some, for all, for ever*".

The goal of efficiency concentrates on maximising economic returns to aquatic ecosystems, or achieving the greatest possible net benefit. The goal of equity is to ensure that the economic benefits obtained from aquatic ecosystems are distributed fairly. The sustainability goal recognises the limits to aquatic resources in the light of population growth and economic development, and aims to use aquatic resources in such a way as not to compromise the economic opportunities of future generations.

Traditional economic approaches have had a rather narrow view of the economic issues surrounding the use and management of aquatic resources. In the past, maximising economic efficiency has effectively meant the maximisation of benefits which contribute directly to standard measures of economic performance, such as GDP. Sustainability has been perceived in terms of sustaining the benefits from economic activities associated with the direct use of water from aquatic systems, rather than sustaining a full range of benefits, including ecosystem services, including biodiversity.

Aquatic ecosystems are used as inputs and outputs in economic processes. Water provides an input into economic production in sectors such as agriculture, electricity and domestic consumption, and water and aquatic habitats are vital for the transport and absorption of waste products. The value of water is most readily appreciated as an input into economic production. This may be termed the '**direct consumptive use value**' of water. Thus dams and other infrastructure facilitate the transfer of water into economic processes of which the products are easily measurable as the economic benefits yielded by the investments in supply infrastructure. However, the economic impacts of modification of river flows and aquatic ecosystems by this abstraction are generally unknown.

Economic production cannot occur without the emission of waste products. However, the use of water resources to dissipate the wastes of economic systems are seldom quantified as economic benefits provided by the aquatic environment. Furthermore, when waste disposal into aquatic systems exceeds their absorption capacity, the environmental damages that impact on the other river users are similarly unaccounted for. These environmental damages, resulting from the reduction of water quantity and quality, are known as '**externalities**' in the economic production process.

Irrespective of whether they directly use water resources, human economic activities in general impact further on the health of water resources. The development of catchment areas for agriculture or other landuses may impact on water resources through processes such as soil erosion, pollution runoff and increased evapotranspiration. In addition, the invasion of alien plants and animals threaten the integrity of aquatic ecosystems and plant invaders of catchment areas affect the quantity and quality of water runoff available for ecological and associated economic systems.

In order to address the goals of efficiency, equity and sustainability, all of these issues need to be addressed. Sustainable use of water *per se* can be achieved at varying levels, but with varying environmental consequences. Ideally, these costs and benefits should be traded off against one another to find an optimal level of protection or damage. Economic productivity achieved by means of the abstraction and pollution of water resources has to be traded off against the benefits of maintaining a healthy ecosystem. Similarly, the expense of control of alien plants in catchment areas and aquatic systems can only be justified if the resultant benefits exceed the costs. Thus, in order for society or governments to take cognisance of the value of environmental reserve, it will be necessary to understand the full economic implications of the degradation of aquatic systems and to account for them as opportunity costs[1] to the damaging economic activities and current management approaches. Understanding the opportunity cost implications of water supply and allocation is thus central to making informed decisions on development and allocation trade-offs. Understanding the value of the Reserve is thus critical to decision making.

Apart from identifying the changes to the supply of benefits and costs, economics can help to identify the changes in the distribution of the benefits and costs. Distribution

[1] The opportunity cost of an activity is the foregone benefit that could be obtained from the next most productive activity.

issues are particularly important in South Africa where particular groups of users have been disadvantaged in the past.

3. INCORPORATING ECONOMICS INTO RDM: BASIC FRAMEWORK

Three parallel processes converge to determine the MC, and thence the Reserve and RQO of a water resource (Fig. 2):

1. An assessment of basic human needs (BHN), which determines the quantity and quality of water that must be made available for direct consumption (in-situ use, or water 'harvesting').
2. An ecological assessment which culminates in determination of EMC, which is essentially the ecologists' desired final MC.
3. An assessment of the social and economic use and value of the resource (values of water use and ecosystem service values) and stakeholder wants.

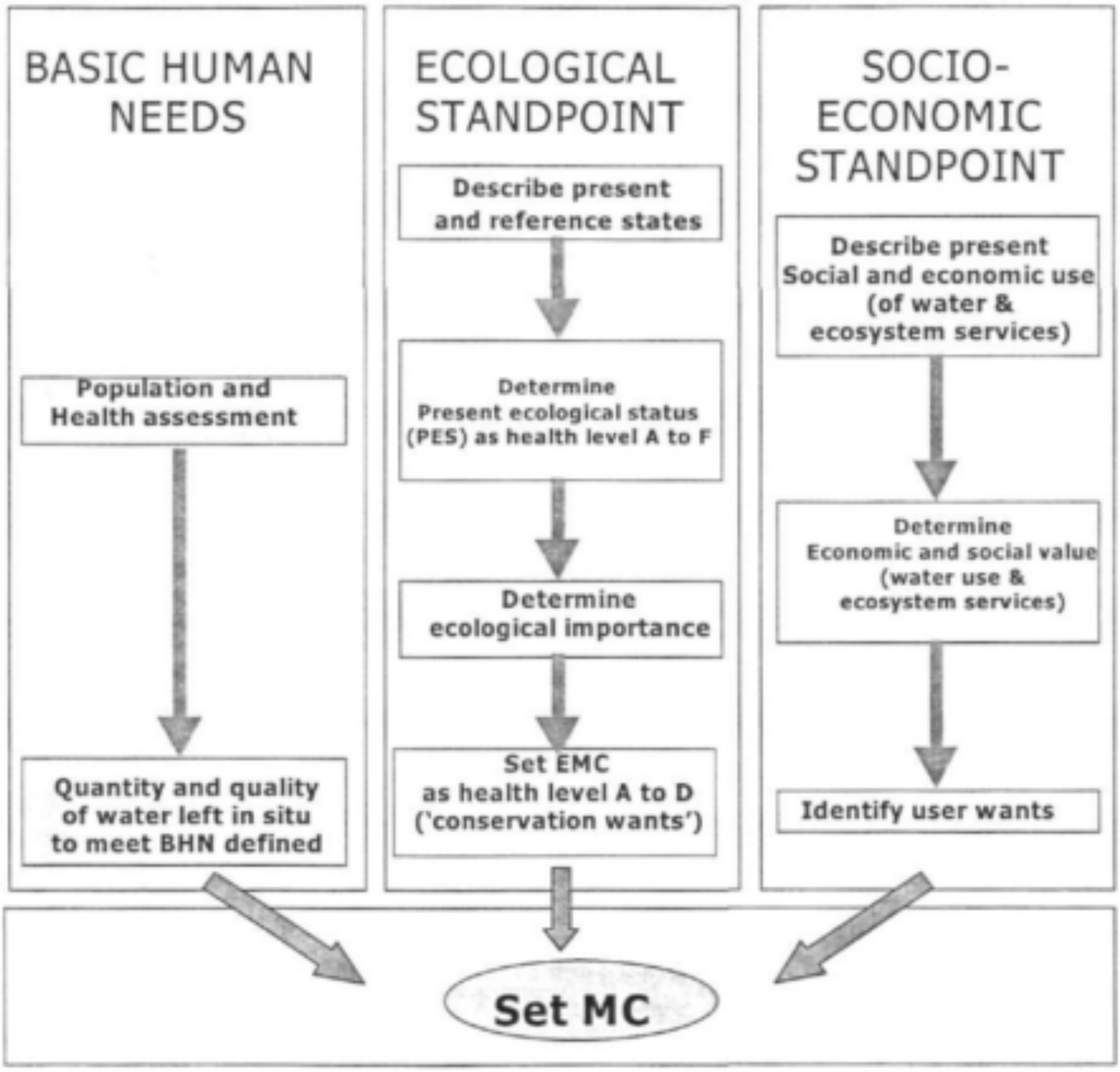

Figure 2. Simplified existing framework for determination of the MC of water resources

The findings of the BHN assessment are non-negotiable, and set constraints for the allocation of water quantity and quality for sustaining ecosystem function and economic uses. Subject to this constraint and an ecological constraint that a resource may not be managed at lower than a D class, the final MC (A to D) is negotiable among the stakeholders. The EMC, which is the desired state of health from a purely ecological/conservation point of view, represents the position of one stakeholder group (e.g. this might be thought of as the position taken by conservationists in South Africa as a whole). The balance between the value of water use and ecosystem services values in relation to the balance of supply options implied by EMC will determine the need for and type of negotiation that might take place to decide on the final MC.

In the existing RDM documentation, economics may be construed as contributing to the decision in setting EMC. We **strongly recommend** that this is not the case, and that the economic input follows the parallel process described above. The wants and needs of different stakeholder groups must be made explicit as such, in order for successful negotiation to take place in arriving at the final MC.

The EMC could represent one 'opening bid' in a negotiation process. What the ecologists recommend is not necessarily what is best for society. The ecologists represent a ecological perspective in the process, and MC may be different from the EMC recommended by the ecologists. The MC has to take BHN and society's wants and needs into account, in other words, it has to address sustainablity, efficiency and equity. Thus society has to negotiate its desired level of supply and management, but with the constraint that a system may not be managed below a D class: this is the minimum level of ecological health at which a system can maintain an acceptable level of function.

For example, a system with a current Present Ecological State (PES) of C, may be considered important from a conservation perspective, and thus assigned an EMC of B. This system is currently used for supplying BHN and certain economic activities (both extractive and non-extractive). There will also be certain demands for the future: BHN may grow with increasing populations, or decrease with changing social conditions; demands for economic uses may change due to increasing demand for certain agricultural products or increasing demands for tourism activities. These demands represent society's wants and needs from the water resource.

Society's future consumption needs are determined with the BHN methodology, and are non-negotiable – this sets a minimum quality of the resource, and a minimum quantity for allocation, although this allocation is unlike other types of allocation, in that people fetch the water from the river, and it is not piped out of the system. As long as this water is not harvested it would stay in the system and add to ecological condition, but it cannot be guaranteed that it will not be harvested, so has to be treated as **water that will be removed**. If the needs are greater than the water available after allocation to the environment determined by EMC, then EMC will be potentially compromised. But, the quality of water required for BHN will never compromise EMC (Fig. 3).

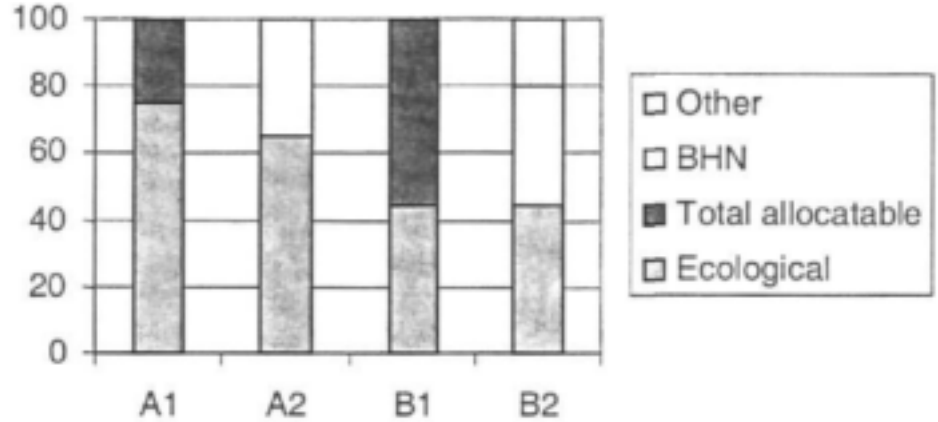

Figure 3. Example illustrating rules for allocation of water resources between broad sectors. In resource A1, the quantity requirements for maintaining the resource in the EMC recommended by ecologists is less than the BHN requirements in that reach. Thus the BHN requirement would have to be met as in A2, and the starting point for negotiation of the MC would be at the reduced quantity of water in the system that is allocatable between environment and other economic uses (extraction). In resource B1, an EMC is assigned which requires 45% of MAR, which means that 55% of the MAR could be allocated to other uses. Part of this has to go to BHN, which in this case is 35% of MAR, leaving 20% of Mean Annual Run-off (MAR) allocatable to other uses (as in B2). Depending on society's wants, this may involve leaving some of the allocatable water in the system to improve its ecological status (e.g. because ecotourism is a strong driver), and deciding how much is wanted for extractive purposes. If society's wants are greater than 20% of MAR, then trade-offs will have to be made between stakeholders wanting to extract resources (i.e. increase the allocatable portion), and stakeholders (including the ecologists arguing for their recommended EMC) who want to maintain the resource at EMC (or higher).

In a participatory process, society's wants are represented in such a way that the optimal solution can potentially be obtained. However, society is composed of individuals who understand their own wants but do not understand the effect of their demands on other members of society. This is why government and bodies such as CMAs have to try to make allocative decisions that maximise the benefits to members of society in an equitable and sustainable manner. This relies on a thorough understanding of economic uses of the system, the magnitude and distribution of benefits, the way in which these might change under different scenarios, people's wants, and the way in which these can be met under different scenarios.

Members of society (or stakeholder groups) know what they want. These include:

- quantities demanded for abstraction,
- demands for activities which generate polluting outputs or flow modification,
- water quality requirements for irrigation, domestic use and recreational use, and
- the levels of ecosystem goods and services required.

In the catchment assessment, current uses of the resource are described, and the demands in terms of water quality required for agriculture, domestic use and recreation, are described. Water quality requirements for agriculture and domestic use are described in terms of classes I to IV, and recreational requirements are described in terms of three levels of quality.

If presented with the wants of others, and the implications of different scenarios on society welfare as a whole, they will be more willing to accept compromise or reach a consensus on the management of water resources. One of the few ways to reach a consensus is through **multi-criteria decision making procedures**, whereby stakeholders can rank their wants and contribute to the decision process which optimises benefits to society. Once a consensus has been reached, the **MC** of a resource can be set, and the Reserve and RQO defined (Fig. 4).

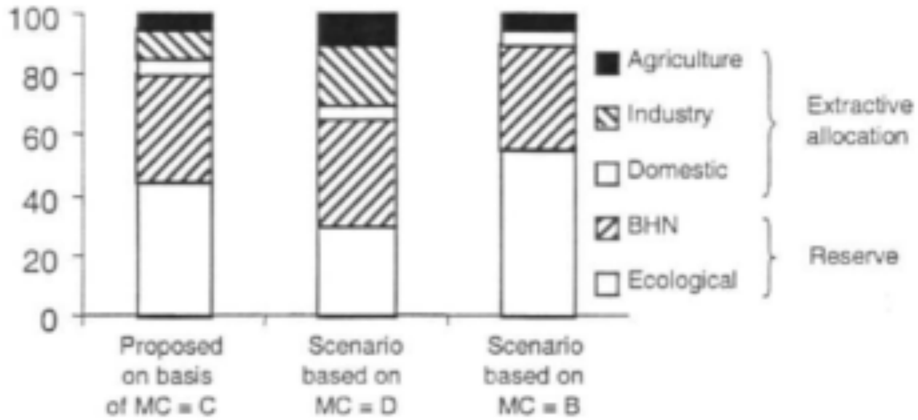

Figure 4. Example illustrating how society's wants could influence the MC. The EMC is determined by the ecologists as a C, and taking BHN into account, the quantity available for allocation is 20% of MAR under this scenario. The proportionate allocation of the latter is shown on the basis of current proportional use, but is arbitrary at this stage. Based on stakeholder wants, the final outcome might change significantly from that based on EMC = C. For example, society may settle for the outcome which would require a final MC of D, because the demand for extractive uses is far greater than the demand for other ecosystem goods and services. On the other hand, they may decide to allocate part of the allocatable proportion back to the environment, thus raising the MC to B, because the demand for ecosystem goods and services is greater than the demand for extractive uses.

In order to reach the type of decisions shown above, it will be necessary to describe, and quantify as far as possible, the socio-economic implications of a range of possibilities. Once the current *status quo* under the existing state (PES = A to F) has been described, alternative scenarios within the range A to D (which will include the reference condition and the EMC) should be described. Such an analysis will be dependent on receiving relevant estimates from hydrologists and ecologists for various parameters under the conditions associated with each MC. These would include estimates such as the magnitude of stocks of certain resources (e.g. fish, plants), or the change in flooding risk at different contours (e.g. change from 1:50yrs to 1:25yrs). Predictions of change in value can then be made based on comparisons with the *status quo*.

Once the stakeholders' preferences are understood, it will then be possible to identify the resource condition or MC (A to D) which most closely satisfies society's wants and needs. The methods for estimating economic value and for arriving at a consensus in terms of setting MC are described in more detail below.

The current framework described so far for the determination of MC of each resource (estuary, river reach, etc) has a major shortcoming if the resource is treated in isolation. Thus the incorporation of this framework in a larger catchment-level framework is described below.

4. CATCHMENT LEVEL CONSIDERATIONS AND STRATEGIC ADAPTIVE MANAGEMENT

4.1 The relationship between reaches and the catchment

Within the existing SAM framework, the RDM process is designed to take place at the level of a river reach, a wetland, or a groundwater resource. In other words, decisions are to be taken for each component of a system that forms part of a WMA. The decisions and actions taken in one component will affect, and be affected by, decisions and actions taken in other components of the system (Fig. 2). This extremely important consideration shapes the overall framework proposed in this document.

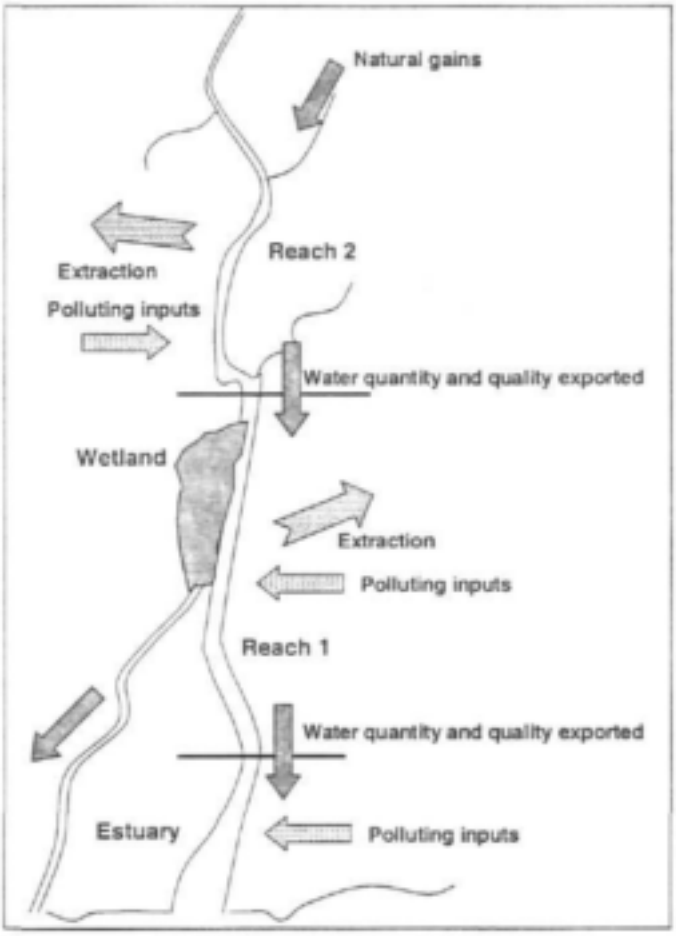

Figure 2. Linkages between different water resources considered separately in the RDM process.

Figure 2 illustrates a simple example in which a catchment area contains two river reaches, a wetland and an estuary. Considering the linkages between these, the following will have to be taken into account:

The possible RQO for a water resource will be constrained by the input requirements determined by the reserve and RQO of downstream resources (or cross-border international requirements).

There are thus two possible options for making decisions at the level of individual resources (e.g. river reaches):

1. RDM is applied **sequentially** from mouth to source, and the constraints set at each reach. This gives automatic priority to lower reaches and estuaries, and the degree of flexibility afforded to higher reaches will be highly dependent on the natural augmentation of supplies via tributaries etc.
2. A **strategic assessment** is made whereby all resources within a catchment are assessed together in order to achieve the optimal allocation of water and water quality objectives between its component resources. This will still require stepwise setting of constraints from mouth to source, but will not automatically give priority to lower reaches and estuaries. It means that MC of one reach could be altered downwards to service the needs of another reach.

We favour the latter option. Thus at a *catchment or WMA level*, the following will first need to be taken into consideration in order to set the **initial constraints** in the catchment-level assessment:

1. International obligations in terms of cross-border water supply
2. Basic Human Needs
3. International obligations in terms of biodiversity conservation (e.g. Ramsar Convention, Biodiversity Convention).

Following this it will be necessary to understand the existing demands on water resources within a catchment, the relative magnitude and distribution of benefits and costs, and the linkages and trade-offs operating between water resources in the catchment. A simple example is given in Fig 3. In this case, both the abstraction and polluting activities taking place in reach 2 affect the tourism based industry in reach 1. Depending on their intensity, the activities in reach 2 may also affect subsistence fishing in the estuary. Activities in reach 1 and the estuary are compatible.

There are also similar considerations within a reach. For instance, due to the high abstraction in reach 2, the absorptive/dilution capacity of the reach will be diminished, which means that industries will have to invest more in treating their return flows.

Thus major, or broadscale, allocative decisions need to be taken at a catchment or WMA level, and need to form part of the catchment vision.

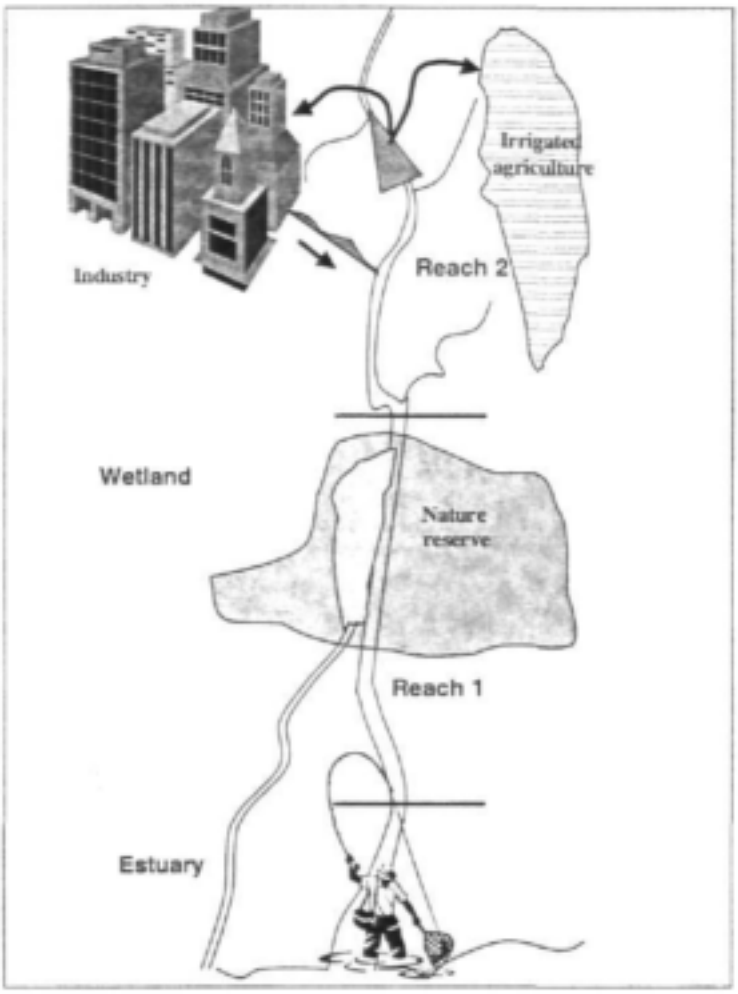

Figure 3. An example of catchment activities illustrating the types of trade-offs one might encounter between the use of different water resources within a catchment.

4.2. Optimising tradeoffs in the catchment through increased efficiency

Within a catchment, activities can be divided into three broad categories:

1. Activities which affect water supply as an **externality**
   These include forestry, dryland agriculture, both of which affect the quality or quantity of runoff into catchment water resources.
2. Activities which **abstract** water and **yield polluted return flows**.
   These include domestic consumption, irrigated agriculture, mining and industry. Fish farming industries would also largely belong in this category. All of these activities depend on the impoundment and/or abstraction of water (i.e. direct use) and all produce polluted return flows which enter the catchment's water resources.
3. Activities which **rely on instream flow and water quality**.
   These include conservation, tourism, recreation, use of aquatic resources, and a host of ecosystem services, described in later sections.

Type 1 and 2 activities affect one another and both affect type 3 activities. The economic value of type 1 and 2 activities is generally more readily recognised than the economic value of type 3 activities.

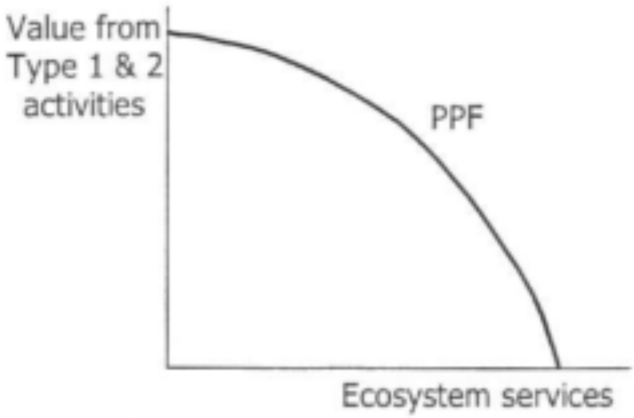

Figure 4. Production possibilities frontier (PPF) in terms of the allocation of water to type 1 and type 2 economic activities vs to the environment (generating type 3 values). The trade-offs between the two types of allocation is relatively even in this example.

There is limited economic value that can be obtained from a water resource, and the type of value generated depends on how the resource is allocated. The maximum value that can be obtained from different allocative combinations is illustrated hypothetically in Fig. 4, where allocation is either to consumptive use (type 1 and 2 activities) or to the environmental reserve. In this example, the tradeoff is relatively even, and would be exactly even if the PPF was a straight line. An even tradeoff means that the economic value obtained from the system would be the same, whether resources were allocated to consumptive activities or to the environment. The curve is likely to be convex, however, as depicted in Fig. 4, due to the laws of diminishing returns as allocation is increased to either sector.

Depending on the value scales for either sectors, the trade-offs may not be even. For example, in a sensitive system, the marginal benefit of allocating more water to the consumptive sector may be offset by a greater loss from the environmental sector. Or in the case of a fairly robust ecosystem, the opposite may be true (Fig. 5).

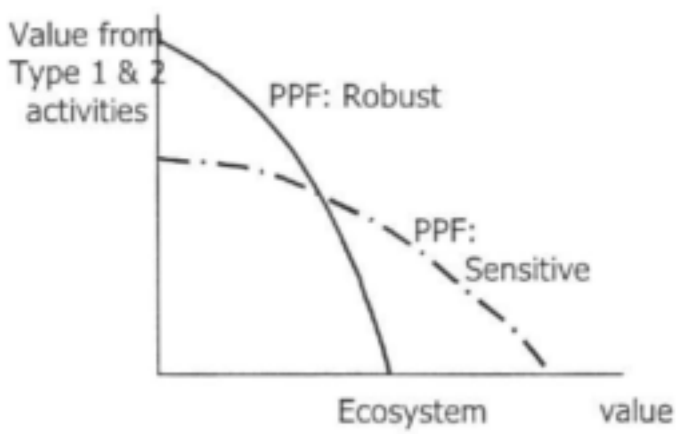

Figure 5. Production possibilities frontiers, as above, for robust and sensitive ecosystems. The trade-offs between allocation to consumptive use or the ecological reserve are uneven.

Irrespective of the nature of the system, and how it affects these type of trade-offs, it is critical to address the issue of maximising efficiency of water use in a catchment at the outset. This will change the magnitude of the trade-offs involved, by expanding the production possibilities frontier, and changing its shape towards that of the robust system depicted above. In other words, the primary issue to consider is how to obtain the most efficient use of water resources, so that economic returns (monetary and non-monetary) per unit of water used are maximised, and externalities per unit output of economic production are minimised. In this way, the opportunity cost of increasing consumptive use value of water will be reduced.

Economic efficiency can be achieved in a number of ways, including through the use of standards and regulations. However, the most efficient and cost-effective way of achieving these goals is through the use of **economic incentives**. Economic incentives can act at two main levels:

I **Supply management**
This is directed at type 1 and type 2 activities, and aims to reduce water losses through streamflow interception and evapotranspiration, and reduce siltation and pollution.

II **Demand management**
This is directed at all type 2 activities, and aims to reduce the amount of water used in achieving economic production, through increased efficiency of use.

Economic incentive measures aimed at improving supply and demand management include the following:

- The treatment of flow-reducing type 1 activities as a permit-requiring water user in the allocation process, and incentives (e.g. tax breaks) for undertaking measures to combat these losses.
- Siltation charges and incentives for undertaking erosion prevention measures.
- Tradable pollution permits like the "bubble" system developed in the USA with a ceiling on the total number of permits within the catchment.
- Tradable water permits, with a ceiling on total water allocation within a catchment.
- Appropriate pricing strategies for domestic, industrial and agricultural users.

The (theoretical) advantage of tradable permits is that it promotes the development of water saving or pollution abatement technology. It is also a least-cost solution in that users that can afford to abate will do so, whereas those who face high abatement costs have the option of purchasing permits. Another (theoretical) advantage of this system is that permits are traded on the open market, which means that the prices will equilibrate at the right level, and track inflation. Investors will also have an interest in policing others' activities in the catchment.

It is important to assess **at the outset** which measures are viable and how such measures will change the use of water within a catchment system before allocative decisions are made. Taking all the above into consideration, it becomes clear that the way in which SAM is implemented should be critically assessed, as should the way in which RDM is integrated into this process. Here we propose that the SAM procedure be adjusted as described in the next section (summarized in Fig. 6 and Box 1).

5. THE DECISION-MAKING PROCESS

There are a number of steps in the SAM framework or activities in RDM which involve making decisions (or making trade offs) or reaching consensus among stakeholders. These include:

- Decisions on feasible options for supply and demand management (i.e. increasing efficiency of water use);
- Development of a catchment vision, setting of MCs and RQO;
- Decisions on allocation between river reaches or quaternary catchments;
- Decisions on allocation of allocatable water resources within reaches.

With each of these decisions, there are stakeholders that stand to lose and others that will gain. Conventional economics reaches decisions on the basis of maximising net economic value to society by considering trade-offs in monetary terms. This may take sustainability issues into account. However, it is not a particularly good tool in terms of solving problems of equity, and also fails where there are values that cannot easily be translated into monetary terms. In addition, preference scales may not follow linear monetary scales. For example, there may be a large degree of preference from something worth R100 to R10 000, but people may be more ambivalent between R2bn and R2.3bn.

Multi Criteria Decision Analysis (MCDA, e.g. Stewart *et al.* 2001) can offer additional decision support in the steps above as:

- it does not require that there is a monetary value for each benefit;
- it can include non-linear preference scales;
- it can include equity and sustainability issues specifically as criteria, or through different weighting systems, and/or through the direct input of stakeholder values in the decision-making process; and
- it can include both qualitative and quantitative inputs.

The MCDA process, briefly, involves evaluating or 'scoring' alternatives from different points of view (criteria) and combining these separate scores to obtain an overall ranking of alternatives.

Various tools are available within the MCDA process for performing these two basic tasks. The details of how the scoring and combining of scores occurs define the many different MCDA methods available, and different approaches may be appropriate in different contexts. In South Africa we have tended to concentrate on the simple multi-attribute rating technique (SMART) approach (e.g. Goodwin and Wright, 1998, Stewart *et al.* 2001), which implies scoring alternatives on an interval scale for each criterion and the simple weighted addition of the scores. This method is generally applicable, reasonably accessible and flexible. The SMART process works by:

a) developing a system of criteria for the evaluation of alternatives,

b) scoring of alternatives relative to each other on the basis of each criterion separately,
c) weighting of criteria,
d) aggregation of separate evaluations, in a way which is theoretically valid under normative assumptions about decision-making (Fig. 6)

MCDA does not *provide* a 'correct' system of weights or scores, as these are determined by the inputs of the stakeholders involved in the decision making process. The 'correct' system reflects the trade-offs which society is willing to make in any specific situation. Using an MCDA process and its tools provides the stakeholders involved with:

a) an overall framework for evaluating alternatives from technical and non-technical points of view,
b) a way of understanding and dealing with the many issues involved,
c) a way of determining values which reflect societal values, and
d) a way of reaching consensus among stakeholders where there may be conflicting demand for resources.

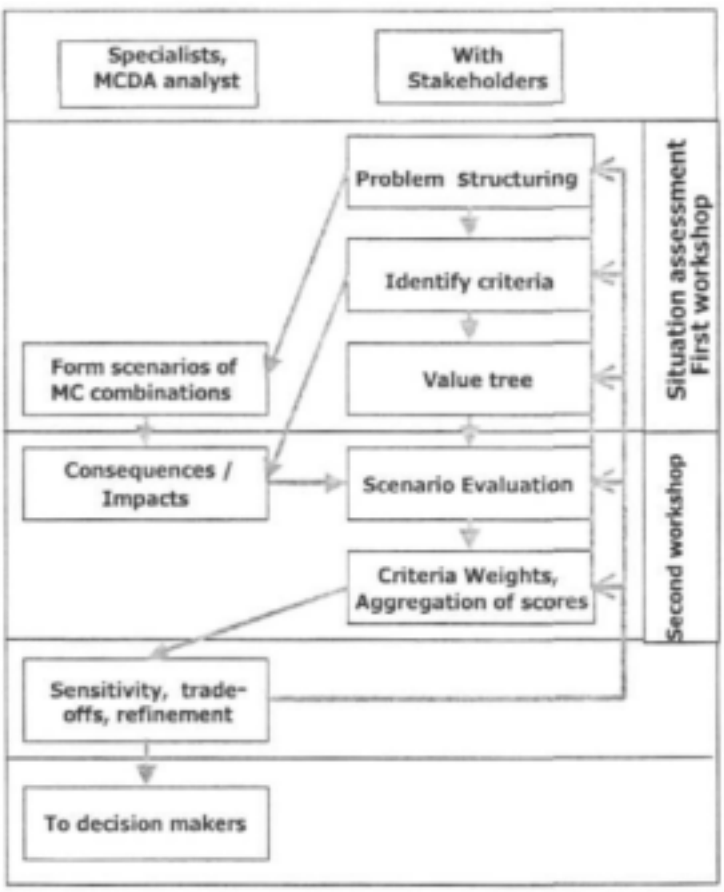

Figure 6. The MCDA process

An extension of the MCDA process, developed in South Africa, is the scenario based policy planning (SBPP) approach of Stewart, Scott & Iloni (1993), which provides additional support in developing alternatives (scenarios), where they are not pre-existing.

The SBPP/SMART process and tools are relevant at several stages of the process of implementing the Water Act as outlined in Box 1:

- firstly, in choosing MCs and Reserves for reaches along a WMA,
- secondly, in forming combined MCs and a Reserve for the WMA as a whole,
- thirdly in forming catchment management strategies (CMSs),
- fourthly, for allocation plans (including streamflow reduction activities).

These choices involve trade-offs at many levels (between reaches, between social, ecological and economic issues, between interest groups), and requires the input of relevant stakeholders.

Box 1: Proposed sequence of events for MCDA and Strategic Adaptive Management

Notes: 1) 'Stakeholders' includes specialists and government representatives. 2) Stakeholder workshop processes are underlined.

1. Situation assessment.

1.1. First draft of stakeholders' aspirations and values which can be formulated into desired future states (DFSs) (there may be several different ones for each resource). These workshops could also identify the relevant stakeholder criteria for later evaluation of scenarios, and should help to inform other aspects of the situation assessment;

1.2. Present ecological status (PES);

1.3. Present and potential future economic linkages, uses and values (this project provides information on the value of the environmental reserve);

1.4. BHN of the catchment;

1.5. Initial decision on BHN, and formulation of EMC and DFSs for each resource/quaternary catchment;

2. Combination of BHN, EMC, DFSs into catchment level MC scenarios.

These need to be *feasible scenarios* in the sense of not violating physical or policy constraints (e.g. might not be feasible to have D class followed by A class. e.g. BHN reserve might place various longitudinal constraints.):

2.1. Determination of ecological and social and economic implications via stakeholder opinion, modelling etc. Level of determination would depend on resources available;

2.2. Determination of a strategy for improving efficiency of water use (where this project models changes in economic values as resource quantity and quality changes);

2.3. Reanalysis of the social and economic implications of feasible strategies, taking efficiency measures into account;)

3. Workshop *evaluation* of scenarios.

Presentation of intermediate steps to stakeholders. Refinement of stakeholders criteria. Stakeholders evaluate scenarios on the basis of each criterion. Stakeholders determine weights of criteria (i.e. trade-offs between issues);

3.1. Sensitivity and robustness of results to various inputs (e.g. scores and weights).

3.2. If necessary, presentation of robustness to stakeholders, and further refinement, where, for example, critical scores or weights are identified.

3.3. Formulation of preferred scenario into MC for all resources within catchment, and into overall vision statement;

4. Already defined criteria form the basis for the *RQO* and *Reserve* which can now be refined;
5. *CMSs* which will help to achieve the designated MCs can now be formulated;
6. *Allocation* of allocatable portion within catchment and reaches;
7. Monitoring and review;
8. Return to step 1 after a designated time period.

5.1 Determining initial Management Classes

The following expands on Box 1 and Figure 6. During workshops within each reach, stakeholders will in some way put forward their DFSs. This process remains rather fuzzy, but would need to indicate, amongst other things, whether the stakeholders wished for improved supply of ecosystem services, or increased possibilities for economic and social use of river water in- or off-stream. The statements may be more or less defined, and there may be one or several for each reach (these statements may be regarded as the 'vision' statements). The workshops would also identify criteria for later use in the evaluation of scenarios. Relevant **stakeholder groups** would include those involved in or representing Type 1, 2 and 3 uses/values and might include representatives of mining, irrigation agriculture, trout industry, communal lands, civics, etc. **Specialists** will also be stakeholders in the process, as representatives of society (government) interests in ecology (sustainability), economy (efficiency) and social issues (equity), and they would determine relevant criteria for these issues. The need to consult with stakeholders at this early stage of the process was emphasised at a workshop to discuss this process. The 'vision' stages of the objectives hierarchy process (Rogers and Bestbier, 1997), could be adapted for use during these early stages of problem structuring, as this provides some structure to the process. However, we believe that it is important not to get bogged down in process and detail at this stage. It is far too early for people to have clear ideas of the alternatives, the impacts of alternatives and their own value structures. Thus trying to insist on a well-structured or definitive 'vision' could be counter-productive. However, given this, the broadness of the MC categories mean that a general statement of a vision or a DFS may not be too restrictive.

The DFSs, together with relevant information from the situation assessment (Box 1) would be used by a specialist/analyst team to identify equivalent MCs for each DFS. Relevant information would include the PES/EMC, physical constraints (e.g. pristine and current flow and quality), BHN assessments for each reach, indicating current achievement of BHN, current economic activities, and the value of ecosystem services.

5.2 Formation of catchment level Management Class scenarios

The MCs for different reaches and stakeholders would then be combined at the catchment level (taking into account further possible constraints where, for example, a MC of D might not be able to preceed a MC of A). Thus, a scenario would consist of a longitudinal statement of MCs down the several reaches of the river (e.g. A-B-A-D). This exercise would need to use as many simplifications as possible, so that there are, *at most* a total of ten scenarios. For example, in a catchment with several reaches, adjacent reaches which are similar or which have similar DFSs or initial MCs might be combined. The final set of scenarios should include extreme and intermediate scenarios, e.g. extreme conservation or development views, as well as the best scenario from the different stakeholder points of view.

The RDM process, has the flaw of 'needing' information from later stages of the process to inform earlier stages. Thus, it is likely that specific supply and demand management options will be considered in detail only in the formulation of CMSs. However, in designating MCs, it is quite possible that MCs which are presently infeasible, could be achieved with appropriate demand management. For example, irrigation farmers might presently use a certain quantity of water a year, and the process might indicate that all stakeholders are happy with this use continuing for various reasons (e.g. the economic and employment benefits). As a result the process might find that a MC of C is appropriate. However, with demand management measures in place, it is possible that a MC of B would be appropriate. One possibility would be to consider two sets of scenarios: one set under current management options, and another under efficient management. It is possible that the situation assessment will have identified areas where efficiency could be improved, and it is probable that at this stage, the effects of these measures would have to rely on expert opinion rather than in-depth analyses.

At this point the **relevant** ecological, social and economic consequences of the scenarios should be determined at an *appropriate* level of detail. For the purposes of this process relevant means those issues that have been identified by stakeholders and studies during the situation assessment as being potentially affected by the scenarios to be considered (e.g. if the MCs being considered will not impact on recreation this is irrelevant). These 'relevant issues' become the criteria for evaluation of the scenarios. The relevant issues or criteria do not necessarily all require in-depth study. For the purposes of an MCDA analysis various levels of detail can be used. All that is essential is that a stakeholder can state that one scenario is preferred to another from a particular point of view, and qualitatively **how much more it is preferred**. Put differently, the relevant stakeholder needs to be able to state how much better or worse one scenario performs relative to others with respect to one criterion. This statement may be based on quantitative information, specialist expertise, personal experience, 'gut feel' or educated guesses, depending on budgetary and time constraints. In all cases the stakeholder needs to apply his or her mind to the issue. In any case, specialist input and previous studies could be used for a first iteration. In subsequent iterations, if and where necessary studies could be commissioned to clarify issues. This might prove necessary if, for example, certain information proves to be critical in choosing the final MC combination scenario (i.e. evaluations on the basis of certain criteria are too uncertain or contentious, or where weights are too uncertain, contentious or differ widely among stakeholder groups).

If only three possible MCs are being considered, as appears to be the case, the categories will be rather broad, and include many possible futures within one category. ***Thus it is our belief that*** effort should be expended more in the later stage of formulation of appropriate CMS and allocation plans than in the designation of a MC. However, the statements of DFSs, and the assessment of MC combination scenarios should all provide invaluable information for inclusion in this next phase.

5.3 Evaluation of scenarios

Stakeholders are gathered together in a workshop setting. It is optional whether to hold separate meetings with different stakeholder groups or to hold a joint meeting. The latter is more in the spirit of consensus building and is cheaper. It might be advisable for workshops with specialists to be held earlier in order to consolidate relevant information for other stakeholders (e.g. the conversion of river quality / condition into the quality and quantity of ecosystem services supplied). The **workshop process** is as follows:

1. From the earlier workshop/s during the situation assessment, **criteria** will have been identified, and various of these will have been further clarified by the situation assessment and specialists. Criteria might include profits, water quality, recreation, biodiversity, habitat quality, availability of natural resources to harvest. etc. These criteria may be refined during this workshop.

2. From this, the analyst drafts an initial **value tree** (or several) which groups similar criteria or criteria which contribute to the same objective (Fig. 7). The value tree structure may be refined during this or later workshops.
   This process might lead to the formation of separate values trees for different stakeholders, or they might agree on a common set of criteria earlier on in the process. The latter is obviously preferable, and should be achievable simply by inclusion of all criteria in one structure but with different weighting systems (e.g. for a certain stakeholder group, zero weight might be given to some criteria which are irrelevant to them). An example of a value trees is shown in Fig. 7. The structure of the tree indicates how evaluations at the lower levels are combined to obtain an upper level overall ranking of scenarios.

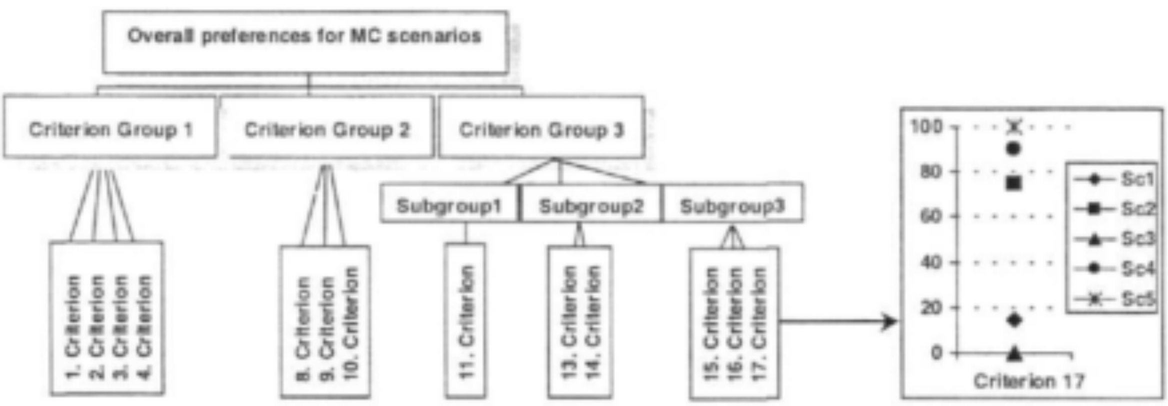

Figure 7. The development of value trees in the MCDA process. The box to the right of the stakeholders' tree shows the way in which scenarios are rated in terms of each criterion.

3. For each criterion, stakeholders decide which scenario is best or worst, and **rate or rank** the ones in between. Appropriate techniques for this scoring stage will depend on the level of quantification of information.

4. Stakeholders determine **weights** between criteria within criteria groups, and between criteria groups, using a swing-weighting procedure (facilitator may resort to simpler weighting procedures if necessary).

5. *If people are uncomfortable with precise statements, or if stakeholder groups* disagree an **indication of ranges** of scores or weights will be obtained.

6. Depending on equipment availability initial results of the weighted aggregation of scores, and **sensitivity** can be presented to stakeholders immediately for comment and feedback.

Thus, different stakeholders may arrive at different overall evaluations (rankings). In order to choose amongst the differing preferences of different stakeholders, or between the needs of the environment and the economy, a sensitivity / robustness analysis will assess the effects of the different stakeholder weights on final preferences. The MC scenarios which were robust to changes in weights, and /or which most frequently were ranked first could be then be chosen.

Examples of evaluations based on different criteria (scoring) are shown in Fig. 8 and Table 1. *Fig. 8 shows the 'value path' for this assessment, as well as an overall ranking* obtained by weighted summation. Example output in Fig. 9 shows the results of a sensitivity analysis using 9 different weight sets on the information in Fig. 8 and Table 1. According to this, Scenario 2 is preferred using the initial overall aggregation shown in Fig. 8, as well as being the most frequently first ranked with all the other weight sets applied. These results would then be presented to the decision-maker (DWAF or CMA) for final analysis and decisions.

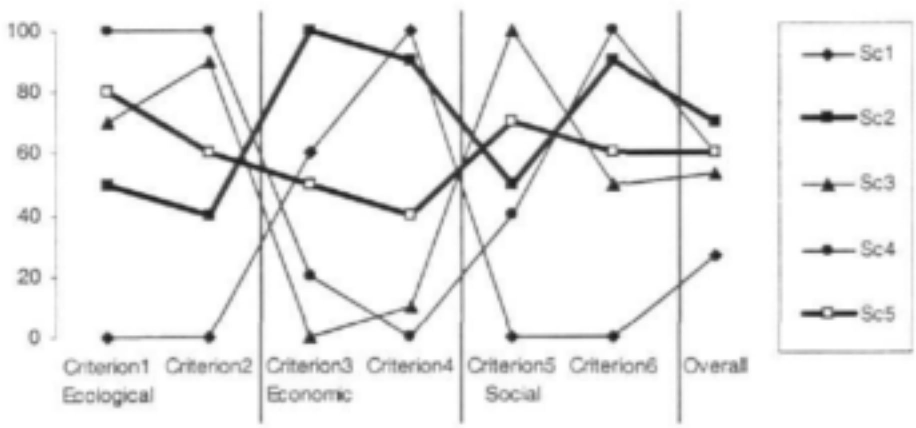

Figure 8. Value paths showing evaluations for different criteria for ecological, economic and social issues, as well as an overall ranking from a weighted summation of these scores.

Table 1. Example of evaluations from ecological, economic and social points of view. Values correspond to those in Fig. 3.

	Ecological		Aggregate	Economic		Aggregate	Social		Aggregate	Overall
	Criterion1	Criterion2	Ecological	Criterion3	Criterion4	Economic	Criterion5	Criterion6	Social	
Sc1	0	0	0	60	100	80	0	0	0	26.7
Sc2	50	40	45	100	90	95	50	90	70	70
Sc3	70	90	80	0	10	5	100	50	75	53.3
Sc4	100	100	100	20	0	10	40	100	70	60
Sc5	80	60	70	50	40	45	70	60	65	60
weight	50	50		50	50		50	50		
weight			50			50			50	

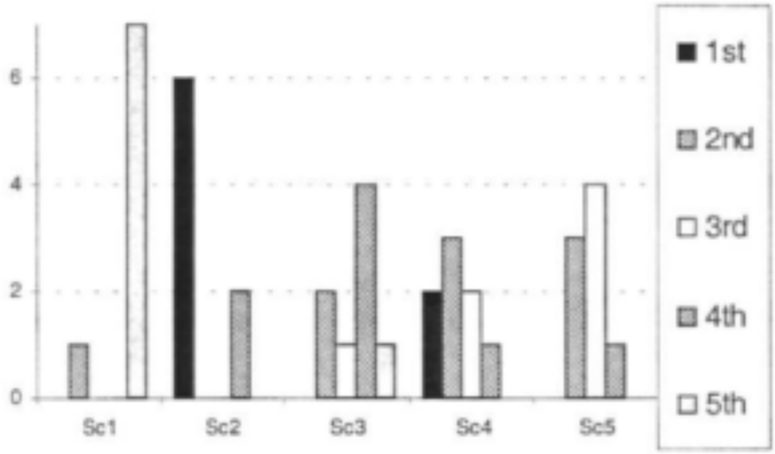

Figure 9. Frequency of ranks obtained by 5 different scenarios using 9 different weight sets.

6. METHODS FOR DETERMINING PRESENT ECONOMIC VALUES OF ECOSYSTEM SERVICES

The methods for collecting and analysing economic data for a catchment will involve:

- Valuing the *status quo*, or the current value of the ecosystem goods and services supplied by the river in its present condition
- Predicting and valuing the magnitude and direction of change in supply of goods and services under different management scenarios (class A to D)

Values are usually determined for the current year. However, it is also important to assess how these values might be expected to change over time if the current *status quo* is maintained, or under alternative scenarios. For example, if a resource is overexploited, then one would not expect the value stream to remain constant over time, but it might decline. The usual planning horizon for economics is about 20 years. This is often problematic when environmental considerations are taken into account, especially where the effects only occur in the very long term (e.g. the degradation of riparian forests). A time horizon of 50 years is thus more appropriate for this type of study. In cost-benefit analysis, or economic studies, values generated in the present are given more weight than values generated in the future. This weighting reflects society's preference for present gains over future gains, and is achieved through the process of discounting. High discount rates give much greater weight to present values, and a zero discount rate would weight future values equally to present values. The former would thus pay little heed to environmental damage incurred in the future, but the latter would take it into account. Because the choice of discount rate is highly controversial, it is recommended that three discount rates are applied, centred around the real interest rate[2] on capital, as follows:

a = prime interest rate – 3%

b = prime interest rate

c = prime interest rate + 3%.

6.1 Consumptive use of Aquatic Ecosystem Products

Description

This is the value of harvesting renewable or non-renewable resources from aquatic ecosystems, other than water. These are the 'goods' provided by the ecosystem, and include minerals, plants and animals.

Methods

User groups are identified and mapped, and user surveys are administered to samples of the user population. User groups might include:

- Rural inhabitants of communal areas
- Informal settlements
- Farmers

[2] Real interest rate is the nominal interest rate minus the inflation rate.

- Nature reserves
- Recreational anglers or hunters

Although recreational consumptive users strictly fall within this value category, it is easier to exclude them from this value estimate and include them under recreational value, below, together with non-consumptive recreational use. The survey will ascertain where (e.g. which reaches) resources are harvested, and the average quantity harvested annually per user or household, as appropriate. It will also ascertain the market value of the resource, and the costs involved in harvesting. It is particularly important to ascertain where the use occurs, as well as where the users originate from. A minimum sample of 30 users or households is required for each user group, and accuracy will increase with sample size. Examples of consumptive use survey forms are provided below:

FISH HARVESTING SURVEY SHEET

RESOURCE ....
QUESTIONNAIRE NO. ....
LOCALITY ....
GPS NO. ....
INTERVIEWEE ....

- ❑ When do you fish – time of the year and/or special conditions
- ❑ What fishing equipment do you use?
- ❑ What did you pay for the equipment?
- ❑ If you made these things how much time did it take?
- ❑ How often do you replace your equipment?
- ❑ How many fish does a person catch in a week in peak fishing season?
- ❑ What size are the fish?
- ❑ How many fish does a person catch for the year?
- ❑ In peak fishing season, how many days per week do people in your household fish?
- ❑ How much time does one person spend fishing per day in peak season?
- ❑ During the off season, how many days per week do people in your household fish?
- ❑ How much time does one person spend fishing per day in the off season?
- ❑ How far do they go to catch fish?
- ❑ Who in your family catches fish?
- ❑ Where do you catch your fish – in the river, dams, estuaries
- ❑ What proportion of your catch did you sell last year?
- ❑ What is the price of the fish you sell?
- ❑ How often did you buy fish and how much do you normally buy?
- ❑ How much do you pay for the fish you buy?

RESOURCE HARVESTING SURVEY SHEET

RESOURCE ....
QUESTIONNAIRE NO. ....
LOCALITY ....
GPS NO. ....
INTERVIEWEE ....

FREQUENCY HARVESTED

- ❑ When is it usually harvested in the year? Months [ ]
- ❑ How often do you harvest the resource? Frequency[ ] Unit [ ]

- ❑ Are there times when you may harvest more or less?
- ❑ What is the time period when the harvesting is more or less?

QUANTITIES HARVESTED

- ❑ How much do you collect each time you harvest? Unit [ ] Mass[ ]
- ❑ If your harvesting changes, how much do you harvest for these periods? Unit [] Mass[ ]

LOCATION HARVESTED

- ❑ Where do you harvest the resource? Place [ ]
- ❑ How far do you travel? Distance [km]
- ❑ How long does it take to harvest? Time [ ]
- ❑ How much do you pay for transport per trip? Cost [ ]

VALUE

- ❑ Do you use the resource [yourself] or [sell it] or [both]?
- ❑ What do you use it for? [ ]
- ❑ Are there other resources or products you can use for this purpose instead?
- ❑ If there are, what are they? [ ]
- ❑ Where do you get them? [ ]
- ❑ How much do they cost? [ ] unit[ ]
- ❑ When selling as a raw material – what units do you sell it in [ ]
- ❑ At what price per unit? [ ]
- ❑ How much of your harvest do you sell [%]?
- ❑ Do you process the material before selling it?
- ❑ What do you make? [ ]
- ❑ How long does it take? [ ]
- ❑ What do you sell it for? [ ]
- ❑ Did you buy this resource last year – how much [ ] unit [ ]
- ❑ For what price? [ ]
- ❑ Where? [ ]

Reporting

The report from this assessment will include information on the following:

- each water resource (e.g. river reach, estuary):
- type of resource (species)
- quantity used annually
- gross value of harvest
- net value of harvest

Further Analysis

Further analysis to assess changes under different MCs would include:

- Harvest quantity is compared with ecologists' assessment of resource productivity to assess sustainability
- Impact of different management scenarios on sustainable harvest will be assessed by means of workshops held with relevant specialists.

6.2 Recreational Use Value

Description

Recreational use value should include both consumptive and non-consumptive recreational values, because they are often difficult to separate. The value of tourism and recreation attributable to a particular environmental amenity is generally difficult to assess, and can be measured in a number of ways, e.g.:

- gross turnover value - total expenditure by users on facilities, equipment, accommodation, and travel; or
- net value of the tourism industry - profit generated through tourism related to water resources.

The former value is comparable with other gross turnover values only. The latter value is less likely to capture recreational use value to local users, but will capture tourism value. The net value of the full industry would include profits generated by all other related enterprises, such as fishing tackle shops, etc. Estimating net value (or business profits) is always a tricky undertaking, since businesses are reluctant to reveal such information. It is possible to arrive at estimates through information on business turnover coupled with rough estimates of capital and running costs of businesses. It is also difficult to estimate the amount of value attributable to a certain resource, when users are attracted to an area for several reasons. For example, much of the tourism in the region will be due to the attractiveness of the area as a whole, but certain activities will be more dependent on the presence and state of the riparian ecosystems than others.

Method

The first step is to identify recreational activities in the catchment that rely on services generated by aquatic ecosystems, and then to develop a matrix of recreational activities and aquatic services. Then the enterprises that are associated with the recreational activities identified are identified. These steps involve interviews with tourism authorities, tourism associations, recreational clubs, marketing agencies, etc. Two types of survey are necessary:

- *User surveys:* to estimate total amount of use and total expenditure attributable to the water resource. These surveys will be aimed at different types of recreational users, such as those involved in boating, windsurfing, skiing, angling and swimming on dams, river sports, such as canoeing, tubing, rafting, angling, hiking, game-viewing, bird-watching and scenic appreciation. The surveys will determine:
    - type and amount of use (e.g. user days per year)
    - expenditure related to this use
    - expected response to change in water quality or quantity

- *Enterprise surveys:* to estimate the annual turnover and profits generated by tourism and recreation businesses. Enterprises might include river rafting operators, hotels and other accommodation establishments, nature conservation agencies. These surveys will be area specific and will determine:
    - occupancy rates and prices
    - capital investment and annual running costs
    - contribution made by the water resource
    - how turnover may change with a change in the condition of the water resource

The part of the surveys dealing with change in condition of the aquatic resource will require prior consultation with ecologists, in order to present a realistic set of scenarios to respondents. The estimates for each of the surveys will then be aggregated for an overall indication of economic responses to changes in quantity and quality of the aquatic resource, for an overall response for the catchment. This overall response will be the basis of the economic valuation of the resource.

Reporting

The report from this assessment will include information on the following:

- Types of use and Number of user days per type of use
- Average expenditure per user day, broken down by type of expenditure
- Types and number of businesses
- Turnover of businesses, and estimated net value

Further analysis

Once the reporting information is available an assessment is made on how the status quo value would change under different MCs. The type of assessment required would include:

- Expected change in demand, and in the above aggregate values, with change in water quality or quantity.

6.3 Flood Regulation

Description

Certain aquatic habitats, such as wetlands and riparian vegetation, act to slow down flood waters, thus reducing the damage caused by flooding downstream. Degradation or loss of these habitats results in increased flood damage, which can be estimated in terms of the value of losses of land and infrastructure. Although simple in concept, this value is difficult to estimate, because it requires complex modeling of the aquatic system which takes the resistance effects of these habitats into account, and estimates of infrastructure value and estimates of the damage that might be caused with increased flooding (e.g. repair costs). Although floods only occur at long intervals, the value can be estimated as the average damage costs avoided per year.

Method

- Ascertain present 1:20, 1:50 and 1:100 year floodlines.
- Within each floodline, establish the amount and potential flood damage costs of:
  - Agricultural lands (crop/stock/land losses and restoration costs)
  - Infrastructure (replacement cost/insurance value)
- Calculate present flood damage costs as: $a \times 1/20 + b \times 1/50 + c \times 1/100$,
  where a, b, and c are potential flood damage costs inside the corresponding floodline.
- Ascertain change of flood frequencies at each present floodline under different management scenarios

- For each scenario, recalculate flood damage costs, substituting the flood frequency values with new values.
- In order to attribute flood retention values to certain reaches, wetlands, etc, recalculate the flood frequencies with and without each attribute, and repeat the above process. The value of each habitat is the increase in flood damage costs associated with its loss.

Reporting

The report from this assessment will include information on the following:

- Types and number of enterprises or assets located within each of the floodlines
- Estimated net value of the assets located within the floodlines
- An assessment of the risk associated with assets and activities located within the floodlines.

Further analysis

Further analysis to assess changes under different MCs would include:

- Changes in value of assets and activities within floodline

6.4 Maintenance of Bank Stability

Description

Riparian vegetation protects and stabilises river banks. If this vegetation is lost, then agricultural and other lands at the river edge can be subject to considerable erosion.

Method

- Ascertain current levels of erosion.
- Estimate how much increased erosion would take place in the absence of riparian vegetation
- Value these losses in terms of their commercial value per ha.
- One has to assume the shape of the relationship between status of riparian vegetation and the level of erosion between these two points:

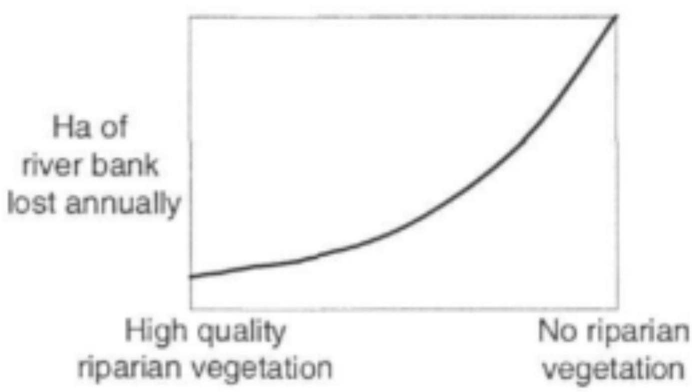

Figure 11: Possible relationship between bank erosion and quality of riparian vegetation.

Reporting

The report from this assessment will include information on the following:

- Types of land use on river banks
- Value of production from land use
- Current quality of riparian vegetation

Further analysis

Further analysis to assess changes under different MCs would include:

- Direction of change in quality of riparian vegetation
- Extent and direction of change in land use
- Extent of change in value of land use

6.5 Maintenance of Beaches

Explanation

The waterflow into an estuary can affect sediment dynamics in such a way that there is reduced sand deposition on adjacent beaches. In areas where the recreational demand for beaches is high, beaches are replaced artificially to maintain the attractiveness of the beach.

Method

- Determine the change in rate in beach sand deposition under different scenarios.
- Estimate the amount of sand that would have to be moved, if any.
- Estimate the cost beach maintenance as the annual replacement cost of this sand.

Reporting

The report from this assessment will include information on the following:

- The rate of change of sand deposition or loss.
- The cost of beach maintenance.

Further analysis

Further analysis to assess changes under different MCs would include:

- The direction and extent of changes in sand deposition.

6.6 Sediment Trapping

Explanation

Sediments are introduced into aquatic systems by natural erosion processes as well as by accelerated erosion of agricultural and forestry lands, etc. Where accelerated erosion occurs, these sediments may reduce the reservoir capacity of dams, damage hydro-electric plants, and may result in the silting up estuaries and harbours. These processes can incur considerable costs such as dredging costs and reduction in the lifespan of dams. Aquatic habitats, such as wetlands, have the ability to trap these sediments to some extent, thus reducing the potential damage caused by siltation. According to Gilliam (1994), studies showing a 90% removal of sediment by riparian areas are not uncommon. The efficacy of sediment trapping depends on the degree to which vegetated areas experience sheet flow, or whether water is channelled through these areas. Sediment removal will also tend to decrease over time due to sediment accumulation in vegetation filters (Dillaha, Sherrard & Lee 1986), and thus sediment removal rates probably have a dynamic relationship with time after floods.

Method

- Ascertain how much sediment is trapped in different habitats
- Establish the current lifespan, and rate of sedimentation and dredging of reservoirs and other affected areas (e.g. harbours).
- Establish the dredging costs and replacement cost of structures.
- Ascertain how total loss of sediment trapping habitats would increase the rate of sedimentation, for calculation of total value of this function
- Ascertain how rate of sediment trapping would change under different management scenarios.
- Convert these rates into increased dredging costs or replacement cost.

For example, if increased sedimentation were to decrease the lifespan of a dam from 50 years to 20 years: change in value of environmental service = discounted cost of replacement in year 50 minus discounted cost of replacement in year 20.

Reporting

The report from this assessment will include information on the following:

- Total value of sediment trapping.
- Value under scenarios A to D.

Further analysis

Further analysis to assess changes under different MCs would include:

- Changes in the rate of sedimentation.
- Economic implications of changes in sedimentation.

6.7 Inputs to Agriculture

Explanation

Floodplain agriculture benefits from relatively fertile soils that are replenished by floods. These fertile soils mean that productivity is higher or that production requires fewer inputs than if the soils were not replenished. The value of the aquatic system's inputs into agriculture is the extra value generated per ha compared with similar cropping on uplands. A decrease in minor flood frequency would be expected to lead to a loss in this extra productivity.

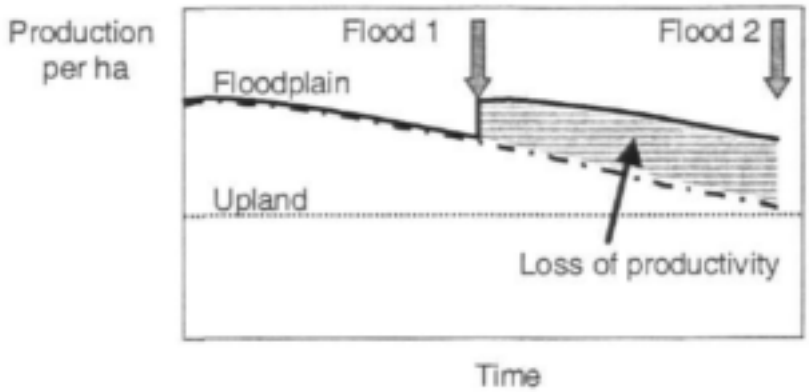

Figure 12: The hypothetical effect of halving of flood frequency on agricultural productivity.

Method

- Ascertain the type and area of crops grown on the floodplain.
- Establish the productivity of crops (e.g. kg/ha/y) compared with nearby upland areas.
- Total value of inputs to floodplain agriculture = value/kg x kg/ha/$y_{floodplain}$ - value/kg x kg/ha/y_{upland} x area (ha) planted on floodplain.
- Estimate change in frequency of replenishment of floodplain soils under scenarios A to D, using input from specialists.
- Establish length of time without flooding for soil to return to similar fertility as upland soil, and estimate the relationships shown in Figure 12.
- Estimate mean annual productivity loss, and convert to Rand value.

Reporting

The report from this assessment will include information on the following:

- Contribution of minor flooding to agricultural production.
- Impacts of reduced flooding under changes in scenarios A to D.

Further analysis

Further analysis to assess changes under different MCs would include:

- Changes in minor flooding in various catchment areas.
- Economic implications of changes production as a result of changes in flooding.

6.8 Inputs to Aquaculture

Description

Some aquaculture takes place within the aquatic environment, other activities divert water through holding tanks or ponds. The aquatic ecosystem only forms one input into the aquaculture production, and the true value of this service is the value generated after the input costs are established. The change in value is a value attributable to the loss or gain in ecosystem value.

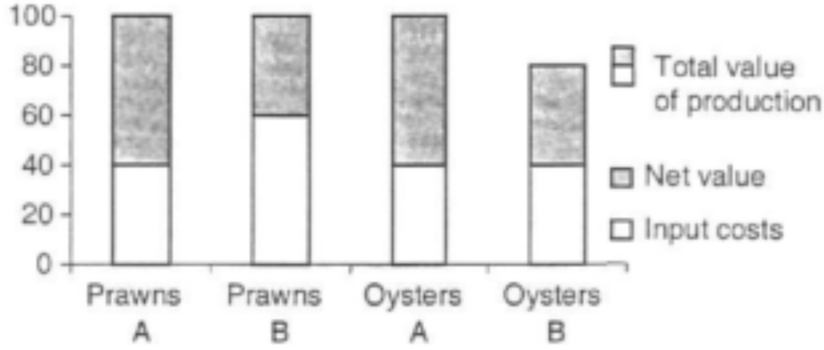

Figure 13. Possible effects of a loss in water quantity/quality on the value of aquaculture. The net value may decrease as a result in increased input cost (as in the prawn example) or as a result in loss of productivity (as in the in-situ production of oysters).

Method

- Establish what aquaculture activities take place within the system
- Estimate the turnover value of aquaculture production.
- Estimate the change in productivity (or increase in input costs such as water purification) under MC scenarios A to D.

Reporting

The report from this assessment will include information on the following:

- Types of aquaculture production
- Value of current aquaculture activities

Further analysis

Further analysis to assess changes under different MCs would include:

- Direction and extent of change in aquaculture production.
- Change in value of production.

6.9 Exports to Marine Ecosystems

Description

Estuaries act as nursery areas for various invertebrate and vertebrate species which then recruit to marine environments. In addition, freshwater and associated inputs to and from estuarine systems affect stocks of certain marine species, notably prawns. Thus marine fisheries may depend to a large extent on freshwater inputs from estuaries or on recruitment in estuaries.

Method

- Identify fisheries that are dependent on freshwater and estuarine systems of the study catchment.
- Determine the value of the fishery (again this is greater than the value of the freshwater/estuarine system's inputs).
- Estimate the change in productivity, or increase in input costs, under different MC scenarios A to D.

Reporting

The report from this assessment will include information on the following:

- Type and number of fisheries dependent on freshwater and estuarine systems.
- Value of this industry.

Further analysis

Further analysis to assess changes under different MCs would include:

- Changes in water quality and quantity associated with MC scenarios A to D.
- Changes in production associated with changes.
- Changes in input or production costs.

6.10 Waste Treatment

Description

Aquatic systems can play an important role in the absorption and breakdown of organic and inorganic pollutants. Organic pollutants, such as nitrates and phosphates, and inorganic pollutants, such as heavy metals, are diluted, taken up by plants, trapped along with sediments or broken down within aquatic systems.

A number of studies have been carried out on this function in natural and created aquatic habitats. From these studies, it appears that several variables determine the degree to which wastes are removed in a system, and there are no simple formulae that can be followed. Waste uptake does not only occur within aquatic ecosystems, but also occurs during the drainage process, as waste water runs through various habitats en route to streams and rivers. Numerous studies in the Northern Hemisphere have shown that a large proportion of the **nitrate** in subsurface flows moving towards streams was removed from the water as it passed through riparian areas. However, riparian buffers may fail to reduce nitrates when leguminous (nitrogen-fixing) trees are present (James et al. 1990). This would be the case where alien legumes have invaded riparian areas. Studies in the northern hemisphere suggest that **phosphorous** is less easily absorbed when it is in dissolved form (Peterjohn & Correl 1984), and is most efficiently removed from water when it is attached to sediment, which is then trapped in riparian zones or wetlands. All of these studies give varying estimates of the amounts of nitrates and phosphates removed by riparian and wetland areas, and data tend to be reported as the percentage change in concentration. Removal rates obviously depend on starting concentrations. These types of data are difficult to extrapolate to a resource economics study, which requires information on exactly how much of a substance is removed on a per area basis for different habitats. In any case, the riparian vegetation in the studies cited above is very different from that in most South African rivers, and many of the studies are of water passing from agricultural areas through forested buffer zones before draining into rivers. In South Africa there is data on the capacity of artificial wetlands to treat wastewater (e.g. one ha wetland can treat about 272 m^3 of wastewater per day), but little data exists on natural systems, which are generally less efficient. Accuracy of estimation of the value of the wastewater treatment by aquatic habitats will depend on finding out absolute rates (e.g. g of N per year) of waste removal.

In South Africa, there are guidelines, or standards, which describe the concentrations above which pollutants become toxic, or have a noticeable environmental impact. In other words, waste water has to be treated so that these guidelines are met. The aquatic habitat is able to assimilate the amount of waste generated up to these threshold levels. If aquatic habitats are degraded or instream flow is reduced, then the capacity of the environment to absorb wastes will be reduced, and producers of waste water have to incur additional costs to meet environmental standards. The cost savings generated by the environment's assimilation capacity represent the value of this ecosystem service.

Method

- Estimate the quantity of pollutants removed from waste water treatment, and the cost of this treatment (perhaps there are standard figures for this in South Africa).
- Ascertain the assimilation capacity of the water resource, in terms of absolute quantities of different pollutants, from water quality specialists (e.g. estimates have been made for the Crocodile catchment).
- Apply the average cost of removal of these pollutants to the absorption capacity;
- Estimate how assimilation capacity might change under different management scenarios, with the aid of water quality specialists.
- Estimate the change in treatment costs associated with each scenario.

Reporting

The report from this assessment will include information on the following:

- List of pollutants entering the system.
- Extent of pollutants actually found in the system
- An assessment of the extent of assimilation of pollutants that is taking place.
- Cost of alternative removal and remedial actions should the absorption capacity not exist naturally.

Further analysis

Further analysis to assess changes under different MCs would include:

- Changes in treatment costs under MC scenarios.

6.11 Control of Pests and Pathogens

Description

Aquatic habitats can host a number of water-borne and water-associated pests and pathogens. Since these are often associated with low-flow conditions, the way in which a system is managed can affect their prevalence within a system. For example extraction of water for an irrigation scheme may lead to increased incidence of bilharzia and malaria due to more sluggish flow within the system. Low flow systems could also be conducive to the invasion of alien water vegetation.

Disease caused by such pests and pathogens carries a significant economic cost. This is through:

- The costs of treatment, and lost economic productivity, and/or
- Increased prevention costs.

Method

- Establish the current incidence and prevalence of water-borne and water-related diseases.
- Establish the extent of aquatic alien plant invasions.
- Estimate the current expenditure on treatment and prevention.
- Estimate the loss of productive time associated with disease and multiply by the average wage rate.
- Estimate the change in incidence and prevalence that might be expected under different scenarios.
- Estimate the associated change in costs of treatment, productivity losses, and/or prevention costs.

Reporting

The report from this assessment will include information on the following:

- Types of water borne and water related diseases present in the system.
- Types of aquatic alien plants present.
- Current costs of eradication and control.
- Current impacts in terms of loss if production or increase in input costs.
- Value under MC scenarios A to D.

Further analysis

Further analysis to assess changes under different MCs would include:

- Changes in the rate or extent of invasion or infestation.
- Economic implications of changes under MC scenarios A to D.

6.12 Option and Existence Values

Description

Option value is the value of retaining the option to use a resource in future. This is often associated with biodiversity, in recognition of the fact that components of biodiversity may be found to be valuable in future. Existence value is the value of knowing that something exists, irrespective of whether it is used. This value is often realised in the form of donations to conservation organisations.

Method

Option and existence value are difficult to separate in reality, and are usually measured together, using Contingent Valuation Methods (CVM, see for example Dixon *et al.* 1986 for a brief introduction). CVM is survey-based, and seeks to ascertain people's willingness to pay to maintain a resource, or willingness to accept compensation for the loss in quantity or quality of a resource. It can easily be applied to ascertain response to change in the quality of water resources under different management scenarios. However, it is a controversial method, in that it is open to a number of biases. A set of guidelines has been produced which helps to minimise these biases. Nevertheless, CVM does not produce a hard economic value, such as economic impact or contribution to GDP. It provides a measure of society's preference, as expressed by their willingness to pay. The method is fairly expensive, requiring very careful survey design and fairly large sample sizes.

It may be possible to obviate the need for this method, by using multi-criteria decision techniques.

Reporting

The report from this assessment will include information on the following:

- The condition of the catchment area in terms of extent of conserved areas and existing levels of biodiversity.
- The presence of endangered or rare species.
- The value (willingness to pay) of society to maintain these species.
- Potential changes under MC scenarios A to D.

Further analysis

Further analysis to assess changes under different MCs would include:

- Changes in the rate or extent of extinctions
- Economic implications of changes under MC scenarios A to D.

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INCORPORATING ECONOMIC CONSIDERATIONS INTO THE DETERMINATION OF THE ENVIRONMENTAL RESERVE

Case Study:
The tourism value of rivers in and adjacent to Kruger National Park, and impacts of a change in river quality

Issue Paper No. 2

By

Jane Turpie, Alison Joubert, Myles Mander, Sharon Bosma, Daniel Chongo, John Foord, Sarah Frazee, Mathew Hemming, Alina Lengyel, Nonofo Mosesane, Jean Mwicigi, Paul Ndang'ang'a, Genevieve Pence, Bianca Preusker, Domitilla Raimondo, Samuel Soto, Lochran Traill and Ruth Wiseman

Institute of Natural Resources
Private Bag X01
Scottsville 3209
Tel: 033 – 3460 796
Fax: 033 – 3460 895
Email: ceo@nu.ac.za

In association with:
Percy FitzPatrick Institute (UCT)
Dept of Statistical Sciences (UCT)
University of Stellenbosch

EXECUTIVE SUMMARY

Following the new National Water Act (1998), methods are being developed and refined for determining the environmental reserve (quantity and quality of water reserved for ecosystem functioning and basic human needs) for all water resources within each of the country's 19 Water Management Areas. The reserve is determined in a process called Resource Directed Measures, which takes ecological, social and economic factors into account to determine the management class of a resource. The management class, in turn, determines the size of the reserve. Following a draft framework for the incorporation of economics into the RDM process, this study forms the first case study to develop a method for determining tourism value, one of the many economic values attributed to the goods and services provided by functioning aquatic ecosystems. All initial studies for testing RDM methodology are taking place within the Crocodile River Catchment, and this study concentrates on the value of tourism in the lower part of this catchment, in Kruger National Park (KNP) and the resorts south of its Crocodile River boundary. The case study was conducted during May-June 2000, and fieldwork was carried out by a group of postgraduate students from the Universities of Cape Town and Stellenbosch. Two surveys were carried out within the KNP (visitor and safari guide surveys), and a survey of managers of resorts along the Crocodile and Komati Rivers was also conducted.

Within the KNP, current tourism value was considered in terms of (a) revenues to KNP, or visitors' on-site expenditure, (b) contribution to the economy, or visitors' on-site and off-site expenditure, and (c) recreational value, including consumers' surplus - which is visitors' willingness to pay over and above actual on- and off-site expenditure. These values were apportioned to different parts of Kruger, viz., the Komati Basin, and within that, the Crocodile Catchment, based on proportional visitor-nights spent in these areas. It was estimated that the current value of KNP tourism within the Crocodile Catchment is about R30 million in terms of on-site expenditure, R58 million in terms of economic impact, or all expenditure related to visiting the park, and R822 million in terms of consumers' surplus. The latter two values can be added to calculate total recreational value. However, for various reasons, we do not recommend the use of consumers' surplus in the RDM decision process.

Four methods were used to isolate the value of rivers from the total tourism value stated above, and all yielded similar values of about 30% of the total. About 30% of tourism business would be lost if rivers were totally degraded. Thus rivers within the Crocodile catchment were worth about R9 million in terms of on-site costs, R19 million in terms of on- and off-site costs, and R74 million in terms of consumer surplus.

The effect of a change in river quality was determined using a joint contingent valuation - conjoint valuation approach. This involved respondents rating four different scenarios, each containing four attributes (crocodiles/hippos, birds, riverscape and trees) at four different levels. Five versions of the survey contained a total of 16 scenarios, and each included the *status quo* scenario. The analysis generated an equation which is able to predict the change in trip expenditure, or total KNP revenue, associated with changes in levels of any of the four attributes. This can thus be used in the RDM process when management class scenarios are described by aquatic ecologists.

Finally, outside KNP, the managers of nine tourist resorts along the Crocodile River and two along the Komati River were surveyed in order to provide a rough estimate of the value of tourism in these establishments, the contribution of the rivers to this value, and the effects of a change in river quality. Most of these resorts make frequent use of the rivers in marketing, and many of the services they offer are river-dependent. Along the Crocodile River, the location near the KNP was considered to be the most important contribution to business (63%), with the river location contributing 31%. Along the Komati, the location along the Maputo-Nelspruit corridor was the most important contribution to business (70%), while the river was considered to account for 25% of business. It was estimated that the Crocodile and Komati Rivers accounted for R19 million and R83 000 of gross turnover of these resorts, respectively. Some resorts were more sensitive to a change in river quality than others. On average, however, there is likely to be a decrease in occupancy rates with a decrease in river quality, especially under a scenario of water weed infestation.

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1 INTRODUCTION

For the first time in South Africa, under the National Water Act (Act 36 of 1998), the environment has been recognised as a legitimate water user, and allowance is made for the allocation of an ecological reserve, which is the quantity and quality of water required by ecosystems to maintain their functions.

Under the National Water Act, the country has been divided into 19 Water Management Areas (WMAs), each of which will be managed by a Catchment Management Agency (CMA). Amongst other things, the CMAs have the responsibility of determining the 'management class' of water resources (river reaches, wetlands etc.) within the WMAs. This, in turn, determines the future state of health of these resources (ranging from relatively pristine to 'hard-working' systems), through the determination of a reserve (for ecosystem functioning and basic human needs) and resource quality objectives (RQOs). The process of definition of management class, the reserve and the RQOs has been termed Resource Directed Measures (RDM). The final Management Class - or society's desired future health state of the ecosystem - will be decided on the basis of ecological status and heath, basic human needs, and economic and social considerations. The framework and methodology for guiding the latter decision process is still under development. However, the essence of this process is that it will incorporate measures of economic value of the environmental reserve, or put simply, the economic value of retaining different levels of quantity or quality of water in the ecosystem (Turpie *et al.* in prep). Ultimately the decision process will rely on predictive capacity regarding the expected economic impacts of different scenarios of catchment management.

The emerging framework and methodology for incorporating economic considerations in the determination of management class and the environmental reserve will be tested in a case study on the Crocodile River Catchment, within the Komati WMA, where a comprehensive RDM study will be undertaken over the next two years. The overall study will develop and test methods to be used in estimating the environmental value of water resources, including ecosystem goods and services such as fishing, plant harvesting, recreation, flood retention, and water purification. This case study concentrates on assessing tourism values of rivers within the lower Crocodile River catchment and the potential economic impact of a change in their quality. The study area comprised the area from the western boundary of Kruger National Park (KNP) to the border of Mozambique. The main tourism activity in this area is centred in (a) the KNP, and (b) the tourism establishments located south of the Crocodile River.

The aims of this study were to:

- develop and test methods for estimating the existing tourism value of rivers within the study area, and
- develop and test methods for estimating the change in tourism value associated with possible future changes in river quality,
  (a) for tourism within a protected area (Section 2), and
  (b) for the tourism establishments alongside rivers (Section 3).

2 THE TOURISM VALUE OF RIVERS IN THE KRUGER NATIONAL PARK, AND RESPONSES TO A CHANGE IN RIVER QUALITY

2.1 INTRODUCTION

In many WMAs rivers flow through protected areas which form the mainstay of tourism in the country. The environmental reserve not only impacts on ecosystem functioning, and hence biodiversity conservation, but also potentially on their tourism value.

The approximately 2 million ha KNP is situated in the north east of South Africa and has a semi-arid to sub-tropical climate (Coller *et al.*, 1997). The Crocodile River forms the southern boundary of the park. There are five major rivers in the park - the Crocodile, Sabie, Olifants, Letaba and Limpopo Rivers. The main rivers are perennial (although in recent years they have run dry) and subject to occasional extreme floods. The rivers are predominantly sandy as a result of alluvial deposits and contain dolerite, diabase and glabro rock outcrops (Coller *et al.*, 1997). The Sabie and Crocodile Rivers and their tributaries, in the southern part of the KNP, form part of the Komati Basin, and are the focus of this study.

This study aimed to:

1. Determine the value of tourism in southern Kruger, within the Komati Basin and Crocodile catchment;
2. Determine the proportion of this value that can be ascribed to rivers; and
3. Determine the potential effect of a change in river quality on this value.

2.2 METHODS

Two survey instruments were developed, one for visitors to the KNP, and the other for tour guides within the park (Appendices 1 and 2). The rationale for their design is described in detail below. The survey instruments were designed, tested, refined and carried out during the week 29th May to 2nd June 2000. Visitors to Berg en Dal, Skukuza, Pretoriuskop and Lower Sabie Rest Camps, and Afsaal, Tshokwane and Nkuhlu picnic sites were approached randomly by the enumerators and interviewed. A total of 183 surveys were completed.

2.2.1 Determining the value of tourism

Several measures of value were considered:

a. Gross Revenue to KNP

Visitor data and revenue data were available from the KNP, separated to different gate entries and different rest camps. This income was apportioned to the Komati Basin, and within this, the Crocodile Catchment area, using the proportions of visitor entries and overnight revenues accruing to gates and camps within these areas. These statistics give a simple measure of gross income to the KNP and its component areas in terms of visitor spending.

b. Contribution to the SA economy

Some spending by visitors outside the park may be attributable to the park itself. This is true in the case of visitors paying outside safari operators for guided trips into the park (apart from the entrance fees, this income accrues to companies outside the park), and in the case where visiting the park formed the main reason for a trip from home (where a portion of the visitors' total travel expenditure is therefore attributable to the park). These values were estimated as follows:

(i) Income to private safari companies operating within Kruger:
Information on the tariffs for day safaris was obtained through telephonic interviews with safari companies. Data on the number of clients brought into the park by safari operators and their gate payments was obtained from the KNP. These figures were used to estimate the total annual turnover generated by private safari companies from their operations in Kruger.

(ii) Visitor expenditure outside Kruger National Park
The visitor survey included questions about visitors' entire journey, and the degree to which the KNP was the reason for that journey:
- VS 3. Where do you come from?
- VS 4. Is that where you travelled from? If not, where?
- VS 6. How long are you staying in Kruger? How long is your whole trip away from home?
- VS 7. How much of the reason for your entire trip was coming to Kruger? (% - prompted)
- VS 8. What have you budgeted for your whole trip?
- VS 9. How much have you budgeted for Kruger (or accommodation details)

c. Recreational value including Consumer's Surplus

The amount of money that visitors spend on enjoying an amenity such as the KNP may only reflect part of their actual willingness to pay for the experience. This often happens in cases where natural amenities are underpriced, although this may not be the case for the KNP. The willingness to pay over and above actual expenditure is called Consumer's Surplus, and the two amounts together form an estimate of total willingness to pay, or total Recreational Use Value. This is usually estimated by means of the Travel Cost Method. Thus questions in the survey addressing trip costs and on-site costs were designed for use in such a travel-cost analysis.

A zonal travel cost method was applied, which compares the frequency of visits from zones of different distances to the reserve with the travel costs from each zone to estimate the visitors' demand curve and the consumer surplus. The origin zones were taken as the different countries and for South Africans, different provinces. Visitation rates from each zone were expressed as a function of the total population in each zone. In order to avoid the problems of multiple site visits, the travel costs were not taken as full trip costs, but as the proportion of total trip costs that visitors ascribed to the KNP. Average costs per visitor were calculated for each origin zone. The consumer surplus was then calculated using integration (see results section).

2.2.2 Determining the proportion of value ascribed to rivers.

No matter how one measures value, this value comes from the multiple attractions that KNP has to offer. Thus the survey instrument had to elicit the proportion of this value that could be attributable to rivers alone. This is a difficult problem, because rivers form part of a package that respondents might find difficult to tease apart. Two approaches were used to estimate this proportion:

(a) *Visitor survey*: Questions were included to find out how self-drive visitors use rivers, and how much enjoyment they got from them.

VS 10. Could you trace the routes that you have used so far on this map please (map of whole KNP provided)

VS 11. Could you give a rough estimate of the % of your time that you have spent in different types of habitats (table)

VS 12 What percentage of your total satisfaction would you attribute to these three different types of habitat? (table)

Habitat	% time	% Satisfaction
Waterholes and dams		
Rivers		
Bushveld		

The percentage of the abovementioned tourism values which could be attributed to the rivers in the park was calculated in three ways: first, by the percentage of total mileage done in the park which was driven near rivers; second, by the percentage of time in the park which visitors spent at rivers; and third, by the estimated percentage satisfaction or enjoyment which the visitors obtained from rivers.

(b) *Safari Guide Survey*: It was felt that whereas tourists may tend to use routes in the park relatively randomly, safari guides, through their greater experience, would tend to have a better idea of the value of rivers in satisfying their clients wishes. Safari guide's movements and allocation of time are thus likely to reflect the value of the resource being used more accurately. Furthermore, it was thought that there might be a seasonal difference in river usage by tourists as animal concentrations change with varying water availability. Since the visitor survey was only conducted in winter, the safari guide survey included questions about seasonal differences in their routes.

GS 2. Which areas of the park do you operate in (trace routes on map)

GS 3. When on a game drive, what proportion of your time do you spend at the following habitat types, and how would this differ in summer?

Habitat	Winter (%)	Summer (%)
Waterholes and dams		
Bushveld		
Rivers		

In order to determine how much of the game-drive generated turnover could be attributed to rivers in the park, the game-drive turnover (net of park entrance fees) was multiplied by the proportion of time that was spent along rivers during safaris.

The safari guide survey was also designed to acquire further qualitative details about the rivers and their attractions for tourists:

GS 6. Are there any species that would make a visit to a river worth your while even if there was only one individual?

GS 7. Would an infestation of alien plants stop you from visiting a river?

GS 8. Are there any river features in the southern part of the park which would justify a special trip?

2.2.3 Determining the impact of river quality on tourism value

The impact of a change in river quality on tourism value was ascertained by means of a joint contingent valuation-conjoint survey approach. The conjoint approach was used to ascertain the relative value of different attributes of river systems. Typically, a conjoint approach would include a cost variable as one of the attributes. Unlike other conjoint studies where the cost variable refers to the cost of a trip (or 'package'), we could not use this approach because of the highly variable total trip costs involved, and because within a trip, the time cost of visiting a river was not really a cost. Thus we adapted the method by including contingent valuation type questions which provided cost values to serve as 'anchors' for the conjoint values.

Data collection in conjoint analysis can be done in two different ways. (1) A two-factor evaluation or trade-off approach where only two attributes are considered at one time and a number of attribute combinations need to be considered by each respondent, and, (2) multi-factor evaluation where respondents are presented with a combination of all attributes at one time (Salman and Shiels, 1984). For this study, a multi-factor evaluation approach was taken, as it is easier to administer, and reflected more realistic scenarios of riverine change. Within multi-factor conjoint analysis, respondent burden grows exponentially as the number of attributes and attribute levels increase (Mackenzie, 1993). For this reason, number of attributes and attribute levels were kept to a minimum while trying to ensure that the full range of relevant river attributes and attribute levels were represented. Four attributes of river systems, which were felt to be important to visitor enjoyment were chosen, namely, number of crocodiles and hippos, number of waterbird species, riverscape, and trees, and four levels were defined for each (Table 2.1). The levels of these attributes will vary depending on ecological catchment management practices and are therefore appropriate for use as indicators of change.

Table 2.1. Summary of attributes and attribute levels.

Crocodiles & hippos (C)	**Water birds (W)**	**Riverscape/Scenery (R)**	**Trees (T)**
None	None	Dry riverbed	No trees
One of each	Very few	Uniform scene (for example, all reeds)	Few /Sparse trees
About 10 of each	About 5 species (incl. "common" species e.g. herons, ducks)	Dominated scene (for example, several habitat types present but one obviously dominating)	Some trees
About 20 of each	About 15 species (incl. Interesting/rare species e.g. Fish Eagles, Finfoots)	Diverse scene (for example, some reed beds, sand bars, and exposed rocks)	Plenty of trees (including big/tall/old trees)

With four attribute levels and four attributes there are 256 possible combinations and 16 of these were chosen using an approximation to an extended centre point design (Stewart *et al.*, 1993, page C5). A worst case (worst on all attributes) and an ideal case (best on all attributes) were included. The *status quo* formed one intermediate point, while 13 more intermediate combinations (better and worse than the status quo) were randomly generated using MSExcel's random number generator, eliminating impossible combinations of attributes. The 16 scenarios were distributed between five questionnaire versions, including the *status quo* scenario in each. Each respondent therefore rated four scenarios (three relative to the *status quo*). The *status quo* was included in all five survey versions so that respondents had a benchmark against which to compare the different scenarios. This also provided a benchmark for adjusting scores from the five questionnaire versions to an approximately common scale. The pristine (ideal) and heavily degraded (worst case) river scenarios were each only included in one of the five survey versions.

In a conjoint analysis using multi-factor sampling, a single rating is given to a combination of attributes of different levels. A rating system for scenario comparison was used where respondents were asked to rate each river scenario using a scale from 1 to 10, with 1 indicating a scenario yielding very little or no satisfaction, and 10 a scenario providing the most satisfaction. Ratings were used because they indicate the relative benefits associated with each scenario explicitly as opposed to other methods, for example binary preference models which limit the utility "benefit" to either extremes, or inexplicit 1s or 0s (Mackenzie, 1993).

Survey responses where respondents had not co-operated or had clearly not answered the question thoughtfully were excluded from the data analysis. The relationship between the different levels of the attributes and the response (score) was examined using a generalized linear version of multiple regression (GENSTAT 5, Version 4.1, 1998). A constant and the four attributes (croc/hippo, waterbirds, riverscape, and trees) were entered as terms to be fitted to the response variable i.e. the score (Z) given to the scenario. Different models were fitted including all the attributes either as continuous variables or as discretely scaled variables, or as a combination of both variable types.

In order to be able to attribute a recreation value to the river scenarios presented in the conjoint analysis, two contingent valuation-style questions were included in the survey:

VS 13. If all of the rivers in Kruger dried up completely, so that there were no crocodiles, hippos or waterbirds present, there were no riverine trees, but everything else in the park were the same, would you spend less time in Kruger Park? Please estimate how much.

VS 14. Consider the fact that the rivers in the Park are used upstream, and are presently not in their original state. If, hypothetically, the rivers were to be restored to their original state - that is, they contained high numbers of crocodiles, hippos, waterbirds, etc, diverse habitats, including lots of riverine trees, do you think that you would spend more time in Kruger Park? Please estimate how much.

Using the final conjoint model, visitor utility indices were generated for the status quo, pristine, and completely degraded river conditions. In order to estimate the effects of changes in river quality on visitor spending two regressions were fitted using the latter three utility indices. The first regressed the indices against the average expenditure per trip under the *status quo* (mean daily expenditure times median trip length), pristine, and totally degraded scenarios (determined from the responses to questions VS 13 and VS 14 above). The second regression did the same, but using the total annual revenue generated in KNP.

2.3 Results

2.3.1 Visitor origins

The results of 163 visitor groups who supplied information on expenditure were analysed, representing 708 visitors to the park. Of these 11 groups were on bus tours, and the remaining groups were self-drive visitors. Sixty per cent of the visitors (including the group totals) surveyed in the park were from Africa, 29% from Europe and 6% from North America (Figure 2.1). Visitors from other continents made up less than one per cent of the total visitors to the park, each. Of the African visitors, South Africans made up 98.9% of the total, with Gauteng (37%) and KwaZulu-Natal residents (35%) comprising the majority (Figure 2.1).

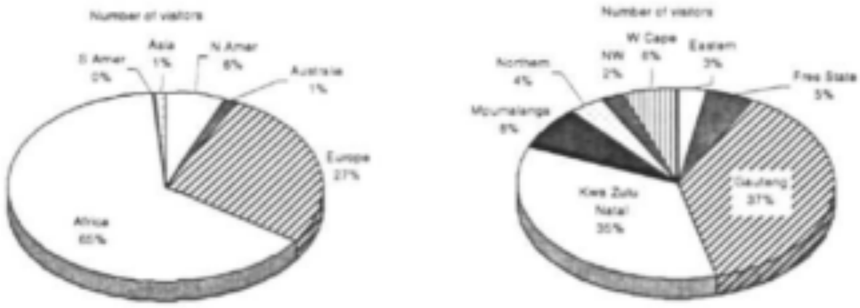


Figure 2.1. (a) Origin of all visitors, and (b) origin of South African visitors sampled in KNP during May-June 2000.

2.3.2 Visitor expenditure

The majority of South Africans visiting the park were on a single-destination trip, with KNP being cited as 85% of the reason for their trip away, on average (Table 2.2). Most international visitors, on the other hand, were on multiple-destination trips, and cited KNP as being approximately 51% of the reason for their trip. Not all foreign visitors considered their trip to have begun in their country of origin, and some were undertaking 'trips within trips' (e.g. a holiday following a business trip to Johannesburg) and in these cases their costs did not include airfares to South Africa. Total trip costs for foreigners were generally higher than those of South Africans (Table 2.2). Foreigners, however, tended to spend less time in the Park, but spent more money in KNP than did South Africans (Table 2.2).

The stated amount spent by visitors in KNP theoretically translates to the KNP's income from tourism. It is unnecessary to extrapolate the above sample to work out total income, as these statistics are available. The total revenue generated by visitors to Kruger for the year 1999/2000 was R135 793 193 which is equivalent to the money spent by visitors (i.e. their on-site costs). This is only part of the visitors' total willingness to pay to experience the KNP.

Table 2.2. Origins and travel costs for visitors to KNP

	South African	International
Percentage of visitor groups surveyed	72	28
Number of groups surveyed	118	45
Number of visitors represented	431 (63%)	253
Average group size	4	4.3
Average (median) length of total trip	10 (9) days	24 (15) days
Average budget for whole trip (per person)	R1708	R13 865
Average (median) length of stay in KNP	6.8 (5) days	4.9 (3) days
Average budget for stay in KNP (per person)	R860	R1849
% importance of KNP in whole trip	85%	51%
Inferred expenditure on KNP (per person)	R1230	R5065

Considering the stated importance of KNP for a visitor's whole trip away, it is possible to infer additional costs incurred elsewhere that are attributable to KNP over and above their on-site costs. For example, for a visit which was solely to visit the park, 100% of the travel costs to the park should also be included in estimating the visitor's total willingness to pay to go there. The inferred willingness to pay (or total expenditure attributable to the Park) is higher than actual on-site expenditure, particularly for international visitors (Table 2.2). Using this information, it is possible to extrapolate the results to estimate the total annual expenditure associated with KNP (i.e. on-site plus off-site costs). This total of R267 million (Table 2.3), is effectively the contribution to the global economy, as it includes airfares and tour costs paid outside the country, although much of the total probably contributes to the South African economy.

Table 2.3. Calculation of total visitor expenditure attributable to Kruger National Park.

	Total KNP costs from sample	%	Estimated total annual expenditure (1999/2000)	Ratio of Total cost attributable to KNP to KNP costs	Estimated total annual KNP plus off-site expenditure attributable to KNP
South African	240 697	59	R80 478 966	1.4	R115 103 637
International	165 434	41	R55 314 227	2.7	R151 523 288
	406 132		**R135 793 193**		**R266 626 926**

The above values are for the whole of the KNP. For the purposes of this study, we are interested in the tourism value of the KNP within the Komati Basin, and particularly, within the Crocodile River Catchment in the southernmost part of the KNP. These values were estimated on the basis of tourist nights spent in the different parts of the park (Table 2.4).

Table 2.4. Calculation of visitor expenditure attributable to the Komati Basin area within KNP, and within that, the Crocodile catchment area.

	Percentage of total KNP visitor nights	On-site expenditure	On-site and off-site expenditure
Whole of Kruger	100	**R135 793 193**	**R266 626 926**
Komati Basin	61.4	R83 377 021	R163 708 933
Crocodile catchment portion	21.9	R29 738 709	R 58 391 297

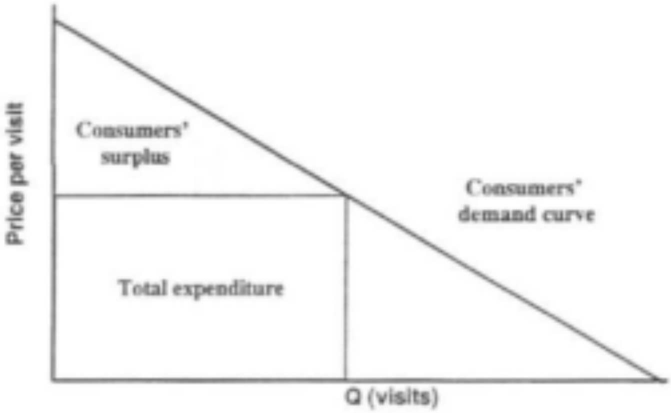
In addition to the expenditure by self-drive and touring visitors, many visitors enter the park on open safari vehicles which operate from various bases around the park. These visitors were not captured in the visitor survey, and only their entrance fees are captured in the above statistics. They incur additional expenditure within the South African economy, in the form of payments to safari companies.

A total of 41 442 people were brought to the southern KNP by private safari operators during 1999/2000, on 5694 safari trips equating to an average of 7.3 clients per vehicle. These figures are for the five gates within the Komati Basin area, but accounted for nearly all (98.7%) private safari vehicles entering the park. Private safaris generate an annual gate turnover of R3 063 840. This is obtained from vehicle and passenger entrance fees of R65 charged to all clients of registered safari operators.

Based on the average price for a half-day game drive of R375, and subtracting the gate fees of R65 per person, the gross income to private safari operators from game-drives in the KNP was estimated to be approximately R12.5 million. In comparison, KNP-run game drives yielded an income of R4.6 million during 1999/2000, from a total of 66 507 park guests (included in the expenditures estimated in Section 2.3.2).

2.3.3 Visitors' consumer surplus

In addition to actual expenditure, recreational value usually comprises a degree of consumer surplus. This is the amount visitors are willing to pay over and above what they have paid to visit the park (Fig. 2.2). A zonal travel cost method was used to estimate the demand curve for visits to the KNP. The average travel costs per person are given in Table 2.4., and the



resultant demand curve is shown in Fig 2.3.

Figure 2.2. The demand curve and the calculation of consumers' surplus

Table 2.4: Average travel cost per visitor per zone

Zone	Average travel cost/visitor	Zone	Average travel cost/visitor
Angola	R1 000	Sweden	R5 000
Argentina	R2 623	Switzerland	R3 399
Australia	R3 535	UK	R4 622
Canada	R14 052	USA	R2 967
France	R10 191	Northern Province	R341
Germany	R8 692	Western Cape	R2 313
Holland	R1 696	North West	R861
India	R4 897	Eastern Cape	R1 231
Italy	R3 750	KwaZulu Natal	R2 417
Namibia	R2 000	OFS	R831
Poland	R8 625	Gauteng	R1 179
Singapore	R4 000	Mpumalanga	R668

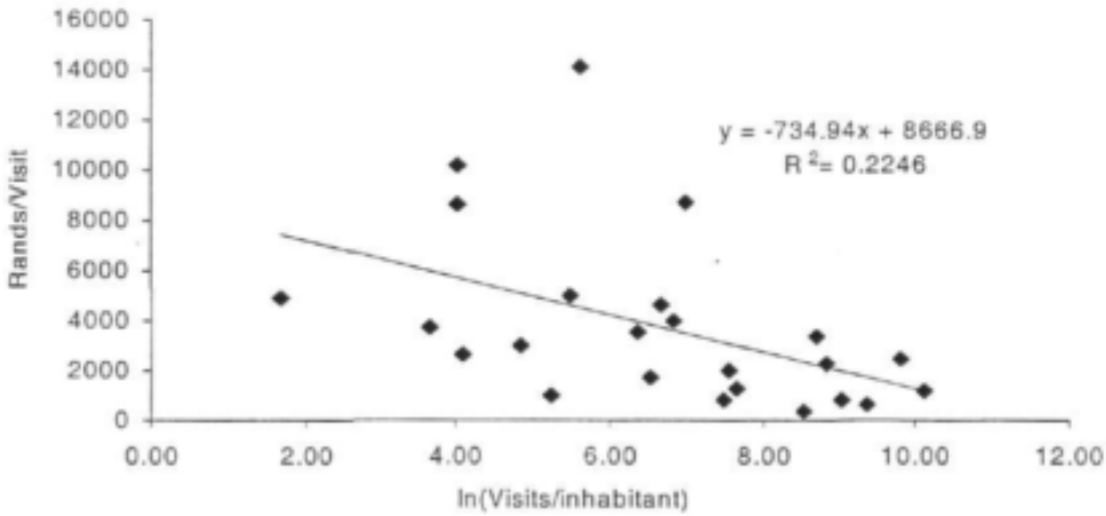


Figure 2.3. Demand curve for visits by international and local visitors to Kruger National Park.

In order to calculate consumers' surplus, the above demand curve was expressed as a semi-log function with Travel Cost as the independent variable, as follows:

$$\mathrm{Ln}(Q) = a + b(TC),$$

where:

$$\mathrm{Ln}(\text{Visitation rate}) = -6.0182 - 0.003(TC) \quad [n=24, r=-0.23, P < 0.05]$$

Consumer surplus for each zone is calculated by taking the integral under the demand function with respect to Price. For the semi-log function the consumer surplus for each zone is calculated as (Hof & King 1992):

$$CS = -e^{a+bP} / b$$

Using this function, annual consumer surplus is estimated to be in the order of R3753.5 million for the whole of KNP. For the Komati Basin and Crocodile Catchment areas, it would be in the order of R2304 million and R822 million, respectively.

2.3.4 The tourism value of rivers in KNP

Three methods were used to estimate the tourism value of rivers: the percentage of mileage driven next to rivers, the percentage of time spent at rivers, and the percentage satisfaction that respondents gained from rivers out of all possible habitats in KNP. Within the Komati Basin area, 32% of the distance travelled by visitors was along rivers, whereas only 28% of the actual road network in this area is along rivers. The percentage of satisfaction gained from rivers (30%) was higher than the percentage time spent along them (25%). The measure based on satisfaction was considered to be the most appropriate. Thus, for the whole of KNP, R41 million of total KNP revenues (i.e. 30% of R135 793 193) and R80 million of overall expenditure (on-site and off-site attributed to KNP) by tourists could be attributed to rivers. The values apportioned to the Komati Basin and the Crocodile catchment, estimated on the basis of total values obtained in the previous section, are summarised in Table 2.5

In addition to the above, responses were obtained from 24 safari guides operating within the KNP. About 27% of the route driven by guides, on average, is along (or over) rivers. These guides claimed to spend, on average, 26% of their time at rivers (as compared to 23% at waterholes and 51% in the bush). Thus, self-drive tourists tend to use a greater proportion of river roads than available, while safari guides use less. There was no significant difference in the use of these habitat types in summer or winter. Based on percentage of time spent at rivers, it is estimated that approximately R3.2 million of the revenues generated outside Kruger for safaris into the park can be attributed to rivers.

Table 2.5. Three estimates of the tourism value *of rivers* in terms of expenditure in KNP (on-site costs), total expenditure (on-site + off-site costs – including money paid to safari companies), and consumer surplus.

	On-site costs	**On-site + off-site costs**	**Consumer Surplus**
Kruger Park	R41 210 518	R83 198 283	R1 127 250 000
Komati Basin	R25 013 106	R52 322 885	R207 639 450
Crocodile Catchment	R8 921 613	R18 662 397	R74 060 325

Safari guides indicated that a number of river attributes were very important attractions in a game-drive and thus justified spending time driving along rivers. The most important of these were hippos (*Hippopotamus amphibius)* and crocodiles (*Crocodylus niloticus)* and concentrations of various game species along the river, particularly during the winter months. More than 90% of drivers felt that the presence of these animal species and the animal concentrations were the most important features of rivers. Approximately two thirds of the drivers recognised the appeal of the riverscape itself as an attractive feature while around half felt that the large river trees and riverine birds were important features. Safari guides also indicated that a number of other specialist species such as bushbuck (*Tragelaphus scriptus)*, nyala (*Tragelaphus angasii)* and, in particular, leopard (*Panthera pardus)* were also very important and attractive features of riverine areas. Most safari guides did not consider the presence of alien aquatic water weeds to be a significant deterrent.

2.3.5 Effect of a change in river quality on tourism value of rivers

A total of 180 responses were used in the conjoint analysis. This final pool of surveys consisted of 38 copies of version A, 34 of version B, 34 of version C, 38 of version D, and 36 of version E. Each version of the survey consisted of four hypothetical scenarios. The scenario describing the *status quo* condition of rivers in KNP (A1, B1, C1, D1, & E1) scored an average of 8.67 on a ten-point scale. The "ideal" scenario (D2) was given a 9.45 rating, and the "worst" scenario (A3) 1.05. The average scores for the other scenarios are presented in Table 2.6, along with the attribute levels of each scenario.

Various generalised linear models were tested in Genstat, ranging from converting all the attributes to categorical variables to assuming all could be considered to be continuous variables. The assumption of continuity is unlikely to be true for the riverscape attribute, and so in the final model, Croc/Hippo (C), Birds (B) and Trees (T) were continuous while riverscape (R) was categorical (Table 2.7). Of all the models tested, this model also explained the most variance in the data (67.1%).

Table 2.6 Survey versions and their corresponding scores and values for each scenario (1-4).

Version	Ave. score	Adjusted Score	Scenario	Croc/hippo (C)	Waterbirds (W)	Riverscape (R)	Trees (T)
A 1	9.45	7.711	*status quo*	10	15+	dominated	some trees
A 2	2.92	1.184	intermediate	1	very few	dry riverbed	no trees
A 3	**1.05**	**-0.68**	**worst**	**0**	**0**	**dry riverbed**	**no trees**
A 4	4.08	2.342	intermediate	1	5 common	uniform	few trees
B 1	8.51	7.711	*status quo*	10	15+	dominated	some trees
B 2	4.51	3.711	intermediate	20	very few	uniform	no trees
B 3	6.36	5.553	intermediate	10	5 common	uniform	many trees
B 4	4.90	4.096	intermediate	10	very few	dominated	few trees
C 1	9.24	7.711	*status quo*	10	15+	dominated	some trees
C 2	6.62	5.089	intermediate	10	15+	uniform	few trees
C 3	3.24	1.711	intermediate	1	0	uniform	few trees
C 4	2.76	1.226	intermediate	1	0	uniform	some trees
D 1	7.71	7.711	*status quo*	10	15+	dominated	some trees
D 2	**9.45**	**9.447**	**ideal**	**20**	**15+**	**diverse**	**many trees**
D 3	3.95	3.947	intermediate	1	very few	diverse	few trees
D 4	1.34	1.342	intermediate	0	very few	dry riverbed	some trees
E 1	8.49	7.711	*status quo*	10	15+	dominated	some trees
E 2	6.07	5.294	intermediate	1	15+	uniform	some trees
E 3	3.39	2.613	intermediate	0	5 common	dry riverbed	few trees
E 4	6.60	5.822	intermediate	20	very few	diverse	some trees

Table 2.7. Summary of parameters for the conjoint model, and summary statistics.

	Co-efficient estimate	Standard error	t(713)	P
Constant	0.142	0.167	0.85	0.394
Croc C	0.0985	0.0138	7.13	<.001
Birds C	0.2251	0.0167	13.51	<.001
Scape 2 F	0.703	0.223	3.15	0.002
Scape 3 F	2.236	0.281	7.96	<.001
Scape 4 F	2.371	0.312	7.61	<.001
Trees C	0.0629	0.0105	6	<.001

The linear regression models produce an equation in the following form:

$$\text{Utility index (Z)} = \text{constant (K)} + \beta C + \beta W + \beta R + \beta T,$$

with the co-efficients obtained being:

$$Z = 0.142 + 0.0985\ C + 0.2251\ B + (0.703 \text{ if R2 or } 2.236 \text{ if R3 or } 2.371 \text{ if R4}) + 0.0629\ T$$

A utility index can be generated from the model for any combination of attribute values representing riverine conditions, including the "ideal", *status quo*, and "worst" river conditions (Table 2.8). In the case of the *status quo* condition of rivers, the score obtained can be considered to be equivalent to the current expenditure KNP. In May/June 2000, the average amount spent by an individual visiting KNP was R308.8 per day. A typical trip to KNP (based on the survey median of 5 days) would therefore generate, and be valued at, R1 544. The *status quo* revenues generated by KNP for the year 1999/2000, were R135 793 193. In the two other cases ("pristine" and completely degraded) the value is a function of a visitor's willingness to remain in KNP for a longer or shorter amount of time. If all of the rivers in KNP were restored to a "pristine" state, the average respondent would spend an average of 24% more time in the Park. A typical trip would then have a value of R1 917, and annual revenues would increase to R169 million. In contrast, if the rivers were allowed to dry up and degrade completely, an average visitor would spend 29% less time in KNP. This visitor, on a typical trip to Kruger, would then only spend a total of R1 094. The annual value (revenues) of the Park would fall to R96 million. It is interesting to note that the current value of rivers, estimated by two different methods (by asking satisfaction obtained in different habitats, and by asking how much less time would be spent in KNP if rivers were totally degraded) yielded almost exactly the same estimate of the value of rivers, i.e. approximately 30% of the value of the KNP experience.

Table 2.8 Condition and value parameters of rivers in three cases.

Condition	Typical amount of time	Value of one trip (R)	Annual Value (R)	Utility index (Z)	C	W	R	T
Ideal	+24%	R 1 917	R 168 635 589	9.75	20	15	4	30
Status quo	5 days	R 1 544	R 135 793 000	7.68	10	15	3	15
Worst	-29%	R 1 094	R 96 173 207	0.37	0	0	1	0

When the utility values are plotted against the trip and annual values associated with KNP, and a regression line is fitted between the points, two equations result (Fig. 2.4). For the value for an individual trip in Rands, the equation is:

$$y = 1038.3 + 80.92\ Z\ (r^2 = 0.94).$$

Similarly, for total annual expenditure in the KNP, the equation is:

$$y = 91316474 + 7116661\ Z\ (r^2 = 0.94).$$

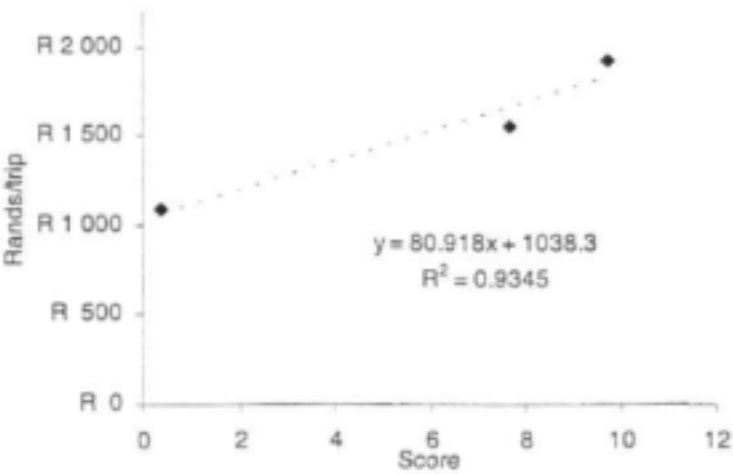


Figure 2.4. Relationship between utility indices and expenditure per trip for tourism in Kruger National Park.

The equation generated above, will allow the monetary valuation of ecological scenarios generated in the RDM process for determining a management class. By applying the conjoint analysis model any given scenario can be scored, and a corresponding monetary value determined. Table 2.9 shows a few examples of this. Scenario 1 changes three of the attributes down by one individual (or one species in the case of birds) from the status quo, Scenario 2 changes the same three attributes up by one individual from the status quo. Scenario 3, more realistically, looks at a more obvious change in level from the status quo.

Table 2.9 Scores, attributes levels and Rand values in terms of on-site expenditure (KNP revenue) of example scenarios. The percentage change in trip value can similarly be used to estimate the change in total on-site plus off-site expenditure, and in consumer surplus.

Scenario	Z score	Crocs /hippo	Birds	Riverscape level	Trees	Average expenditure per trip	Annual Value (x1000)		
							Whole KNP	Komati Basin	Crocodile catchment
Status quo	7.7	10	15	3	15	R 1 660	R145 994*	R89 640	R31 972
Scenario 1	7.3	9	14	3	14	R 1 629	R143 243	R87 951	R31 370
Scenario 2	8.1	11	16	3	16	R 1 691	R148 744	R91 328	R32 574
Scenario 3	3.1	5	5	2	10	R 1 288	R113 321	R69 579	R24 817

*This value is different to the actual KNP revenues as it is predicted by the model.

While it is useful to apply the methodology presented in this project to whole scenarios, or across the spectrum of attributes (especially when future ecological management classes are being assessed), it is also insightful to consider single or paired attributes. Seeing one crocodile along an average stretch of river, for example, adds a value of about R8 per visitor-trip to the value of KNP. One waterbird species adds about R18, and one tree per hectare accounts for an extra R5. An improvement from a dominated riverscape to a diverse riverscape would add R16. Degradation to a uniform riverscape, due, for example, to encroachment by reeds, would reduce the value per visitor-trip by R119.

3 AN ANALYSIS OF THE VALUE OF RIVERS TO TOURISM OPERATIONS LOCATED ON THE CROCODILE AND KOMATI RIVERS, SOUTH OF THE KRUGER NATIONAL PARK.

3.1 INTRODUCTION

This study aimed to determine the value of the rivers to tourism businesses located near or on the Crocodile River south of KNP, and on the Komati River in this region. The accommodation facilities located outside the Park are an important generator of tourism revenue for Mpumalanga and tend to offer more 'upmarket' accommodation than KNP. Due to time constraints, it was not possible to survey visitors to these establishments, and thus the approach used was one of surveying the managers on the importance of their river location, as well as collecting certain information on the establishments.

There are currently 15 operational accommodation facilities near the Crocodile River south of KNP (Kruger Park South Tourism Association, 1999). Nine of these facilities are located along the river, four are game resorts and the remaining two are located within 6km of a KNP gate. The number of beds per facility ranged from 6 to 578.

3.2 METHODS

Information was gathered from each of the nine facilities located along the Crocodile River and from two facilities along the Komati River by means of structured conversations (Appendix 3) with representatives (generally the owner or manager). This interview served to:

1. Ascertain occupancy rates;
2. Determine the importance of the river for the various services offered;
3. Determine the importance of various locational factors, including river frontage;
4. Determine the sensitivity of the business to river quality; and
5. Ascertain the expected change in occupancy that might accompany a change in river quality, through the presentation of scenarios.

The three scenarios presented were:

> Scenario 1. The river surface becomes covered in floating water plants, e.g. water hyacinth, with the result that there is less wildlife and fewer birds and fish.
>
> Scenario 2. The river flow is permanently reduced to a trickle, resulting in a general decrease in large trees, hippos, crocodiles, waterbuck and waterbirds, and an increase in reeds.
>
> Scenario 3. The river flow is fully restored and there is an increase in abundance and diversity of wildlife, waterbirds and fish, lush vegetation and large trees along the river bank and an absence of floating water plants.

3.3 RESULTS

3.3.1 The importance of rivers in service provision and marketing

Services offered by the 11 facilities are summarised in Table 3.1, together with managers' perceived importance of proximity the river and to KNP for each of these services. The river was of imperative value (mean = 10) to animal or bird hides and viewing platforms. It also rated high (mean > 8) for fishing, guided walks and bird watching. This indicates that managers attribute almost all their animal and bird related activities to the proximity of their business to the river. The notable exception is game drives (n = 4), which are attributed almost completely to KNP (mean = 9.6), and the river is perceived to contribute very little value (mean = 1.6). Proximity to KNP and to the river were rated high for accommodation (means = 8.9 and 6.5 respectively). This indicates that, although KNP is the main attraction to visitors, the river also plays an important role. One manager felt that operations with river frontage had a significant competitive advantage over other accommodation facilities not located along a river. The rating of other facilities and activities, including a restaurant, pub/bar, self-guided trails, swimming pool and boma/lapa, also indicates that some value is added from the river. The means for river value in all these cases ranged from 2.7 to 5.6.

Table 3.1. Summary of managers' scores of the importance of the river and proximity to Kruger National Park to their facilities and activities. A score of 0 means the river or Park has no importance or impact on the facility and 10 means it could not exist without the river or Park. * Total possible n of 11.

Service	N*	River	KNP
Accommodation	11	6.5	8.9
Restaurant	9	2.7	0.9
Pub/Bar	7	3	1.4
Bird/Animal Hide	4	10	2.5
Viewing Platform	6	10	3.3
Swimming Pool	9	5.2	3.1
Boma/Lapa	4	4.5	0
Self-guided Trail	5	5.6	1.6
Fishing	4	8	2.5
Game Drives	5	1.6	9.6
Guided Walks	2	8.3	9
Bird Watching	8	8.3	4.8

It is possible that managers would have changed the values they gave if they were prompted to think about certain values a little longer - interviews were conducted under considerable time constraints. Whittington *et al* (1996) found that people's responses to questions could change significantly if they were allowed longer time to think. An example here was the mean importance of the river of 5.2 and of KNP of 3.1 for swimming pools. These values are exaggerated, as the proximity of KNP or the river is unlikely to have a large effect, if any, on the use of a swimming pool. Such an obvious misunderstanding indicates that caution is necessary when interpreting the values given by the managers.

The overall results of this analysis show that the operations value the river slightly more than the proximity to KNP in relation to the facilities and activities that they offer. This is understandable, as the river is more accessible to them for their own development. It is important to note, however, that this does not take the relative importance of any of the facilities or activities into account. In other words nominal activities, such as fishing or hiking trails that do not contribute much, if at all, to the income of the operation, have been weighted the same as accommodation, which probably brings in the largest portion of the total revenue. For this reason it is more important to consider the effect people thought the river has on the economic value of their business as a whole (see next section).

In any branch of tourism, advertising is important to attract customers. Most operations involved in the tourism industry spend between 5 and 10% of their revenue on marketing (Guyette, 1996; Turpie *et al.*, 1999). It is assumed that the text and images used in advertising materials will reflect characteristics valued by managers for their ability to attract customers. Accommodation facilities located outside KNP use brochures with pictures and references to the river and other attractions to encourage prospective visitors to patronise their businesses. Table 3.2 shows the frequency of river references in the advertising materials. The river features prominently in most of the material. Of the ten businesses surveyed, four refer to the river in the name of their facility, and the river is referenced several times in the brochures. Over one third of the photographs used depict the river (Table 3.2).

Table 3.2. Marketing material of businesses in the study area, outside of Kruger National Park.

Name	Name refers to river	No. of times river is mentioned	% of photo's with river
Buhala Country House	N	4	33.3
Elephant Walk Retreat	N	1	33.3
Inzinyoni	N	1	
Malelane Gate Resort	N	3	21.1
Malelane Sun Inter-Continental	N	3	100.0
Ngwenya Lodge (Zulu for crocodile)	Y	1	50.0
River Guest Cottage	Y	8	45.5
River House	Y	2	60.0
Komati River Chalets	Y	3	-
Mean(n=9)	-	2.89	38.46

Assuming that all visitors use the advertising material when deciding where to stay, the rivers can be considered to add value to the business by attracting visitors. Due to the high profile of rivers in these materials we also conclude that river views and activities provide a competitive advantage over those accommodation facilities not situated on a river, and that rivers play an important role in the marketing of tourism-related businesses outside the KNP.

3.3.2 Economic Value of Rivers

Annual gross income was estimated on the basis of number of beds, price per bed based on a standard double rate, and the annual occupancy rate (Table 3.3). Based on an observation that managers often overestimate their annual occupancy (Turpie et al., 1999), the occupancy rates used in the calculation are ten percent less than the rates supplied by the survey responses for each business. An estimate for total annual revenue is based on a 10% positive adjustment on income generated from accommodation. This adjustment was made based on the assumption that an individual will spend a minimum of 10% more in a place of accommodation on food, drink, and/or other activities or amenities. This assumption is believed to hold true across all price ranges as those facilities that charge higher prices tend to offer a greater variety of amenities such as a curio shop from which they generate income.

Table 3.3: Summary of accommodation facilities surveyed and estimated gross income (Rands).

Name	Type	Years of operation	# of Beds	Occupancy Rate*	Annual beds occupied	Price per bed**	Estimated annual revenue***
<u>**Crocodile River**</u>							
Buhala Country House	B&B	5	16	68%	4 380	425	1 842 885
Elephant Walk Retreat	Lodge	5	30	68%	8 212	200	1 626 075
Inzinyoni	B&B	6	6	20%	438	250	120 450
Malelane Gate Resort	Resort	5	204	50%	40 953	155	6 284 238
Malelane Sun Intercontinental	Resort	7	204	59%	48 399	620	29 707 306
Ngwenya Lodge	Lodge	10	578	72%	168 776	120	20 050 589
Pan Lodge	Lodge	4.5	10	50%	1 807	120	238 491
River Guest Cottages	Resort	5.5	15	45%	2 738	150	406 519
River House	Lodge	2	24	59%	5 256	350	1 972 971
Crocodile Subtotal			*1 078*				*62 249 524*
<u>**Komati River**</u>							
Border Country Inn	Hotel	35	44	59%	9 636	150	1 550 192
Komati River Chalets	Hotel	8month	10	20%	730	130	104 390
Komati Subtotal			*54*				*1 654 582*
TOTAL			**1 132**				**63 904 106**

* *Occupancy rate is 10% lower than rates obtained during interviews*

** *Price per bed is based on standard double rate.*

*** *Estimated annual revenue assumes 10% addition to gross accommodation revenues*

Respondents were asked to estimate the relative importance of different locational factors to their business turnover. In general, proximity to KNP was considered to be most important to their businesses, and proximity to the river was considered to account for over 30% (range 0 – 80%) of business along the Crocodile River, and 5% (range 0 – 10%) along the Komati River (Fig. 3.1). The small sample size prohibits statistical analysis for the value differences between the Crocodile and Komati Rivers, but the substantial differences in value of the rivers necessitated the use of separate averages for deriving the income attributable to the rivers.

Proximity to Moçambique was the factor that corresponded to the greatest source of value for businesses along the Komati River. If we accept that the value responses are based on the respondent's experience and learning (Smith, 1990), then these values can be assumed to be an accurate reflection of the current value of the river to the business in its present quality state. Based on the estimates given by individual businesses, the current value of the Crocodile and Komati Rivers to tourism businesses is approximately R19 million per year (Table 3.4).

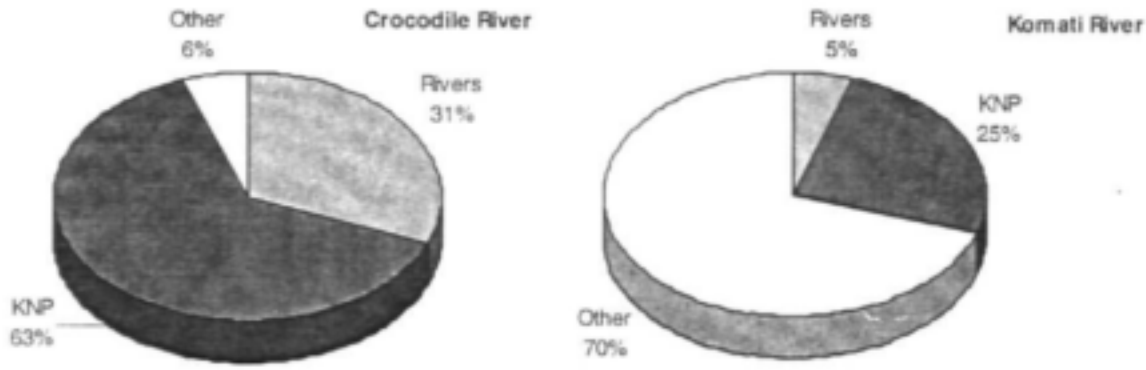


Figure 3.1. The mean percentage contribution of different locational factors to business turnover in lodges along the Crocodile and Komati Rivers.

Table 3.4 The value of rivers in terms of their contribution to lodge turnover along the Crocodile and Komati Rivers in the vicinity of Kruger National Park.

	Estimated Annual Revenue***	% importance of river location	Estimated value of rivers
Crocodile River			
Buhala Country House	R1 842 885	0	R0
Elephant Walk Retreat	R1 626 075	30	R487 823
Inzinyoni	R120 450	40	R48 180
Malelane Gate Resort	R6 284 238	10	R628 424
Malelane Sun Intercontinental	R29 707 306	10	R2 970 731
Ngwenya Lodge	R20 050 589	50	R10 025 294
Pan Lodge	R238 491	10	R23 849
River Guest Cottages	R406 519	80	R325 215
River House	R1 972 971	50	R986 486
Crocodile Subtotal	**R62 249 524**		**R19 366 518**
Komati River			
Border Country Inn	R1 550 192	0	R0
Komati River Chalets	R104 390	10	R10 439
Komati Subtotal	**R1 654 582**		**R82 729**
TOTAL	**R63 904 106**		**R19 449 248**

*** *Estimated annual revenue assumes 10% addition to gross accommodation revenues*

3.3.3 Possible economic impacts of changes in river quality

Having established the *status quo* or current value of the business, respondents were asked to consider three hypothetical scenarios in which the state of the river changed and to consider the effect that this change could have on the value of the business (Table 3.5).

Table 3.5: Responses to effects of change of river quality on business.

(n = 11)	Scenario 1 *River choked with weeds*	Scenario 2 *Greatly reduced river flow*	Scenario 3 *Pristine river*
Sensitivity to change:			
Not sensitive or a little sensitive	4	3	6
Moderately to very sensitive	7	8	5
Change in Activities offered:			
No	7	8	9
Yes	4	3	2
Change in occupancy rate:			
No change	8	6	8
Increase	-	2 (+35%)	3 (+24%)
Decrease	3 (-38%)	3 (-34%)	-
Overall change (mean n=11)	*-10%*	*-3%*	*+6%*

Most respondents reported that their businesses would be sensitive to a deterioration in the state of the river but less than half reported to be sensitive to a positive change. In all three scenarios most respondents would not change the activities or facilities they offer as a result of a change in river condition regardless of whether this change were positive or negative. Those that would change activities offered were those which relied exclusively, or greatly on the river, for example, for fishing or bird watching.

There does appear to be a tendency for operations with a smaller number of facilities to be less sensitive to negative changes and more sensitive to positive changes in river quality. This possibly could be attributed to the fact that operations with a higher number of facilities and activities make more use of the river and would thus be impacted more by a change in the quality. Conversely, if an operation does not make much use of the river, a positive change in river quality might entice them to make more use of the river causing them to be sensitive to such a change (in a positive way). The operations along the Komati were much less sensitive (mean = 5) to any changes in the river quality than the operations along the Crocodile (mean = 9). Although most respondents indicated that their businesses are sensitive to a change in river conditions most did not feel that these changes would affect occupancy rates.

For Scenario 1 (weed infestation) 27% of respondents estimated a decrease in occupancy rate of about 38%. In the case of severe flow reduction (Scenario 2) the 45% of respondents who considered that their occupancy rate would change were evenly split between an increase *or* decrease of about 34%. This depended on activities offered. For example, some respondents noted that reduced water flow could attract more game to the river improve game viewing and therefore improve occupancy rates. On the other hand, others commented that reduced water flow would adversely affect fishing and water–based activities such as the viewing of hippopotami, crocodiles and water birds and reduce occupancy. In the case of a pristine river (Scenario 3) most businesses (72%) reported no expected change in occupancy rates. An estimated increase of 24% was reported by 27% of respondents. No-one expected a drop in occupancy.

The mean change in occupancy (i.e. including all the 'no change' ratings) shows an anticipated overall drop in occupancy rate of 10 % if the river were choked with weed (Scenario 1); an overall drop in occupancy of 3% if the river flow were reduced to a trickle (Scenario 2); and an overall increase in occupancy rate of 6% if the river were restored to pristine conditions (Scenario 3). This translates into financial values of a drop in annual turnover of R 6.4 million (Scenario 1); a decrease in annual turnover of R 1.9 million (Scenario 2) and an increase in annual turnover of R 3.8 million (Scenario 3).

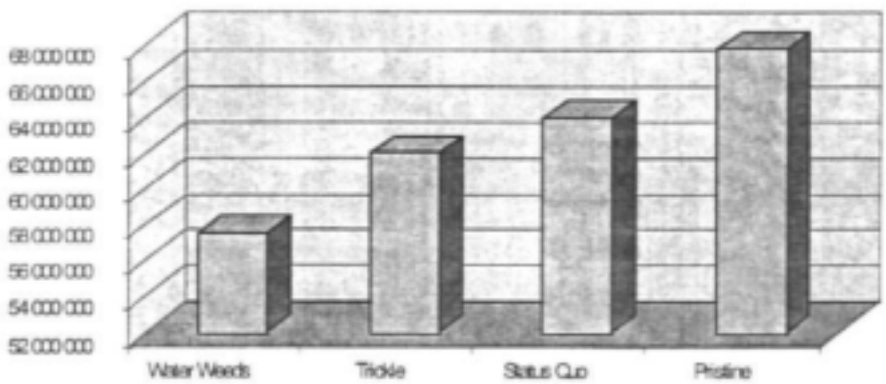


Figure 3.2. Economic value of different river qualities in terms of revenues to river-side tourism operations.

Finally, managers were asked whether they thought their resorts would still be viable without the river and nine out of eleven answered affirmatively. This was due to their proximity to KNP and in some cases their location on the route to Maputo. The two operations that do not consider themselves viable without the river are the two with the highest total "sensitivity to change" score. Two respondents remarked that even if the businesses were still viable without the river they would not stay on in the business (i.e. would sell) if the river disappeared. Two respondents reported that their businesses would never have been built if not on the river site but, now established, would continue to be viable. Their marketing strategies would change and they would "market *away* the river and market *in* more of the Kruger".

4 DISCUSSION

This study quantified the tourism and recreational value of rivers of KNP and its component catchment areas. The values obtained do not take into account their total ecological value in terms of the ecosystem functions that the rivers fulfil, other use and non-use values, nor recreational values not associated with KNP.

4.1 MEASURING TOURISM VALUE

Three measures of recreational value were considered in this study: revenues from on-site expenditure (i.e. within KNP), total on- and off-site expenditure (attributable to the resource under consideration) and consumer surplus. All three measures are potentially valid, but they differ in terms of who benefits or receives the value. While both measures of expenditure reflect proven willingness to pay, consumer surplus reflects additional, theoretical willingness to pay. On-site expenditure reflects the benefits to the protected area authority, but total expenditure reflects the benefits to the economy as a whole. In both of these cases, there is a knock-on effect called the multiplier effect, in which these expenditures lead to further spending in other sectors of the economy. However, we have not attempted to measure this value here.

On-site expenditure is the easiest to measure and to understand. The measurement of total expenditure attributable to a resource is rarely applied and is based on a subjective assessment by the users. As long as questions aimed at eliciting these assessments are well phrased so as to be properly understood by the respondents, this measure can be considered relatively accurate. In this study, respondents did not appear to have a problem with this concept.

Recreational use value is the total value or willingness to pay for the enjoyment of an amenity. Strictly speaking, it thus comprises consumer surplus as well as expenditure. Consumer surplus is most commonly estimated by means of the Travel Cost method (Bockstael *et al.* 1991; Tobias & Mendelsohn 1991; Dobbs 1993; Freeman 1993; Navrud & Mungatana 1994). This method is favoured where on-site expenditure ill-reflects the value of an amenity due to low or zero entry costs. Where prices reflect market value, the estimation of consumer surplus is less critical to valuation and decision-making. In this study, although we accounted for the problem of multiple site visits by eliciting the amount of total trip expenditure attributable to KNP, we still arrived at an extremely high estimate of consumer surplus in the order of R 4 billion. Interestingly, this value is almost three times as high as the estimated US$ 203 million consumer surplus for all of Kenya's national parks. For several reasons we feel that consumer surplus should not be considered in the reserve determination process.

- Consumer surplus is a difficult concept for most stakeholders and decision-makers to digest;
- The result obtained may vary considerably depending on the way in which origin zones are grouped; and

- Other socio-economic factors such as income and consequent differential spending power in different zones should be taken into account, making the method even more complex.

4.2 Isolating the value of rivers

Tourists are attracted to KNP by multiple features which form part of the 'package' for which they are willing to pay. Because of the inter-relatedness of natural features, it can be difficult to tease apart the component values. In this study, we experimented with different ways of isolating the value of rivers in the tourists' experience. These included mileage travelled along rivers, time spent along rivers, stated satisfaction gained along rivers, and the stated decrease in time that visitors would be willing to spend in the park if rivers no longer functioned at all. Interestingly, the results from all four methods were similar. We felt that the measure derived from the stated satisfaction was intuitively the most appropriate to use, because it is a direct measure of 'utility'. However, not all respondents felt comfortable with, or could answer the question, and if this method is used in future, careful attention should be paid to the wording of the question. In addition, it is useful to have a back-up measure, and the fourth measure should probably be used, as it is essential for assessing changes in quality as well (see below).

Furthermore, our value implicitly assumes that 100% of tourist value is attributable to driving around in three habitats. In future studies, a fourth category should be probably included: that of relaxing in the camp.

4.3 Estimating economic impacts of changes in river quality

Stated preference elicitation methods are usually used to value changes in environmental quality. These methods include contingent valuation, contingent ranking, polychotomous choice and conjoint analysis (e.g. Stevens *et al.* 2000). The contingent valuation method (CVM) is often the most viable method and is widely used to evaluate non-market environmental amenities (Mackenzie 1993; Stevens *et al.* 2000; Shultz *et al.* 1998). However, CVM is viewed with skepticism and its accuracy continues to be a subject of debate (Bishop *et al.* 1985; Boxall *et al.* 1996; Stevens *et al.*2000).

Conjoint analysis is a market research technique which is able to extract preferences for multiple attributes at multiple levels (Boxall *et al.* 1996), a complexity that reflects the complexity of ecological systems. Conjoint analysis makes substitutes explicit and this may encourage respondents to explore their preferences in more detail as well as express ambivalence or indifference directly, reducing non-response and protest behavior (Stevens *et al.* 2000). A major advantage of this method is that it gives respondents a chance to reflect the trade-offs that they make between the attributes of alternatives (Boxall *et al.* 1996). For example, when a visitor is considering a combination of river attributes for rating or ranking, his decision is governed by trade-offs, and although he or she may be unable to articulate them, they may be revealed by choices among hypothetical rivers having qualities which are varied in systematic ways. In addition, the method is able to determine the monetary values which will be attached to various levels of different river attributes.

In this study, the conjoint analysis assessed how the tourism value of KNP would change in response to changes in river quality as depicted by the changes in level of selected attributes. Although many river attributes may contribute to a visitor's experience, it was necessary to select a limited set of these, in order to keep sample size requirements to a manageable level, and to minimise the respondent burden. Thus, in selecting attributes we tried to choose those which would be both good indicators of river quality and important attributes in terms of the tourist experience. To a large extent our attributes matched those named by tour guides using the park. However, based on their comments, large mammals, especially leopards, should possibly also have been included. In future, when a water resource is classified, various ecological indicators will be used (e.g. invertebrates, fish species, riparian vegetation etc.). An assumption of this study was that the attributes used and their levels will be able to be related to such ecologically significant attributes and potential changes in their levels resulting from changes in management class. The models calculate changes in the tourism value of KNP under hypothetical future (riverine) scenarios which could then be related to ecological management classes. The attributes (crocodile and hippos, waterbirds, riverscape, and trees) are all indicators of river condition, in that, as the condition of a river changes in a positive or negative direction, so will the attribute level change. The attributes are all, to some degree, measurable and important to both ecology and tourism. As such, they will be helpful in determining which ecological management class should be assigned to a given river.

Another difficult aspect of design was the designation of attribute levels. In this study attribute levels were set relatively arbitrarily, but in future should be better researched so as to make them as compatible with the RDM process as possible. In addition, our survey was slightly ambiguous in the description of levels of trees, in that the words "few" and "some" were chosen to represent two different categories of tree densities.

For future survey design should be done in close collaboration with ecologists and hydrologists for choosing of attributes and attribute levels.

Two models were developed in the conjoint analysis; one which modelled the score, given a combination of four attribute levels (the conjoint model), and another which modelled the monetary value associated with that score (the monetary value model). The various conjoint models' results differed slightly depending on the assumptions made about the data, and the assumptions and models should be further examined in detail, to ensure that the model which best combines goodness of fit and reasonable assumptions is used. Only three data points were available (status quo, worst, best) for the monetary value model, and imaginative ways will have to be found to increase this number. The best fit model to these points reflected bigger increases in monetary value at higher attribute levels than at lower attribute levels. This is counter-intuitive, and likely to be a result of the small number of points, and therefore a linear regression was used instead. Although the estimates of reduction in time spent in KNP with loss of river function agreed with other measures (see above), we felt that the estimates of change in time spent in KNP with improvements in river quality were unrealistic (e.g. that on average people would stay 24% longer if rivers were in 'ideal' conditions), and these may have skewed this model's results. There seemed to be a discrepancy between those that interpreted the question as purely hypothetical (i.e. nothing would constrain their ability to remain in the park longer), and those that assumed that real-world constraints (such as pre-determined holiday lengths) would still exist. This is most likely the result of interviewer bias, or an unclear presentation of the scenario, and attention should therefore be paid to the wording of this question.

A drawback of the conjoint method is that it requires a relatively large sample size. Thus while such a method can be applied in a survey of visitors, it cannot be applied in a survey where numbers are limited, such as is the case for tourism establishments. The methods applied in this study thus differed for the two components of the study. In the conjoint analysis, a sample size of 180 proved to be sufficient to obtain highly statistically significant models. However, if further attributes are added in future such studies, the sample size would have to be increased.

Finally, it should be noted that the survey was carried out on weekdays and in winter and would therefore be biased against local visitors (weekenders) and those who visit KNP during school holidays (foreigners and locals) or in summer (e.g. birdwatchers).

4.4 The assessment of commercial tourism value

Measurement of the value of commercial tourism enterprises along rivers outside of protected areas is somewhat more difficult in that it involves a much smaller sample size if the study is to be conducted in a short period. In addition, it is also more difficult to estimate gross turnover values of private enterprises than for publicly-owned protected areas, simply because private entrepreneurs are unlikely to be willing to divulge such information directly. Thus it was necessary to use various statistics and assumptions to estimate these values.

Because of time constraints, we surveyed only lodge managers, although it would have been useful to survey tourists themselves as well. Based on the small sample size, and the possible greater degree of strategic bias amongst managers than consumers, the level of confidence of the results of this survey is probably lower than for the KNP visitor survey. Managers who appeared to be environmentally aware and were informed of developments such as the New Water Act of 1998 gave higher value ratings for the impact of rivers on their business. Lack of environmental awareness and education should be considered in designing natural resource valuations.

5 CONCLUSIONS

This study was reasonably successful in determining the tourism value of rivers in the lower Crocodile Catchment, and in estimating the effects of changes in river quality on these values. There is scope for improvement in survey design for future studies, but we believe that the results obtained in this study could be satisfactorily applied in the RDM case study on the Crocodile Catchment. Nevertheless, the results would be more accurate if a follow-up survey was carried out in summer, to capture a broader range of tourists using the KNP.

6 ACKNOWLEDGEMENTS

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APPENDIX 1: VISITOR SURVEY, KRUGER NATIONAL PARK
VERSION A

NAME: DATE: PLACE: TIME:

We are doing a survey on behalf of the Institute of Natural Resources, on the value of tourism in Kruger NP, and visitor activities in the park. Do you mind spending about ten minutes answering some questions? If yes, proceed.

1. Is this your first visit to Kruger NP? ________
   If not how often do you come here?________
2. How long have you been in Kruger so far? ________
3. Where do you come from? (country)____________ (town)__________
4. Is that where you travelled from? Y/N If not, where?______________
5. How many people are in your party? Foreign ________ SA visitors ________
6. a) How long are you staying in Kruger? ____________
   b) How long is your whole trip away from home?________
7. How much of the reason for your entire trip was coming to Kruger?
   100% (Entire reason); 75% (main reason); 50% (half); 25% (part); ____ (own estimate)
8. What have you budgeted for your entire holiday/trip, including Kruger? (plus the other places you are visiting) – including flights, hired cars, accommodation, fuel, toll stations etc. (even a rough estimate will be fine) ______
9. a) How much have you budgeted for Kruger?__________
   b) (If unsure about Kruger budget), What type of accommodation are you staying in Kruger? Chalet____ Camping_____ Caravan_____
10. (Show map) We're trying to get an idea of the routes that visitors use most often. Could you trace the routes that you have used so far on this map please? (Whatever you can remember).
11. Could you give a rough estimate of the percentage of your time that you have spent enjoying wildlife in different types of habitat: **waterholes** & **dams, rivers,** and **bushveld** (incl. time spent driving, in camp etc.)
12. Was the enjoyment that you got from the different areas approximately the same as the amount of time you spent in each area? So if the total enjoyment or satisfaction that you have had from this trip to Kruger so far is 100%, what % of that would you attribute to these three different types of habitat?

	% Time	**% Satisfaction**
Water holes and dams		
Rivers		
Bushveld		

In particular, we are interested in the contribution that rivers make to your enjoyment of your trip, so we would like ask you a few questions about them specifically.

13. If all of the rivers in Kruger dried up completely, so that there were no crocodiles, hippos, or water birds present, there are no riverine trees, but everything else in the Park were the same (the bush for example), would you spend less time in Kruger Park?_______ Please estimate how much.__________
13. Considering that the rivers in the Park are used upstream, and are presently not in their original state, if, hypothetically, the rivers in Kruger Park were to be restored to their

original state, that is, they contained high numbers of crocodiles, hippos, waterbirds etc.,diverse habitats (lots of water, some sand banks, reed beds etc.), including riverine trees; do you think that you would spend more time in Kruger Park?_______Please estimate how much.________________

15. Would you please consider the following four hypothetical visits to rivers, and, assuming that all of the rivers in Kruger National Park were in the exact same condition as described, score them on a scale of 1 to 10. A score of 10 should represent the river experience that you would find ideal, and 1 the least enjoyable experience you could imagine

	Crocodile and hippo	**Waterbirds**	**View / "riverscape"**	**Trees**	**Score 1-10**
1	About 10 of each	15+ species (incl. interesting/rare species e.g. Fish Eagles, Finfoots)	Dominated scene (e.g., several habitat types present but one obviously dominating)	some trees	
2	1 crocodile	very few species	dry riverbed	No trees	
3	None	None	dry riverbed	No trees	
4	One of each	5 species of common waterbirds (e.g. herons, ducks)	Uniform scene (e.g, all reeds)	few trees	

APPENDIX 2: SAFARI GUIDES, KRUGER NATIONAL PARK

NAME: DATE: PLACE: TIME:

1. How long have you been taking safari tours in the KNP?
2. Which areas of the park do you operate in, and why? (Circle on map and draw in most frequent routes).
3. When on a game drive, what proportion of time do you spend in the following habitat types? How would this differ in summer?

Habitat	Winter (%)	Summer (%)
Waterholes and dams		
Bushveld		
Rivers		

We're most specifically interested in the recreational value of rivers, and the use thereof.

4. What features of rivers are most important for your clients?

Riverscape		Waterbirds	
Sound of water		Hippos & Crocodiles	
Vegetation		Other wildlife	
Other (give details).			

5. If you had easy access to any river in the park, which would you go to, and why?
6. Are there any species that would make a visit to a river worthwhile, even if there was only one individual of that species present?
7. Would an infestation of alien aquatic plants stop you from visiting a river?
8. Are there any river features in the southern part of the park which would justify a special trip?

APPENDIX 3: PRIVATE RESORTS ALONG CROCODILE & KOMATI RIVERS

Interviewer: Date: Name of Resort:
Type of accommodation: B&B Hotel Lodge Resort

SECTION 1

1. How long has the resort been in operation?
2. Have you been here since the place opened? When did you start working here??
3. Have you seen any noticeable trends in tourism to the area (increase/decrease in tourism, change in the type of tourists?
4. Have you seen any changes in the natural environment since you have been here ?
5. What facilities and activities do you offer? Please rate the value of the river on each of these on a scale from 1 to 10. (10 means that the facility or activity will not exist without the river, 1 means that the presence of the river has no impact on the value of the facility or activity

Facilities	**River-related**	**Imp. Rate**	**KNP related**	**Imp. Rate**
Accommodation				
Restaurant				
Pub/Bar				
Animal/Bird hide				
Viewing platform				
Sport Facilities (e.g. Tennis, Golf...)				
Swimming Pool				
Boma/Lapa				

Activity	**River-related**	**Imp. Rate**	**KNP-related**	**Imp. Rate**
Hiking Trail (self-guided)				
Horse Riding				
Fishing				
Rafting/Canoeing				
Motorised Boating				
Game Drives				
Guided Walks				
Bird watching				
4x4 Trails (self-guided)				
Other				

6. In terms of the location of your business, to what extent does your business rely on: (percentage)

Access to Kruger N.P.	
Proximity to the River	
Other locational factors	

Considering the importance of the river to your business, I'd like you to imagine the following situations and think about how it might affect your business:

Scenario 1

Suppose the river surface becomes covered in floating water plants, for example, water hyacynth. As a result, there will be less wildlife, birds, and fish along the river.

7. How sensitive will your business be to this change?

1	2	3	4	5
Not sensitive		Moderately sensitive		Very sensitive

8. Would you change the activities you offer? Yes No
9. If yes, which ones??
10. Would you expect a change in occupancy rate? Yes No
11. If yes, by how much (percentage)?

Scenario 2

Suppose the river flow reduces permanently to a trickle and small pools. There will be a general decrease in large trees and species such as hippos, crocodiles, waterbuck, and waterbirds. There may also be an increase in reeds.

12. How sensitive will your business be to this change?

1	2	3	4	5
Not sensitive		Moderately sensitive		Very sensitive

13. Would you change the activities you offer? Yes No
14. If yes, which ones??
15. Would you expect a change in occupancy rate? Yes No
16. If yes, by how much (percentage)?

Scenario 3

Suppose the river flow increases and there is an increase in the abundance and diversity of wildlife, birds, and fish. There will be lush vegetation and many large trees along the river bank. There are no floating water plants.

17. How sensitive will your business be to this change?

1	2	3	4	5
Not sensitive		Moderately sensitive		Very sensitive

18. Would you change the activities you offer? Yes No

19. If yes, which ones??
20. Would you expect a change in occupancy rate? Yes No
21. If yes, by how much (percentage)?

22. Suppose the river is no longer present. Will your business still be viable? Yes No

Classification Statistics

23. How many beds does your resort have?

Fewer than 10	40-70
10-20	70-100
20-40	More than 100

24. What is your annual occupancy rate?

Less than 10%	50-60%
10-20%	60-70%
20-30%	70-80%
30-40%	80-90%
40%-50%	90-100%

INCORPORATING ECONOMIC CONSIDERATIONS INTO THE DETERMINATION OF THE ENVIRONMENTAL RESERVE:

Methodology used and estimates made for the value of selected ecosystem services supplied by the Crocodile River Catchment

Issue Paper No 3

By

David Cox, Myles Mander, Danette Stipcich,
Barbara Wiseman, Fonda Lewis & Steven Ngubane

Institute of Natural Resources
Private Bag X01
Scottsville 3209
Tel: 033 – 3460 796
Fax: 033 – 3460 895
Email: Ceo@nu.ac.za

In association with:
Dept. Water Affairs and Forestry
Umgeni Water

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1INTRODUCTION

Issue paper No 1 proposed a framework for incorporating economic criteria into the quantification, allocation and management of the environmental reserve for rivers. The framework included several proposed methods on valuing the ecosystem services supplied by rivers. In this issue paper (No 3) we describe the application of these methods within the Crocodile River Catchment context. During the course of application several of the methods had to altered and Assumptions had to be made. These are reflected in the discussion that follows.

2 METHODS FOR DETERMINING PRESENT ECONOMIC VALUES OF RIVER ECOSYSTEM SERVICES

Various methods for collecting and analysing the economic values for the river ecosystem were followed and will be summarised in the following order of discussion:

1.1 DATA COLLECTION

- Number surveys carried out
- Area under survey
- Target group of the survey
- Type of survey
- Limitations

1.2 EVALUATION

- Approach to the equation: Formula
- Assumptions
- Inputs used in calculation
- Calculation
- Limitations

1.3 APPENDIX

- Questionnaire
- Data capturing

The following ecosystem services were assessed:

2 CONSUMPTIVE UTILIZATION OF AQUATIC RESOURCES

2.1 DATA COLLECTION

2.1.1 Number of surveys carried out

A total of 10 household interviews were conducted in a survey of the consumptive use of fish resources. No data was collected for the use of aquatic plant resources, as none of the households approached reported using plant resources, even though resources (eg. sedges and reeds) were observed to occur in the area.

2.1.2 Survey area

The former homeland areas are widely characterised by communities who rely extensively on access to natural resources for consumptive utilization, through which they meet a range of household resource needs including nutritional requirements resources and building materials. Within the Crocodile Catchment the former homeland areas occur in the eastern section of the lowveld area. The sample survey was therefore undertaken in the Matsulu settlement area, which is characteristic of a community which has direct access to and utilizes aquatic resources. This area can be described as a high-density settlement and is located along a section of the Crocodile River.

2.1.3 Target group

The survey aimed to sample households representative of rural communities who are undertaking consumptive used of aquatic resources in the Crocodile River Catchment, eg fish, reeds, and sedges. These target communities could be categorised into three primary groups:

- Rural (non-urban) households living in former homeland areas
- Peri-urban households living in former township areas
- Farm labour households living on privately owned land

This survey focussed on resource use activities of the first category, ie rural (non-urban) households living in former homeland areas, specifically the Matsulu area, along the southern and south-western boundaries of Kruger National Park. Households that were known to be undertaking fishing activities were specifically focussed on in order to gain information to value these resource harvesting activities.

2.1.4 Type of survey

The survey took the form of questionnaire interviews with selected households. The questionnaire was in two parts (Appendix 1):

- Consumptive use of fish resources
- Consumptive use of plant resources

The objective of the survey was to identify resources used, quantify the amount used and value this usage using local market values.

2.1.5 Limitations

- The only aquatic resources that were reportedly being used were fish resources. While aquatic plant resources were observed to occur in the survey area, they were not reported as being used. The evaluation of the consumptive utilization of aquatic resources in the Crocodile Catchment is therefore limited to fish resources, and does not include the wider value of other aquatic resources available in the Catchment.

- It was anticipated that it would have been possible to undertake a far greater number of interviews, however a number of arrests for illegal gill netting were made by the MPB (Mpumalanga Parks Board) the night of the first day's survey and the following day local residents were unwilling to take part in the survey as they feared it may have been related to the arrests. Therefore while eight interviews were completed on day one of the survey only three more interviews were conducted on the second.

2.2 EVALUATION

2.1.5 Inputs for calculations

- Number of fish caught per household per month

Individual household surveys provided information on numbers of fish caught per day, and the number of days and months fished. From this data estimates were calculated on the average number of fish caught per household per year.

- Types of fish caught

Six different types of fish were reported to be caught. However there were no consistent patterns of size or value relating to specific species. The calculations therefore ignored species variation and rather focussed on averages of numbers and sizes across catches in general.

- Price of fish

The price at which fish were sold appeared to be influenced by size, as well as ability of local households to pay. For example, fish sizes reported to range from one to twelve kilograms, while the price at which fish were sold ranged from R4 to R7. Based on the number of fish of the various sizes caught the average value per fish was estimated at R4.50. This value was used to calculate both value of fish caught and consumed by the household, as well as value of fish sold to other households. Households that reported selling part of their catch were asked to estimate the percentage of their catch that they sell versus that which the keep for consumption.

- Numbers of households selling fish

The number of households selling fish in the catchment was calculated as a ratio of the number in the survey of 10 who reported selling part of their catch.

- Time spent fishing

Most households that spent time fishing reported fishing mainly in the summer months (ie three months of the year).

2.2.2 Approach to the equation

The aim of the calculations were to generate an estimated economic value of the fish being caught by households (TC) as well as a breakdown of value of fish consumed by the household (RC) and for sale to other local households (RS) in the Crocodile Catchment.

The formula used in the calculation of the annual value of fish **caught** by households was:

(1) $$AV = FC \times MF \times P$$

Where,

AV = Average annual Rand value of fish caught per household
FC = average number of fish caught per household per month
MF = number of months of the year that are spent fishing
P = local market price of fish

The formula used in the calculation of the annual value of fish caught and **consumed** by households was:

(2) $$RC = (FC \times \%C) \times P \times MF$$

Where,

RC = annual Rand value of fish caught and consumed by the household
FC = average number of fish caught per month
%C = percentage of the total catch that are consumed by the household
P = local market price of fish
MF = number of months of the year that are spent fishing

The formula used in the calculation of the annual value of fish caught and **sold** locally by households was:

(3) $$RS = (FC \times \%S) \times P \times MF$$

Where,

RS = annual Rand value of fish caught and sold by the household
FC = average number of fish caught per month
%S = percentage of the total catch that are sold by the household
P = local market price of fish
MF = number of months of the year that are spent fishing

2.2.3 Limitations

- Levels of confidence in many of the input values are low due to the very small sample size and the fact that the survey was only undertaken in one area of the catchment.

- Economic values associated with fish resources were based on local market values for the fish resources (R4.50 per fish). This valuation appears to be well below the commercial market value for fish resources. The local market therefore probably reflects the ability of local consumers to pay, rather than a reflection of the value of the resource. Furthermore, while this value reflects the local market value of the resource, it is not necessarily a true reflection of the social value of the resource, for example in terms of the important nutritional supplement it represents.

- The values generated are gross values and exclude the costs of harvesting the fish.

2.3 RESULTS

2.3.1 Calculations of fishing values from sample survey

Table 1: Average value of fish caught by Black rural households in the Crocodile Catchment per annum *(calculated at a local market value of R4.50 per fish)*

Interview no.	Fish caught/month	Value per month	Months fished	Value per year
1	255	R1 114.50	3	R3 442.50
2	150	R675.00	3	R2 025.00
3	56	R252.00	3	R756.00
4	565	R2542.50	3	R7 627.50
5	465	R2092.50	3	R6 277.50
6	144	R648.00	3	R1944.00
7	270	R1215.00	3	R3645.00
8	40	R180.00	3	R540.00
9	104	R468.00	3	R1 404.00
10	180	R810.00	3	R2430.00
Total value of fish caught by 10 households per annum				R30091.50
Average value of fish caught per household per annum				R3009.15

Table 2: Value of fish consumed (*calculated at a local market value of R4.50 per fish)*

Interview no.	No. fish caught per month	Percent consumed	No. fish consumed	Value of fish consumed	No. months fished	Value per year
1	255	75	191	R860.63	3	R2581.88
2	150	50	75	R337.50	3	R1012.50
3	56	100	56	R252.00	3	R756.00
4	565	50	283	R1271.25	3	R3813.75
5	465	50	233	R1046.25	3	R3138.75
6	144	100	144	R648.00	3	R1944.00
7	270	100	270	R1215.00	3	R3645.00

8	40	100	40	R180.00	3	R540.00
9	104	60	62	R280.80	3	R842.40
10	180	100	180	R810.00	3	R2430.00
Total value of fish consumed by the 10 households per annum						R18 983.03
Average value of fish consumed per household per annum						R 1 898.30

Table 3: Value of fish sold (*calculated at a local market value of R4.50 per fish*)

Interview no.	No. fish caught per month	Percent sold	No. fish sold per month	Value of fish sold per month	No. months fished	Value per year
1	255	75	191	R860.63	3	R2581.88
2	150	50	75	R337.50	3	R1012.50
4	565	50	283	R1271.25	3	R3813.75
5	465	50	233	R1046.25	3	R3138.75
9	104	40	42	R187.20	3	R561.60
Total value of fish sold by the 5 households per annum						R11 108.48
Average value of fish sold per interviewed household per annum						R 2 221.70

2.3.2 Total Value of Fish Caught within the Crocodile Catchment

Formula 1, 2 and 3 provide an indication of the value of the harvesting of fish resources at a household level, however due to limitations in sample size and data availability it was difficult to extrapolate these figures to provide an estimate of the value of consumptive utilization of fish resources at a catchment level. In order to generate this estimate a scenario was developed and includes a number of assumptions:

- Population estimate for the Crocodile Catchment
  Census data for the Catchment was obtained from the report on *Water Quality and Management in the Crocodile Catchment* (DWAF 1995). This report had census data for 1990 and was extrapolated for 2001 using a growth rate of 2.46% (as given in the report). Using this data the Black rural population living in the Crocodile Catchment in the year 2001 was estimated at 354 699 (Appendix 2).

- Average household size
  The average household size for Black households in Mpumalanga was reported as 4.7 (Strategic Health Review, UCT 1996). Using this information together with the population figures it was estimated that there may be 74 468 Black rural households within the Crocodile Catchment.

- Percentage of Black rural households with the opportunity to fish
  It is **assumed** that an important influence on whether or not households will fish is their proximity to rivers. While no data was available regarding the spatial

distribution of the Black rural households within the catchment, it was **assumed** that 15% of the households were within close proximity of rivers with populations of edible fish and would therefore engage in fishing activities. Based on this assumption, of the total estimated Black rural households in the Catchment, 11 320 had the opportunity to engage in fishing activities.

- Number of rural households fishing
  Local opinion obtained during the household survey indicated that of the households located in proximity to the Crocodile River (ie with opportunity to fish) approximately 30% engaged in fishing activity in some form. Using this percentage, it was estimated that 3 396 Black rural households located in the Crocodile Catchment catch fish.

- Local market value of fish throughout Catchment
  As no other data was available for local market values for fish, the average value of R4.50 obtained from the survey was applied. In addition the estimated average number of fish caught obtained from the survey was also used in the estimation of fish caught by Black rural households throughout the catchment.

Using these estimates, the value of fish caught by all Black rural households in the Crocodile Catchment was calculated using the following formula:

$$CVc = AV \times HF \tag{4}$$

Where,

CVc	=	Gross value of fish caught per Black rural households per year
HF	=	Number of Black rural household fishing in the Catchment

Table 4: Estimated gross value of consumptive utilization of fish resources by Black rural households in the Crocodile Catchment:

Description	[illegible]
Size of Black rural population in Crocodile Catchment (2001)	[illegible]
Estimated average household size (number of people)	[illegible]
Number of Black rural households in Crocodile catchment	[illegible]
Estimated % households located in vicinity of rivers	[illegible]
Number of Black rural households in vicinity of rivers	[illegible]
Percentage of these Black rural households catching fish	[illegible]
Number of Black rural households catching fish	[illegible]
Average value of fish caught per household per year (formula 1)	R3 009.15
Estimated gross value of fish consumed by rural households	**R10 219 238.71**

This estimate illustrates the gross value of the fish consumed and excludes the costs of catching the fish. While assumptions on the percentages of people living close to rivers are used, the estimate does provide an orders of magnitude value of the fish resource base, which is significantly affected by the quantity and quality of water within the Rivers of the Crocodile Catchment.

3 TOTAL RECREATION EXPENDITURE

The survey was aimed at users of recreation services provided by rivers. Water-based recreation requires that water be available in the rivers and therefore any expenditure on these activities is a function of adequate water being available within those rivers. We chose to value the expenditure on water-based activities as a means to develop some 'first estimates' of recreation value. From a budget and repeatability perspective we attempted to use information that would be accessible, rather than have to undertake primary research. This implied surveying individuals and establishments that use rivers and associated water bodies. Consequently the survey focused on fishing and other related enterprises. Data was collected and evaluated from three target groups listed below. The data collection and evaluation of each will be dealt with separately.

- *Fishing*
- *Lodges and Restaurants*
- *Retail Outlets for fishing or related equipment*

Importantly, the values derived are gross values as we did not attempt to include the costs associated with each activity. Furthermore, as only expenditure is assessed, and not the willingness-to-pay for access to river services, the values can be considered a minimum estimate.

3.1 DATA COLLECTION: Fishing

The key contributors to the use of recreation as a service of the system were identified as people doing fly fishing and bass fishing.

3.1.1 Number surveys carried out

	Fly fishermen	Bass fishermen
No identified	**1602**	**84**
No approached	**1532**	**6**
No responded	**38**	**6**
No useable (sample size)	**28**	**5**
Response as % approached	**2.5%**	

3.1.2 Area under survey

Fly-fishing: The survey was distributed to all Flyfishing Clubs. Flyfishing occurs mainly in the western highlands of the Crocodile catchment

Bass fishing: The chairman of the Lowveld Angling Association, based in Nelspruit, was supplied with the survey, which he then distributed to bass fishermen with which he made contact with. Bass fishing mainly occur in the eastern lowveld of the catchment and partly in the western highlands where the dams are stocked with bass.

3.1.3 Target group of survey

The survey was aimed at the members of all the local fishing clubs within the catchment (Appendix 3).

Fly-fishing: Members of 5 identified fishing clubs within the highlands of the catchment

Bass-fishing: Bass fishermen identified by the chairman of the Lowveld Angling Association

3.1.4 Type of survey

The fishing survey was in the form of a questionnaire (Appendix 4) that was faxed to the participants identified from a club membership list. Where this information was not available, copies were sent to Club committee member. In the case of the bass fishing, questionnaires were left at a local key fishing retail outlet for distribution. Responses to the questionnaires were faxed back but further telephonic follow-ups and interviews with the participants were necessary.

The objectives of the questionnaire were to:

- Establish value of equipment used by the fishermen.
- Establish the replacement frequency of this equipment and hence value spent on equipment per annum.
- Establish the numbers of fishing expeditions and average cost per expedition in terms of, accommodation, transport and any additional costs per year.
- Establish the amount of time (effort) spent fishing in the catchment area per year as a proportion of total fishing expeditions.
- Establish the value of other per annum costs related to fishing expeditions, primarily licensing and membership fees.
- Establish the number fishing clubs from the catchment and their membership numbers.
- Establish the number syndicates from the catchment and their membership numbers.
- Fishing numbers from Lodges.

3.1.5 Limitations to data collection

- Response to "fishing surveys" sent out was very poor (38 out of 1532 surveys).
- The number of usable questionnaires was reduced by the fact that many of the fishermen were not contactable by telephone or had responded inadequately.
- Club Committee members were reluctant to release contact details for their club members, and could not be relied on to distribute the questionnaires effectively.
- Follow-up calls to clarify misunderstood or missing data were necessary.
- Difficulties were experienced in contacting the Bass Fishing Clubs of the lowveld, which were much smaller than the Fly Fishing Clubs of the highlands. Information on Bass Fishing Clubs was not readily available and difficult to target.

3.2 EVALUATION: Fishing

Objective: to arrive at an economic estimate of total annual expenditure by fishermen on all fishing related expenditure that can be attributed to the catchment area.

3.2.1 Approach to the equation

Flyfishing expenditure was distinguished from bass fishing expenditure, by collecting the data separately and calculating an average per annum expenditure for each. The same formula was applied to the flyfishing and bass fishing data.

Formula used:

1. $TE_c = {}_{AVE}S_c \times TF$

Where,

TE_c = Total expenditure by fishermen in the catchment per annum

TF = Total amount fishermen fishing per annum in catchment

${}_{AVE}S_c$ =Average expenditure per fishermen per annum within the catchment

2. $S_c = (E_n + FE_n + OC_n) \times \%C_n$

${}_{AVE}S_c = (SUM_{(1\text{-}28)}\ ((E_n+FE_n+Oc_n) \times \%C_n))/N$

where,

E = Total value of equipment

FE = Total expenditure on fishing expeditions per annum

OC = Total other fishing related costs per annum

$\%C$ = % total fishing trips that fall within the catchment

N = Sample size

n = Recorded participant in survey

3. $TF = MC + MS + ML$

Where,

MC = Total membership from fishing clubs falling in the catchment area

MS = Total number of fishermen from syndicates in the catchment

ML = Total number of fishermen from lodges in the catchment

How each value in the formula was calculated will be explained under the inputs used in the calculations.

3.2.2 Inputs used in calculations

Inputs required to satisfy the key formula $TE_c = {}_{AVE}S_c \times TF$, were obtained from a sample for the area. Inputs required to satisfy $S_c = (E_n + FE_n + OC_n) \times \%C_n$ were as follows,

- Equipment:
  Cost (current cost) and replacement period of; rod, line, reel, accessories, boat and motor, float, clothing and any other equipment related expense
- Fishing expeditions:
  cost per expedition, other expedition related expenses, and the percentage time spend (expeditions per year) in the catchment area per year
- Other costs:
  Expenditure on license fees per year and club fees per year

All these inputs were used in both the fly-fishing survey as well as the bass fishing survey, they are incorporated into the key formula as follows:

E = Total value of equipment

(1) = $aveR/rr + L/rl + E/re + A/ra + B/rb + M/rm + aveF/rf + aveCO/rfo$

(2) = aveR/rr + L/rl + E/re + A/ra + aveF/rf + aveCO/rfo

Note: Two equations appear here (1) Includes the cost of boats and motors into the total, (2) excludes the cost of boats and motors from the total.
Each equipment value (current cost) is divided by the replacement period of that specific item to derive a per annum value for the item

Where,

ave	= Average, (if more than one of each type of equipment is entered)
R	= Value of Rod
rr	= replacement frequency of rod
L	= Value of line
Rl	= Replacement frequency of line divided
E	= Value of reel
re	= Replacement frequency of the reel
A	= Value of accessories
re	= Replacement frequency of accessories
B	= Value of boat
rb	= Replacement frequency of the boat
M	= Value of motor
rm	= Replacement frequency of the motor
F	= Value of Floatation device
rf	= Replacement frequency of floatation device
CO	= Clothing and Other
rfo	= Replacement frequency of clothing and other

FE = Total expenditure on fishing expeditions per annum
= (ACC+ TC + AC) x aveQ

Where,

ACC = Total accommodation costs per expedition
TC = Total transport costs per expedition
AC = Total additional costs related per expedition

Note: An average value between "most and least" spent by the participant in the sample survey per expedition was calculated for the above-mentioned costs.

aveQ = Average amount expeditions per annum

Note: An average was calculated between the most and fewest number of expeditions per year as stated by the participant in the sample survey.

OC = Total other fishing related costs per annum
= LC + MF

Where,

LC = Total licence fees per annum
MF = Total membership fees per annum

Note: Membership registration fees were not included into the calculation.

C = the percentage of the total amount of expeditions (frequency) per year that is within the catchment area = Effort or time spent per annum in catchment

3.2.3 *Assumptions*

- The number of fishermen not captured by club membership numbers will be captured in accommodation occupancy rates from lodges and syndicates.
- The value of equipment in the survey is assumed to be current value (or the replacement cost)
- The percentage time (effort) spent in the catchment by the fishermen is based on the percentage expeditions falling in the catchment area
- If no replacement period was state by the respondent, then the following replacement frequencies were used:

Table 5: Replacement frequencies as reported by fishing equipment stockists *(Sollies, Nelspruit):*

Flyfishing		**Conventional Fishing**	
Item and Value	**Replacement in Years**	**Item and Value**	**Replacement in Years**
Rods		Rods	
R0 - R500	4	R0 - R700	10
R500 – R800	6	R700 – R1200	15
R800 – R1000	7	R1200 +	25
R1000 – R1500	11	Reels	
R1500 – R2500	15	R0 - R500	5
R2500 +	25	R500 – R800	5
All Reels	10	R800 -R1200	8
Line	4	R1200 - R4200	10
		R4200+	25
		Line	1
Miscellaneous for both categories			
General accessories	2		
Clothing	5		
Floatation device	5		
Boat	17		
Motor (lasting 3000h)	12		
Fishing nets	10		
Fish finder	15		

3.2.4 Limitations to evaluation

- Only a very rough and conservative estimate of the number of fishermen in the area could be made. The number of fishing licences issued in Mpumalanga could not be used to calculate the number of fishermen as information regarding their residence address is not recorded.
- The Club members are a conservative estimate of the number of local fishermen that would fish within the catchment. A large number of club members reside outside the catchment area.
- Difficulty in deriving fishermen numbers from lodges and syndicates.

- A large proportion of fishermen in the area are fishing without fishing licences. (Appendix 4)

3.3 RESULTS

3.3.1 Flyfishing : data capturing and calculations

Table 6: Value of equipment/annum: *(Cost of equipment / replacement period)*

REC NO	Ave Value Rods	Ave Value: Line, reel & accessories	Ave Value Boat & Motor	Ave Value Float	Ave Value Clothing & other	Total Value per annum	% Within catchment	% Attributed to flyfishing	Total Value/yr within catchment
1	460.00	7390.00	0.00	200.00	0.00	8050.00	30	100	2415.00
2	240.00	800.00	0.00	0.00	500.00	1540.00	100	100	1540.00
3	200.00	350.00	0.00	0.00	80.00	630.00	5	95	29.93
4	324.17	350.00	0.00	0.00	250.00	924.17	99	99	905.78
5	1020.00	1480.00	0.00	0.00	600.00	3100.00	100	100	3100.00
6	429.70	666.67	0.00	150.00	250.00	1496.36	5	100	74.82
7	385.00	733.33	3431.37	140.00	0.00	4689.71	90	100	4220.74
8	206.29	685.71	10367.65	160.00	0.00	11419.65	100	100	11419.65
9	250.00	273.33	0.00	0.00	20.00	543.33	100	100	543.33
10	257.14	6446.67	0.00	600.00	330.00	7633.81	90	100	6870.43
11	400.00	700.00	2372.55	300.00	0.00	3772.55	90	100	3395.29
12	398.27	3833.33	2843.14	300.00	140.00	7514.74	20	100	1502.95
13	1464.67	13640.00	6029.41	0.00	30.56	21164.63	50	100	10582.32
14	200.00	220.00	0.00	0.00	50.00	470.00	90	100	423.00
15	204.00	1933.33	0.00	320.00	200.00	2657.33	80	100	2125.87
16	360.71	1250.00	0.00	0.00	200.00	1810.71	50	100	905.36
17	1500.00	3000.00	0.00	0.00	0.00	4500.00	20	100	900.00
18	187.50	563.33	205.88	125.00	0.00	1081.72	100	100	1081.72
19	287.50	12875.00	0.00	0.00	90.00	13252.50	75	100	9939.38
20	350.00	650.00	0.00	230.00	140.00	1370.00	100	100	1370.00
21	241.67	142.86	0.00	0.00	0.00	384.52	25	100	96.13
22	750.00	100.00	0.00	0.00	1000.00	1850.00	100	100	1850.00
23	376.19	2500.00	2941.18	0.00	0.00	5817.37	5	20	58.17
24	1800.00	3200.00	470.59	0.00	0.00	5470.59	50	100	2735.29
25	329.00	6900.00	0.00	0.00	100.00	7329.00	100	100	7329.00
26	990.00	3000.00	3250.00	200.00	0.00	7440.00	33	80	1964.16
27	520.00	1260.00	0.00	240.00	0.00	2020.00	20	100	404.00
28	250.00	90.00	0.00	200.00	25.00	565.00	33	100	186.45

TOTAL	77968.75
AVE	2784.60

Table 7: Cost of fishing expeditions *(Total expenditure on fishing trips per annum)*

REC NO	Ave Frequency expeditions/yr	Ave Accom./expedition	Ave Travel cost/expedition	Other cost/expedition	Total per Annum	% Within catchment	% Attributed to flyfishing	Total Cost/yr within catchment
1	24	575.00	405.00	200.00	28320.00	30	100	8496
2	5	2000.00	375.00	500.00	14375.00	100	100	14375
3	18	1300.00	325.00	500.00	37187.50	5	95	1766.40625
4	6	1700.00	175.00	300.00	11962.50	99	99	11724.44625
5	2	500.00	1000.00	0.00	3000.00	100	100	3000
6	19	2500.00	625.00	300.00	63362.50	5	100	3168.125
7	20	275.00	500.00	100.00	17500.00	90	100	15750
8	52	450.00	0.00	0.00	23400.00	100	100	23400
9	3	300.00	450.00	350.00	3300.00	100	100	3300
10	7	740.00	235.00	0.00	6825.00	90	100	6142.5
11	6	6250.00	600.00	0.00	41100.00	90	100	36990
12	7	3000.00	650.00	500.00	29050.00	20	100	5810
13	20	800.00	350.00	400.00	31000.00	50	100	15500
14	4	1000.00	650.00	300.00	7800.00	90	100	7020
15	14	1600.00	600.00	500.00	36450.00	80	100	29160
16	5	990.00	3250.00	400.00	20880.00	50	100	10440
17	12	1250.00	500.00	250.00	23000.00	20	100	4600
18	5	275.00	150.00	0.00	1912.50	100	100	1912.5
19	25	0.00	150.00	30.00	4500.00	75	100	3375
20	6	400.00	200.00	0.00	3300.00	100	100	3300
21	3	1500.00	500.00	100.00	5250.00	25	100	1312.5
22	8	700.00	1000.00	0.00	12750.00	100	100	12750
23	16	1625.00	1100.00	300.00	48400.00	5	20	484
24	5	5000.00	600.00	0.00	28000.00	50	100	14000
25	26	2000.00	390.00	0.00	62140.00	100	100	62140
26	7	1625.00	0.00	800.00	16975.00	33	80	4481.4
27	11	2375.00	450.00	400.00	35475.00	20	100	7095
28	4	2875.00	200.00	100.00	12700.00	33	100	4191
TOTAL								315683.88

AVE	11274.42

Table 8: Other costs / annum

REC NO	Total Licence fees	Ave Total membership fees	Total per year	% Within catchment	% Attributed to flyfishing	Total Cost/yr within catchment
1	20.00	300.00	320.00	30	100	96.00
2	0.00	200.00	200.00	100	100	200.00
3	350.00	350.00	700.00	5	95	33.25
4	0.00	350.00	350.00	99	99	343.04
5	2000.00	80.00	2080.00	100	100	2080.00
6	130.00	615.00	745.00	5	100	37.25
7	150.00	380.00	530.00	90	100	477.00
8	0.00	450.00	450.00	100	100	450.00
9	0.00	100.00	100.00	100	100	100.00
10	0.00	100.00	100.00	90	100	90.00
11	50.00	100.00	150.00	90	100	135.00
12	2250.00	0.00	2250.00	20	100	450.00
13	30.00	200.00	230.00	50	100	115.00
14	20.00	50.00	70.00	90	100	63.00
15	20.00	550.00	570.00	80	100	456.00
16	39.00	850.00	889.00	50	100	444.50
17	15.00	200.00	215.00	20	100	43.00
18	200.00	200.00	400.00	100	100	400.00
19	450.00	400.00	850.00	75	100	637.50
20	46.00	3630.00	3676.00	100	100	3676.00
21	85.00	100.00	185.00	25	100	46.25
22	600.00	500.00	1100.00	100	100	1100.00
23	100.00	380.00	480.00	5	20	4.80
24	0.00	550.00	550.00	50	100	275.00
25	20.00	250.00	270.00	100	100	270.00
26	500.00	200.00	700.00	33	80	184.80
27	100.00	100.00	200.00	20	100	40.00
28	0.00	120.00	120.00	33	100	39.60
TOTAL						**2752.29**
AVE						**550.46**

Table 9: Summary of Total expenditure of flyfishermen per annum

REC NO	Total Equipment value		Total expedition costs	Total other costs	Total per annum	
	Boats & Motors incl	Boats & Motors excl			Boats & Motors incl	Boats & Motors excl
1	2415.00	2415.00	8496.00	96.00	11007.00	11007.00
2	1540.00	1540.00	14375.00	200.00	16115.00	16115.00
3	29.93	29.93	1766.41	33.25	1829.58	1829.58
4	905.78	905.78	11724.45	343.04	12973.26	12973.26
5	3100.00	3100.00	3000.00	2080.00	8180.00	8180.00
6	74.82	74.82	3168.13	37.25	3280.19	3280.19
7	4220.74	1132.50	15750.00	477.00	20447.74	17359.50
8	11419.65	1052.00	23400.00	450.00	35269.65	24902.00
9	543.33	543.33	3300.00	100.00	3943.33	3943.33
10	6870.43	6870.43	6142.50	90.00	13102.93	13102.93
11	3395.29	1260.00	36990.00	135.00	40520.29	38385.00
12	1502.95	934.32	5810.00	450.00	7762.95	7194.32
13	10582.32	7567.61	15500.00	115.00	26197.32	23182.61
14	423.00	423.00	7020.00	63.00	7506.00	7506.00
15	2125.87	2125.87	29160.00	456.00	31741.87	31741.87
16	905.36	905.36	10440.00	444.50	11789.86	11789.86
17	900.00	900.00	4600.00	43.00	5543.00	5543.00
18	1081.72	875.83	1912.50	400.00	3394.22	3188.33
19	9939.38	9939.38	3375.00	637.50	13951.88	13951.88
20	1370.00	1370.00	3300.00	3676.00	8346.00	8346.00
21	96.13	96.13	1312.50	46.25	1454.88	1454.88
22	1850.00	1850.00	12750.00	1100.00	15700.00	15700.00
23	58.17	28.76	484.00	4.80	546.97	517.56
24	2735.29	2500.00	14000.00	275.00	17010.29	16775.00
25	7329.00	7329.00	62140.00	270.00	69739.00	69739.00
26	1964.16	1106.16	4481.40	184.80	6630.36	5772.36
27	404.00	404.00	7095.00	40.00	7539.00	7539.00
28	186.45	186.45	4191.00	39.60	4417.05	4417.05
TOTAL	**77968.75**	**57465.65**	**77968.75**	**12286.99**	**405939.61**	**385436.51**
AVE	**2784.60**	**2052.34**	**11274.42**	**438.82**	**14497.84**	**13765.59**

Table 10: Summary of results from flyfishing survey

Average Cost of equipment per year (Boats & Motors incl.)	R2784.60
Average Cost of equipment per year (Boats & Motors excl.)	R2052.34
Average Cost of fishing expeditions per year	R11274.42
Average of other costs per year	R438.82
Total Average expenditure per year (Boats & Motors incl.)	R14497.84
Total Average expenditure per year (Boats & Motors excl.)	R13765.59
Number club-register fishermen within the catchment	1602
Total expenditure per year (Boats & Motors excl.) *	R22 052 475.18

** Note: It is assumed that the average flyfisherman fish without a boat*

3.3.2 Bass fishing : data capturing and calculations

Table 11: Value of equipment/annum : (*Cost of equipment / replacement period*)

REC NO	Ave Value Rods	Ave Value: Line, reel & accessories	Ave Value Boat & Motor	Ave Value Float	Ave Value Clothing & other	Total Value per annum	% Within catchment	Total Value/yr within catchment
1	1200.00	14040.00	7058.82	0.00	866.67	23165.49	80	18532.39
2	1000.00	3450.00	6764.71	0.00	2320.00	13534.71	80	10827.76
3	780.00	12600.00	6470.59	0.00	886.67	20737.25	80	16589.80
4	1750.00	5300.00	5500.00	0.00	0.00	12550.00	65	8157.50
5	250.00	3806.00	283.33	0.00	0.00	4339.33	100	4339.33
TOTAL								**58446.79**
AVE								**11689.36**

Table 12: Cost of fishing expeditions (*Total expenditure on fishing trips per annum*)

REC NO	Ave Frequency expeditions/yr	Ave Accom. /expedition	Ave Travel cost/expedition	Other cost/expedition	Total per Annum	% Within catchment	Total Cost/yr within catchment
1	23	450.00	350.00	300.00	24750	80	19800.00
2	22	512.50	325.00	450.00	27681	80	22145.00
3	10	100.00	1000.00	2000.00	31000	80	24800.00
4	46	300.00	155.00	120.00	26450	65	17192.50
5	14	0.00	65.00	50.00	1610	100	1610.00
TOTAL							**85547.50**
AVE							**17109.50**

Table 13: Other costs / annum

REC NO	Total License fees	Total membership fees	Total per year	% Within catchment	Total Cost/yr within catchment
1	0.00	500.00	500.00	80	400.00
2	0.00	900.00	900.00	80	720.00
3	0.00	400.00	400.00	80	320.00
4	20.00	200.00	220.00	65	143.00
5	20.00	0.00	20.00	100	20.00
TOTAL					**1603.00**
AVE					**320.60**

Table 14: Summary of Total expenditure of bass fishermen per annum

REC NO	Total Equipment value	Total expedition costs	Total other costs	Total per annum
1	18532.39	19800.00	400.00	38732.39
2	10827.76	22145.00	720.00	33692.76
3	16589.80	24800.00	320.00	41709.80
4	8157.50	17192.50	143.00	25493.00
5	4339.33	1610.00	20.00	5969.33
TOTAL	58446.79	58446.79	1603.00	145597.29
AVE	11689.36	17109.50	320.60	29119.46

Table 15: Summary of results from bass fishing survey

Average Cost of equipment per year	R11689.36
Average Cost of fishing expeditions per year	R17109.50
Average of other costs per year	R320.60
Total Average expenditure per year	R29119.46
Estimated number bass fishermen within the catchment *	200
Total expenditure per year	R5 823 892.00

**Note: This is an assumed figure of fishermen fishing with a high level of expenditure within the catchment based on discussions with people involved in fishing.*

The sample survey is not a representative sample size and results in a low level confidence for the expenditure value. To derive an estimated expenditure value per annum for the "not accounted for" fishermen (excluding the numbers already accounted for in the flyfishing and bass survey) issued with fishing licenses within the catchment and the fishermen fishing without licenses, a more reasonable scenario was developed. The number fishermen used in the scenario was based on the following assumptions and calculations.

Fishing licenses issued within the catchment (Appendix 3):	2550
Unlicensed fishermen within the catchment *:	2452
Total number fishermen within the catchment:	5002
Minus club-registered flyfishermen within the catchment:	1602
Minus the bass fishermen already accounted for within the cachment:	200
Total number "not accounted" for fishermen per annum within the catchment:	3200

** Note: The number unlicensed fishermen are based on discussions with local authorities and fishermen from the catchment who report that approximately 50 % of the fishermen fish are licensed.*

3.3.3 Reasonable Scenario for fishermen

Table 16: Expenses Scenario

	Cost per fishing expeditions					
Equipment per year	Expeditions per year	Accom.	Travel	Other	Total expedition costs per yr	Total per annum
R300	14	R10	R100	R50	R2240	R2540

Table 17: Summary of evaluation

Average Cost of equipment per year	R300.00
Average Cost of fishing expeditions per year	R2240.00
Average of other costs per year	R20.00
Total Average expenditure per year	R2560.00
Estimated "not accounted" fishermen within the catchment	3200
Total expenditure per year	**R8 192 000.00**

3.4 DATA COLLECTION: Lodges and Restaurants

Lodges associated with rivers were identified as a major enterprise depending on the rivers in the catchment, especially in the highlands where most of the tourism is fishing related.

3.4.1 *Number of surveys carried out*

	Lodges	Restaurants
No. identified	71	8
No. approached	36	8
No. responded	16	1
No. useable	13	1
Response as % approached	44.5%	12.5%

3.4.2 *Area under Survey*

Focus was primarily on the highland areas as far east as Nelspruit. This area was not surveyed in previous study adjacent to KNP (Working Paper No 5). Most of the lodges or resorts located on rivers, owe their existence to rivers and fishing which the area is renowned for.

3.4.3 Target Group of Survey

Flyfishing venues throughout the entire highlands area were targeted, in particular venues in and around the towns of Belfast, Dullstroom, Machadodorp and Waterval Boven. All Restaurants listed in the area, which was located in the towns of Waterval Boven, and Dullstroom were approached.

3.4.4 Type of Survey

The primary objectives of the questionnaires was to,

- Determine the annual turnover for each of the lodges and restaurants

Lodge questionnaires (appendix 5) were faxed to either the owner or manager of the venue. Prior to this each received a phone call in explanation of the survey. At least one and up to three follow-up calls by telephone were required. The questionnaires were to be faxed back. The restaurants were all contacted by telephone and interviewed.

3.4.5 Limitations to data collection

- Lodges east of Nelspruit were not approached
- The unwillingness of lodge and restaurant owners in co-operating with supplying the necessary data required in the questionnaire. As a result there was only data for one restaurant.

3.5 EVALUATION: Lodges and Restaurants

A. Lodges

Objective: To arrive at the gross turnover per annum and to estimate the employment generated by restaurants and lodges.

3.5.1 Approach to the equation

Formulae used:

1. Estimated gross annual turnover = no of lodges x (SUM $_{1\text{-}14}$ (AT_n)/N)
   Estimated gross annual turnover for sample = SUM $_{1\text{-}14}$ (AT_n)
   Estimated average annual turnover = SUM $_{1\text{-}14}$ (AT_n)/N
   Where,
   AT = Annual Turnover
   n= the record number
   N= sample size

2. $AT_n = (ACC_n \times \%W_n) + R_n + F_n + C_n$

   Where,
   ACC = revenue from accommodation
   %W = the percentage of the income from accommodation that is water based
   R = income from the restaurant (where applicable)
   F = income from fishing (where applicable)
   C =income from camping (where applicable)
   NOTE: all of the above are estimated annual incomes

3.5.2 Inputs used in calculations

Inputs required to satisfy the equation, $AT_n = (ACC_n \times \%W_n) + R_n + F_n + C_n$ were as follows,

- The number of accommodation units, and the capacity of each
- The daily rate paid for the accommodation whether per unit or per person
- The occupancy rates

$ACC_n = MR_n \times O_n$

Where,
MR = the total monthly rate for accommodation at 100% capacity
O = the occupancy rates

MR = (SUM (U x UR)) x 30 or alternatively = (SUM (U x (CP x DR))) x 30
Where,
U = each accommodation unit
UR = unit rate (set for that unit, or alternatively defined as CP x DR which is the per person per night rate)
CP = the capacity for that unit
DR = the daily rate paid for the unit
Note: The daily rate is calculated individually for each type of unit at the lodge, all the units for each lodge are then summed and a monthly rate then calculated.

O = SUM (a, b,c,d,e x M)

Where,
a,b,c,d and e, are equal to 0%, 25%, 50%, 75% and 100% respectively, M is the number of months at each occupancy rate.

3.5.3 Assumptions

- Conservative figures are built into the equation.
- The annual investments by fishing members belonging to other provincial fishing clubs, fishing in the catchment, are captured with the lodge data (accommodation costs only and not equipment costs).

B. Restaurants

Objective: To arrive at a gross annual turnover for the restaurants associated with Rivers within the catchment.

3.5.4 *Approach to the equation*
Formula: Average turnover per year (sample) x number restaurants from the catchment

3.5.5 Inputs to calculation

- Establish the average turnover per restaurant from survey
- Establish the number restaurants in the catchment

3.5.6 Limitations

- Only one restaurant owner would divulge his turnover therefore no average annual turnover for restaurants could be calculated.

3.6 RESULTS: Lodges and Restaurants

3.6.1 Turnover generated through water based lodges: data capturing and calculations

Table 18 Guest Accommodation *(income generated/night)*

REC NO	Accommodation units: Type 1 Number	Type 1 Cost/unit	Type 2 Number	Type 2 Cost/unit	Type 3 Number	Type 3 Cost/unit	Type 3 Number	Type 3 Cost/unit	Type 4 Number	Type 4 Cost/unit	Total accom. income/night
1	1	800.00	1	400.00	1	300.00	1	260.00	0	0.00	1760.00
2	2	733.32	0	0.00	0	0.00	0	0.00	1	250.00	1716.64
3	1	471.29	1	608.38	0	0.00	0	0.00	0	0.00	1079.67
4	5	149.59	0	0.00	0	0.00	0	0.00	0	0.00	747.95
5	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0.00
6	1	376.11	2	250.74	0	0.00	0	0.00	0	0.00	877.59
7	2	255.00	1	425.00	6	340.00	2	170.00	0	0.00	3315.00
8	1	520.00	1	1040.00	4	300.00	0	0.00	0	0.00	2760.00
9	14	2684.00	10	1200.00	0	0.00	0	0.00	0	0.00	49576.00
10	2	2480.00	0	0.00	0	0.00	0	0.00	0	0.00	4960.00
11	1	284.00	0	0.00	0	0.00	0	0.00	0	0.00	284.00
12	1	1000.00	3	375.00	0	0.00	0	0.00	0	0.00	2125.00
13	1	750.00	1	1000.00	0	0.00	0	0.00	0	0.00	1750.00

Table 19: Guest Accommodation *(income generated/annum)*

REC NO	Total income /night	Total income /month	Amount of months occupied as per occupancy rate: 25%	50%	75%	100%	Total income /annum	% attributed to water	Total income/yr linked to water
1	1760.00	52800.00	0	12	0	0	316800.00	100	316800.00
2	1716.64	51499.20	12	0	0	0	154497.60	100	154497.60
3	1079.67	32390.14	0	0	0	12	388681.64	100	388681.64
4	747.95	22438.36	0	0	0	12	269260.27	100	269260.27
5	0.00	0.00	0	0	0	0	0.00	100	0.00
6	877.59	26327.67	0	9	0	3	197457.53	100	197457.53
7	3315.00	99450.00	0	0	9	0	671287.50	100	671287.50
8	2760.00	82800.00	9	1	0	2	393300.00	100	393300.00
9	49576.00	1487280.00	0	12	0	0	8923680.00	30	2677104.00
10	4960.00	148800.00	12	0	0	0	446400.00	100	446400.00
11	284.00	8520.00	0	0	0	12	102240.00	100	102240.00
12	2125.00	63750.00	3	3	3	3	478125.00	100	478125.00
13	1750.00	52\500.00	3	3	6	0	354375.00	100	354375.00

Table 20: Other income generated by resort per annum

REC NO	Income generated per annum			Total other income/annum
	Restaurant	Fishing	Camping	
1	80000.00	0.00	0.00	80000.00
2	0.00	0.00	0.00	0.00
3	0.00	4200.00	0.00	4200.00
4	0.00	10000.00	0.00	10000.00
5	0.00	0.00	15000.00	15000.00
6	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00
9	0.00	42000.00	0.00	42000.00
10	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00

Table 21: Annual turnover

REC NO	Total income/yr linked to water	Total other income/annum	Total annual turnover
1	316800.00	80000.00	396800.00
2	154497.60	0.00	154497.60
3	388681.64	4200.00	392881.64
4	269260.27	10000.00	279260.27
5	0.00	15000.00	15000.00
6	197457.53	0.00	197457.53
7	671287.50	0.00	671287.50
8	393300.00	0.00	393300.00
9	2677104.00	42000.00	2719104.00
10	446400.00	0.00	446400.00
11	102240.00	0.00	102240.00
12	478125.00	0.00	478125.00
13	354375.00	0.00	354375.00
Total (all)			6600728.55
Total (excl turnovers of rec no 5 & 9)			3866624.55
Average (all)			**507748.35**
Average (excl rec no 5 & 9)			**351511.32**

Table 22: Summary of results from lodges and restaurants survey

	Whole sample	Excluding the extreme high and low values
Ave Sample turnover	R 507,748.35	R 351,511.32
No. of venues	71	69
Gross turnover	R36 050 132.85	R24 957 303.72

3.7 DATA COLLECTION: Retail Outlets

Flyfishing tackle shops and any other fishing related shops were approached.

3.7.1 Number of Surveys Carried out

	Retail Outlets
No. identified	12
No. approached	12
No. responded	7
No. useable	7
Response as % approached	58.3%

3.7.2 Area under survey

Fishing equipment outlets in Machadodorp, Dullstroom and Waterval Boven were targeted. The key retail outlets that supply conventional fishing supplies/Bass fishing equipment occur in Nelspruit.

3.7.3 Target Group of Survey

Specialist retailers concentrating on fishing equipment.

3.7.4 Type of survey

The primary objective of the questionnaire was to determine the annual turnover for each retail outlet.

Majority of the Retail outlet owners or managers were approached in person and the relevant information obtained. Others were telephoned and the relevant information gathered telephonically. Alternatively the questionnaire (Appendix 7) was faxed.

3.7.5 Limitations

- Unwillingness of owners to divulge their turnovers, especially the key retailers.

3.8 EVALUATION: Retail Outlets

Objective: To arrive at an estimated gross annual turnover for retail outlets in the area.

3.8.1 Approach to the equation

Formula: Average turnover per year (sample) x number retail shops from the catchment

The average annual turnover for each outlet was used to derive an average annual turnover for the sample.

3.8.2 Inputs used in calculations

- Establish the average turnover per retail outlet from survey.
- Establish the number retail outlets in the catchment.

3.8.3 Limitations

- The owners were reluctant to discuss their turn-overs.

3.9 RESULTS: Retail Outlets

3.9.1 Retail Outlets sample survey

Table 23: Retail value of fishing equipment (Data capturing and calculations)

	Turnover	***Staff***	***Foreign:Local customer ratio***
REC NO		skilled	Foreign/Local
1	228000.00		0.11
2	600000.00	3	0.25
3	480000.00	3	1.00
4	60000.00	2	0.00
5	100000.00		0.00
6	510000.00	4	0.05
7	101250.00	2	0.00
TOTAL	2079250.00	14	
AVERAGE	297035.71		

Table 24: Summary of results from retail outlets survey

Average annual turnover	R297035.71
Number of retail outlets	12
Gross annual turnover	R3 564 428.52

3.10 SUMMARY OF RESULTS

The assessment of expenditure on recreation activities associated with rivers in the Crocodile catchment is estimated to total approximately R75 million per annum (see Table 25). This estimate excludes the expenditure on accommodation east of Nelspruit. Importantly this value is the gross value as costs are not included but is does serve to illustrate the magnitude of value of recreation fishing to the local economy. It also serves to illustrate that an environmental reserve that adequately caters for a healthy fish population within the river system generates a significant economic benefit. In comparison, the Forestry sector in Mpumalanga (including other large catchments) generates R479 million per annum (http://www.ithala.co.za/database/economy/241.html) in terms of its logging activities.

Table 25: Summary of expenditure on recreation activities in the Crocodile catchment

User Group	Numbers	Total expenditure
Flyfishermen (club members without boats)	1602	R22 052 475
Bass fishermen (club members with boats)	200	R5 823 892
Other fishermen	3200	R8 192 000
Lodges and restaurants	71	R36 050 132
Retail outlets	14	R3 564 428
Total expenditure on recreation associated with rivers		**R75 682 927**

The assessment does not include other recreation benefits such as canoeing, rafting, swimming, walking, and sightseeing which also have value but were not considered as a priority in this assessment. In other catchment these may be more important than recreational fishing. Furthermore, while the survey has identified the expenditure on recreation fishing, the value to people may be greater than this as they may have a greater willingness-to-pay than what they pay out in cash.

4 FLOOD REGULATION

4.1 INTRODUCTION

Flooding is a natural occurrence in all river systems, often causing major damages to infrastructure and resulting in the loss of land and lives. Floods are consequently viewed as negative events in terms of their influence on society. It is widely accepted that by increasing resistance to and thereby slowing down flood waters, certain aquatic ecosystems such as wetlands and riparian vegetation reduce the damage caused by flooding. Although flooding has a negative impact on mans activities, it is an important function in maintaining the natural ecology of river systems. The biota which inhabit rivers are reliant on natural stresses provided by floods and drought. Floods are also responsible for rejuvenating flood plain areas and providing sediments and nutrients to estuarine and marine systems.

Unlike most ecosystem systems which result in direct positive benefits and values, the benefits derived from flood regulation lie in the degree to which it reduces costs to society.

4.2 DATA COLLECTION

4.2.1 Flood lines

The first step of the proposed method required that

- the present 1:20; 1:50 and 1:100 year floodlines be ascertained

Based on this information, the proposed calculation for deriving the annual costs of flooding was: $a*1/20 + b*1/50 + c*1/100$

Where a, b and c are the potential flood damage costs within the corresponding flood lines.

Flood lines are only available for certain sections of the catchment e.g. urban areas where town councils require the information for planning purposes. Although the Water Act specifies the 1:20 year flood line as the development line, local governments continue to specify the 1:50 year flood line (du Plessis *et al*, 1999). This situation was confirmed by Paul Blignaut (*Pers comm*) an engineer for the Nelspruit Town Council (NTC), who advised that all planning and development within their jurisdiction was based on the 1:50 year flood line. In the case of stretches of the Crocodile River that fall within the NTC jurisdiction, the 1:50 year flood line has only been derived for certain areas because there are large sections along the river where there is no development.

Du Plessis *et al* (1999), highlight this problem by confirming that "*Although the current hydraulic simulation models are suitable for the determination of flood-lines, little topographical data is available in the right format and scale for the execution of flood and flood management studies. In many cases only 1:50 000 topographical maps are available for flood prone areas in South Africa, which is unsatisfactory for modelling flood damage.*"

The lack of existing data for and the effort data required to establish flood-lines limited the application of the original methodology because:

- Spatial information relating to flood frequencies only exists for certain areas. The fact that flood lines have been delineated for urban areas means that costs may be captured for areas associated with high value infrastructure. It may be argued that the most costly damages per area occur in urban centres. Lack of this information for rural areas does however preclude the assessment of losses occurring in these regions i.e. arable land, crops and agricultural infrastructure e.g. fences and pumps, and low lying arable land utilised by rural farmers. Although the values may less be per hectare when compared to urban areas, larger stretches of rural land along a river may be affected so that cumulatively they may be as important.
- The lack of data related to different flood frequencies is also significant in that it prevents the calculation of the value of flood regulation under different flood scenarios. Depending on the topography in a catchment, the flood lines associated with a 1:100 year flood may vary significantly from a 1:50 year flood, or not much at all. It is therefore difficult to

accurately estimate or extrapolate different floodlines based on the 1:50 year line.

4.2.2 Potential Flood Damage Costs

The amount and cost of flood damage may be established by

- adding the insurance value or replacement costs of the infrastructure and agricultural land and crops within these floodlines.
- where floods have recently occurred in a catchment, the associated costs may be related to the floodlines or magnitude to establish costs associated with floods of different magnitude. A comparison of the two methods in a catchment where data existed would be a useful verification exercise.

Du Plessis, *et al* (1999) used various types of remote sensing to determine land-use within the established flood-lines in order to estimate potential damages from floods along the Mfolozi flood-plain and on the Orange River. The Department of Agricultural Economics at the University of the Orange Frees State, in association with SRK consulting and CADNET have developed WATEES, a tool for disaster management. The GIS based modelling tool depends on the demarcation of the probable flood-lines and the land-use within them. An economic evaluation is then undertaken to determine the costs of potential damages. The methodology used by WATEES is therefore a tool which may be used to derive flood damage costs. It may however not be practical or economically feasible to replicate this effort for all catchments, even if only applied to major urban centres.

4.2.3 The relationship between Aquatic Ecosystems, Flood Regulation and Damages associated with Floods.

Having established the potential annual costs associated with different flooding frequencies, the methodology proposed that the value of flood regulation (costs avoided) be calculated by determining; *how the existing riparian vegetation and wetlands within the catchment would reduce flow rates and heights and subsequently the costs associated with resulting damages.*

The original methodology recognised that it would require complex modelling to establish how the roughness provided by riparian vegetation reduces flood flow rates. The modelling would need to account for the following:

- At a certain flood level the resistance of the riparian vegetation to the force of the flow is overcome, resulting in its removal. This was the case in the floods experienced in the Crocodile catchment in February 2000 where even large species of trees such as figs were uprooted. Under such a scenario the flood regulation function may not be performed for the duration of the flood i.e. one needs to establish whether the vegetation was removed before or after the peak. Should the vegetation have been removed before the flood peak, its role in minimising damage would be reduced.

- Another point to consider is that the riparian vegetation will have been in better condition along certain stretches of the Crocodile River e.g. the border of the Kruger National Park so that it may have been more effective at regulating the flood in these areas. Again, this needs to be related to the velocity and height of the flow at different points along the river. As discussed in the previous point, the magnitude and intensity of the flow along a stretch may however have been so great that the vegetation was removed before the flood peak arrived. Because the intensity of the flow at any point in the river is influenced by the flow and the riparian vegetation upstream, the flood regulating function would vary along the course of the river and would need to be modelled accordingly.
- The presence of large volumes of debris in these flood waters results in increased damage. Road bridges are normally designed to accommodate flows associated with 1:50 year flood frequencies, but engineers are not always able to take into account the effect of large debris on the bridges during floods. Where floods result in the removal of the riparian vegetation, the accumulation of this debris against structures in the river acts as a barrier resulting in greater stress on the bridge and in certain cases causes the river to flow over them. The increased stress increases the chances of the structure failing. When such blockages are overcome due to the bridge failing, the large pulses which are then released serve to increase the destruction downstream. Such blockages in a system also cause the level of the flood to rise behind the point of obstruction so that the level of the flood may increase to levels which are considerably higher than would naturally have occurred.
- According to van der Spuy (*pers comm*) manager of the flood studies section of the Hydrology Directorate at the DWAF, the flood frequency associated with a single event varies along the river. Depending on the location and the type of rainfall which occurs, the flood frequencies may be greater higher up in the catchment or vice versa e.g. if a sub-catchment experiences an isolated flash storm, the flood levels may be classified as 1:50 years in that catchment, but would be reduced further downstream where the capacity of the main stream could accommodate greater flows. Such frequencies are also influenced by events such as dams breaking and releasing their storage volumes as pulses. These factors complicate the process of classifying floods in terms of return frequencies and any assessment of the degree to which the riparian vegetation reduces the damages associated with flooding.
- Historic floods are poorly documented in South Africa and are of cardinal importance to the calibration of hydraulic simulation models. No institution accepts ownership of and responsibility for the documentation of post flood data (du Plessis *et al*, 1999). Van der Spuy (*pers comm*) confirmed that surveys were being completed for analysis and classification of the February 2000 floods in the Crocodile catchment. Early indications are that in certain areas the flood exceeded the 1:100 year return frequency. As discussed however, this varied throughout the catchment, with records being as low as the 1:50 year return frequency in certain reaches of the river.

4.3 EVALUATION

The calculation associated with the original methodology was:

AVFR = (DCAa * %RCa) + (DCAb * %RCb) + (DCAc * %RCc)

Where AVFR = Annual Value of the Flood reduction function

DCa = Damage costs arising from a flood

%RCa = % reduction in costs due to flood reduction function

a,b,c = different flood magnitudes

The actual costs of the February 2000 floods in the Crocodile catchment are summarised in a report by the Department of Agriculture, Conservation and the Environment (DACE), and information from the DWAF regarding damages to their flow monitoring network obtained from the 'Mpumalanga Hydrology' section of their website.

The damages covered by the DACE includes the damages to

- Pumps and electricity and powerlines
- Irrigation equipment
- Roads and bridges
- Dams and weirs and canals
- Soil works and fences
- Farm workers houses

The total costs for repairs to the affected infrastructure was R100 982 569. In addition to this, the costs of incurred by the DWAF amounted to R9.3 million, providing a total of R101 912 569 million.

4.4 SUMMARY

Information indicating floodlines in South Africa is limited, as are records of historical floods, their magnitude and associated costs. Although the methods and tools exist to establish both floodlines and potential costs associated with floods at different reaches, these are probably not replicable on a national basis due to time and financial implications.

The way in which aquatic habitats reduce the impact of floods presents a greater problem to the process of valuing this function. Neither the intensity of a flood, or the status and condition of the riparian vegetation are the same at any two points in a river. Superimposed on these variables are factors such as infrastructure, the shape of the river, the size depth and type of channel bed which all contribute to character of the flood and the degree to which aquatic habitats may influence flood peaks in terms of intensity and duration. It is also necessary to establish the point at which the flood overcomes resistance from aquatic habitats so that the vegetation is removed and the associated flood reduction function is no longer performed. So even where floodlines and potential flood damage costs are known, the complexities involved in trying to establish the degree to which the flood attenuation function reduces these requires understanding of complex ecological relationships and the ability to model these.

If the flood regulation capacity of the aquatic habitats present in the Crocodile catchment only reduced the damages by 10%, this would equal a saving of approximately R10 million (the calculated costs did not include those borne by the commercial sector which may have significantly increased the total). It must also be borne in mind that the February 2000 floods ranged between 1:75 and 1:120 year return frequencies. There may or may not be a proportional increase in costs as the magnitude of floods increases i.e. the topography of a system may dictate that the infrastructure affected by a 1:10 year flood is also inundated by a 1:100 year so that the costs associated with both do not vary significantly.

Due to the potential significance of the value of this ecosystem service to society it is recommended that further investigations into the relationships that govern its effectiveness are warranted. Due to the complexities associated with establishing the percentage by which this function reduces costs, it may simplify replicability if the value derived for a certain type of catchment can be applied to catchments with similar characteristics, infrastructure and urban development along the river.

5 MAINTENANCE OF BANK STABILITY

5.1 INTRODUCTION

The proposed basis for valuing this function is understanding the extent to which the existing vegetation prevents the loss of river bank stability, and thereby reduces damage to infrastructure and loss of arable land along river banks. It is proposed that the value of the bank maintenance function is expressed in the costs of replacing affected infrastructure and losses in production under the existing erosion rates, subtracted from the costs associated with a scenario where no riparian vegetation existed. Bank stability is however not only a function of the state of the riparian vegetation and depends on a myriad of inter-related components of the system, all of which are unique to each catchment and the resulting river system.

The complexities associated with understanding the process of bank erosion and valuing the role of riparian vegetation in reducing this are discussed below.

5.2 BANK EROSION PROCESSES IN RIVER SYSTEMS

Although riparian vegetation is one of the most critical aspects in determining the stability of a systems banks, the bank erosion process is influenced by a wide range of other interdependent factors (Dollar, *pers comm*). Some of these are:

- Bank Angle

As discussed by in Dollar (2000), as sediment moves down a river and is trapped by riparian vegetation, the banks become less steep and provide greater resistance to erosion. This process is however dependant a sufficient volume of a particular type and size of sediment being produced in the catchment, and the existence of riparian vegetation to capture it. The steeper banks are the greater the chances are for plane failures, which involve large sections of bank breaking off from the rest of the bank. Again, the sheer stress of a bank is not only dependant on height or gradient, but is also influenced by the material of which the bank comprises.

- Bank Material

Clay material is more resistant to erosion than silt or finer bank material. In addition, the rate at which de-moisturising takes place also affects the sheer stress of a river bank. If the bank material is such that it evaporates rapidly this decreases the stress tolerance of the bank to erosion (Dollar, *pers comm*). Bank material also influences the vegetation which may grow at a particular point in a river.

- Stream Bed

The force of the flow and therefore erosion capacity is also dependant on the type of river bed. Where the river bed comprises of large cobbles resistance is higher than would be the case for finer sediments.

Dollar (2000) mentions the work undertaken by Abernethy and Rutherfurd (1998) who developed a scale approach to determine where along a river's length vegetation will most effectively stabilise stream banks.

This approach considers plant characteristics in relation to changing channel scale to determine the role of riparian vegetation in local bank erosion processes at different points in the channel. Dollar (2000) discusses bank erosion studies which highlighted the complexities of the bank erosion process, as it consists of subaerial preparation, fluvial entrainment of bank sediment and mass failure mechanisms. Moving downstream, each process domain exerts an influence over the bank erosion process to a greater or lesser extent. This is largely a function of downstream changes in changes in channel scale (Abernethy and Rutherfurd, 1998).

Dollar (2000) summarises studies which showed that subaerial erosion was dominant in small, upland streams. Middle order streams are dominated by fluvial entrainment and banks in larger catchments retreat mainly due to mass failure events. This is due mainly to the fact that steep streams in the upper reaches flow down steep gradients, while the higher discharges in the lower reaches are offset by their lower slopes. The discharge and slope often combine in the middle reaches to produce peak levels of erosivity.

Abernethy and Rutherford (1998) applied the above approach to the Latrobe River in Australia i.e. by determining the downstream variations in the erosivity of the flow by considering power per unit of wetted area of the wetted channel boundary or mean stream power, an estimation can be made of areas of erosion hazard.

Based on the work undertaken, Abernethy and Rutherfurd (1998) suggested that re-vegetating the bear channel and re-introducing pre-disturbance large woody debris into the flow in the upper reaches will have the greatest effect on the flow capacity for fluvial entrainment of bank sediments in the in the upper reaches. In the middle reaches where the stream power reaches its peak, re-vegetation achieves a 30% reduction in the mean stream power. This declines downstream so that the bottom-of the catchment re-vegetation yields only a 15% reduction in mean stream power.

They also showed that the impact of vegetation is scale dependant. This operates in three ways:

- Vegetation influences erosion processes in different ways as channel scale changes downstream.
- Increased hydraulic resistance due to standing vegetation and large woody debris within the channel effects the erosivity of the flow. Reductions in flow erosivity

by vegetation are more pronounced in mid-basin reaches where the mean stream power peaks.

- The main role of vegetation in stabilizing banks is increased bank substrate strength to the presence of roots.

Bank erosion in river systems therefore varies along the gradient of the catchment and is dependant on inputs from the catchment (e.g. sediment and flow), channel form and the various process and relationships which affect bank stability. It is also important to understand what types of erosion occur at different altitudes within the catchment. The factors influencing bank stability and erosion discussed above are only a few of the complexities which need to be understood and considered in conjunction with the type and characteristics of the riparian vegetation (e.g. density, root depth) before one can predict the extent of the bank erosion that would occur in the absence of the existing vegetation.

5.3 EVALUATION

5.3.1 Calculation

It was proposed that the value of the river system in terms maintaining bank stability is expressed in the cost of the infrastructure and arable land which would be lost if the existing riparian vegetation was not performing this function. In order to quantify this, the following equation is proposed:

1] VMBS = CMLBE - CCLBE

Where VMBS = The value of maintaining bank stability

CMLBE = The cost of maximum levels of bank erosion i.e. under a scenario of no riparian vegetation

CCLBE = The cost of current levels of bank erosion

5.3.2 Inputs to calculation

- Cost of Maximum levels of bank erosion (CMLBE)
  CMLBE = MABE * VLIA

Where MABE = maximum area of bank eroded.

To quantify this value would require detailed studies of representative sections of the river in order to understand the factors affecting channel stability, their relationship with the riparian vegetation and flow and sediment dynamics. This may allow one to estimate what erosion would take place if the current riparian vegetation was not present.

VLIA = value of the land (hectares * value/ha) and infrastructure affected (obtained from insurance claims). The two values would need to be added.

- Cost of Current Levels of Bank Erosion (CCLBE)
  CCLBE = CABE * VLIA

Where CABE = Current area of bank eroded (hectares). It may be possible to establish volumes of river bank lost to erosion by establishing distance markers and monitoring changes in the river width over a year.

VLIA = Value of land and infrastructure affected.

5.3.3 Assumptions and limitations

- A major assumption relating to this function is that the banks are actually eroding. Increased forestry, abstraction and population growth have generally led to a reduction in flows over the last few decades. As a result there has been encroachment of the riparian vegetation and a narrowing of the Crocodile River channel in certain areas i.e. increased bank stabilisation and reduced erosion (D van Bladderen *pers comm*).
- A replacement cost is assumed for any infrastructure which may be damaged due to the predicted maximum erosion scenario. In reality infrastructure may only need to be repaired, the costs of which may be significantly lower than the replacement costs.
- One has to assume that the maximum level of erosion is being projected at flows for the year during which bank stability function is being valued.
- According to Dollar (*pers comm*), more than 50% of the sedimentation in the Amazon river can be attributed to bank erosion. Although the rates are not as high in South Africa, unnaturally high rates of sediment caused by man induced erosion impacts on the life-span of dams and affects the ecology of the river e.g. fish gills are clogged and high turbidities affect fish feeding. This in turn affects related food chains. As it is difficult to relate how changes in sediment rates and impacts to the ecology might increase without the existing riparian vegetation, a limitation of this calculation is that these costs/savings are not included.

5.4 SUMMARY

The relationship between riparian vegetation and bank stability is complex and varies along the river profile and between catchments. Although it is possible to establish areas where vegetation along a river gradient would be the most effective in reducing bank by gaining understanding of the stream power in relation to the riparian vegetation and channel steepness and form, determining what levels of erosion would occur if riparian vegetation was removed would require an understanding of the large number and variety of factors and relationships which affect erosion of river banks.

To establish such understanding for individual rivers and catchments will require detailed investigation and modeling which has not been undertaken for the crocodile catchment.

It is important to note that banks may not always be eroding, but that the river channel may in fact be narrowing. Such a scenario allows for increased development and habitation closer to the river. In the long term this may however result in increased damages due to large floods, which are not held back and actually remove the riparian vegetation, affecting more infrastructure closer to the river. The benefit of reducing bank erosion may therefore be viewed as a short term benefit and in the long term may in fact be considered a dis-benefit.

In view of the complexities of the relationship between riparian vegetation and the maintenance of bank stability it is has not been possible to provide a value for this function of river systems. This coupled with the fact that it is a short term benefit, result in the recommendation to exclude the maintenance of bank stability from future refinement of methods for including economic input in the determination of the ecological reserve.

6 SEDIMENT TRAPPING

6.1 INTRODUCTION

Sediment trapping is a function that varies between and within catchments and which is influenced by a large number of variables which complicates efforts to value it. Owing to the difficulties encountered in deriving a value according to the proposed methodology, the limitations are discussed with a view to identifying gaps in knowledge which need to be addressed and changes to the approach adopted for this study.

6.2 DATA COLLECTION

Each step of the proposed methodology is presented, followed by the limitations encountered for each.

6.2.1 Ascertain how much sediment is trapped in different habitats

The volume of sediment trapped in aquatic environments differs between and within catchments depending on factors such as geology, soil type, general vegetation cover, topography, land-use and the amount, type and density of the riparian vegetation. The hydrological regime is also a major determinant of the volumes of sediment trapped by riparian vegetation as it influences rates of sediment movement through the system and the types of erosion which take place e.g. sheet or gully. Complicated modeling which relies on a large amounts of data for each of these influencing factors is therefore required to derive such information. As the conditions at any one location in a catchment are dependant on what is happening upstream, it is not possible to look at a particular site in isolation. The catchment needs to be modeled as a whole.

An un-natural influence on a systems sediment regime is the degree to which the catchment is regulated. Large impoundments trap sediment, and secondly the release of large sediment free floods from major impoundments will increase the scour rate due to the increased energy density of releases (K Legge, *pers comm*). Such releases alter the status of the riparian vegetation and sediment deposition downstream. An impoundment lower down in a catchment will also be exposed to greater inputs of sediment than a similar structure located upstream.

Another complicating influence is the dynamic nature of river systems and the influence of major natural events. Large floods (as occurred in the Crocodile system in January 2000) remove large proportions of the riparian vegetation which may take some years to return to the pre-flood condition. During the period of re-growth, the sediment trapping function will be greatly reduced. Such events also remove the sediment trapped in the riparian zones up until the occurrence of the event, thereby reducing the importance of this function to a short term economic benefit.

6.2.2 Establish the current lifespan, and rate of sedimentation and dredging of reservoirs and other affected areas (e.g. harbours).

- The economic life-span of a dam constructed by the Department of Water Affairs (DWAF) is 50 years (K Legge, *pers com*). It is therefore standard practice to include additional capacity which will accommodate a 50 year silt volume without influencing the dam storage required over this period. The sediment rates and predicted entrapment within impoundments, which are used in the design specifications are determined based on work undertaken by Rosenboom (1992). Prior to the work undertaken by Roosenboom, predictive capabilities were limited and there are examples where sediment yield was underestimated resulting in the premature siltation of dams e.g. Welbedacht. Such situations resulted in the need to augment the loss in storage capacity earlier than predicted, which has financial implications as one needs to build, for example 2 dams every 50 years as opposed to one.
- The Geomatics Department of the DWAF undertake sediment surveys of all major impoundments. This allows them to gauge changes in capacity in relation to water demand and to plan for future storage and augmentation needs. The frequency at which surveys are undertaken are dictated by the sediment yield of a catchment. Where sediment yield is very high such as the Caledon River Catchment, surveys are undertaken annually e.g. Welbedacht Dam. In the case of the Kwena Dam in the Crocodile catchment, surveys are undertaken at a frequency of every five to 10 years.

6.2.3 Establish the dredging costs and replacement cost of structures.

- Investigations undertaken in South Africa into dredging impoundments where sedimentation is a major problem have proved this option to be uneconomical (H Elges, *pers comm*). Where sedimentation exceeds projected rates and thereby reduces the life span of a dam, additional storage facilities are constructed prior to original expectations in order to meet existing and future demand.

  According to Kroon (*pers comm*), following the development of theories for predicting sedimentation rates by Roosenboom, cases such as those experienced at Welbedacht are no longer such an issue. One of the products arising from Roosenboom's work was a sediment yield map for the country, and the construction of impoundments in catchments where sedimentation is a problem is avoided. The financial implications of having to replace dams earlier than planned can therefore not be viewed as a regular or reliable method of valuing the sediment trapping function of most river systems.

6.2.4 Ascertain how total loss of sediment trapping habitats would increase the rate of sedimentation, for calculation of total value of this function

The total value of this function is dependant on the first step of the data collection i.e. calculating volumes of sediment trapped by aquatic habitats in the system. As the modelling required to derive this information was not possible within the scope of this project, neither was the determination of the total volume of sediment trapped.

In view of the difficulties in applying the proposed method for valuing the sediment trapping function of river systems, alternative methods have been proposed.

6.3 REVISED METHODS FOR ASSESSMENT

According to the DWAF (Elges, *pers comm*) dams are designed to allow for a 50 year silt volume based on sediment volumes and rates specific to catchments. As discussed, tools are available now days which allow these to be predicted. It is proposed that the costs associated with accommodating the maximum sediment rates in the original design of impoundments is the value of the function provided by the system. The maximum sediment rates are those where there is no riparian vegetation or wetlands.

6.4 EVALUATION

6.4.1 Approach to the calculation

The aim of the calculation is to obtain a value for the total sediment trapping function (FV) carried out by aquatic ecosystems. The value would be encapsulated in the cost of building all dams in the catchment at the current sediment volumes, subtracted from the cost of building them to accommodate maximum sediment volumes (MSV) i.e. where riparian vegetation and wetlands were removed from the model designed to derive sediment trapped in the system.

FV equals the current actual sediment volumes (ASV) in tons/annum subtracted from the maximum volumes of sediment that would be produced if there was no riparian vegetation or wetlands (MSV).

The proposed equation is as follows:

1] $FV = (MCASD_1 + MCASD_2 + \ldots..) - (ACASD_1 + ACASD_2 + \ldots..)$

Where $MCASD_1$ = Maximum cost of accommodating sediment based on sediment rates derived from a model where riparian vegetation and wetlands are removed. The cost will need to be established for each dam in the catchment and the values summed to obtain a value for the entire catchment.

$ACASD_1$ = Actual cost of accommodating sediment in a dam based on current rates of sedimentation. The cost for all dams in the catchment needs to be added.

FV = Function value (R/annum)

2] $ACASD_1 = (CCD_1 * PDC)/50$

CCD_1 = Current cost of constructing the dam

PDC = Percentage of the dam capacity affected by sedimentation (recorded as a percentage of the original design capacity of the dam).

50 = economic life span of dams

3] $PDC = (DCD / LESV) * 100$

DCD = The design capacity of the dam (m^3)

LESV = Life end sediment volumes of the dam (m^3)

4] $CCD = (OCD * IR)\ n$

OCD = the original cost of the dam
IR = the Inflation rate and
n = the number of years since the dam was constructed

5] LESV = ASR * 50 years
ASR = Actual sediment rates as determined by the dam capacity determination surveys undertaken by the Geomatics Directorate of the DWAF.

The same steps would be required to determine MCASD, but using the maximum sediment rates established by the modelling exercise.

6.4.2 Limitations to the calculation

- The calculation does not include the multitude of small farm dams which although small, may collectively influence the rates of sedimentation in the catchment to a level worth including in the modelling process. Calculating the value of sediment trapping in maintaining their life-span may also add to the total value of the function.
- The ASR and therefore the $ACASD_t$ will vary annually according to the variable inputs within the catchment. As a result, the value of sediment trapping in the catchment will vary over time and within the 50 year life span of the dams in the catchment. This should only cause major changes in the values obtained where large events significantly alter the condition and status of the aquatic ecosystems. Other factors such as increased erosion occur more slowly and may therefore only have a visible influence in the values over a period of 5-10 years.
- The various dams in the catchment would have been built at different times, so that inflation needs to be considered in deriving construction costs for a specific year e.g. the Kwena Dam was constructed 16 years ago at a price of R53 million, which at today's prices equates to R 477 million (Kroon, *pers comm*).

6.5 SUMMARY

Although application of the original methodology did not prove feasible due to the fact that:

- early replacement of dams is no longer a major issue, and
- dredging of impoundments is not carried out in South Africa, and
- there are limitations in the understanding with regard to the influence of riparian vegetation on trapping sediments,

an alternative methodology and associated equation for deriving a total value for sediment trapping function of a river system are proposed.

Actual sedimentation rates are obtainable through sediment surveys undertaken for large dams on a regular basis. The key to the method however lies in the ability to model maximum sediment rates which may occur if there were no aquatic habitats trapping sediment. In turn, this requirement is dependant on a sound understanding of how the type, thickness and density of riparian vegetation and various wetlands characteristics (position in landscape, length, breadth, substrate) determine the amount of sediment which is trapped in a system.

Albeit that the relationships are understood and can be modelled, the modelling process would be a data intensive, time consuming and costly undertaking. Sediment rates were not found to be a major problem in the Crocodile catchment, but the values associated with this function may be of significance in other sediment driven systems.

Due to the fact that large flood events reduce the sediment trapping function of river systems to a short term benefit, it is recommended that the valuation of this ecosystem function is not pursued any further.

7 INPUTS TO AQUACULTURE

In the Crocodile river catchment several trout hatcheries are functional. Trout hatcheries require cool high quality water as an input into production and discharge polluted water into the river systems. Consequently hatcheries depend on a river that is able supply water of a quality that can sustain large numbers of water-quality sensitive trout and a river that is able to absorb the effluent from the hatchery. Trout hatcheries are therefore dependent on a well functioning river ecosystem and therefore a generous environmental reserve. Without a generous reserve, trout hatcheries would not exist within the upper Crocodile catchment.

7.1 DATA COLLECTION

7.1.1 Data collection method

A survey was undertaken to identify as the trout hatcheries within the Crocodile Catchment. Questionnaires (Appendix 8) were faxed out to nine hatcheries in and around the crocodile catchment. Of these nine, four were identified as being located inside the catchment and follow up interviews were conducted telephonically with these four to confirm and expand on information provided in the questionnaire. The following information was obtained:

- Nature of production and operation (eg hatchery, processing plant, etc)
- Scale of operation (annual turnover)
- Number of staff and total wage bill
- Associated operations and enterprises
- Reasons for location within Crocodile Catchment

7.1.2 Survey area

The survey focussed primarily on hatcheries and processing plants within the Crocodile Catchment, however also recording hatcheries located outside of the Catchment that supplied fish to processing plants within the Catchment. Due to the nature of hatchery operations (in terms of water and climate requirements) all the surveyed operations were located in the west of the Catchment in the highlands region.

7.1.3 Target group

The survey focussed on operations involved in fish production, which within the Crocodile Catchment were those who operated trout hatcheries. These trout hatcheries included those who were producing trout both for live sale to restock dams for fishing, as well as for processing and sale as fish and fish products to restaurants and retail outlets.

7.1.4 Limitations

- Accuracy

Businesses are not run exclusively within the Catchment, with some of the resources being bought or sold outside of the Catchment. It was therefore difficult for those operations surveyed to identify what proportion of their business was directly attributable to the Crocodile Catchment.

7.2 EVALUATION

7.2.1 Approach to the equation (formula)

The value of fish production and processing was calculated using the following formula:

(1) $$VP = [(Tl \times P) + (Tp \times P)] - (Fbl \times P)$$

Where,
VP = Value of Production
Tl = tonnes of live fish produced and sold
Tp = tonnes of processed fish produced and sold
Fbl = tonnes of live fish traded locally between hatchery and processors (this is to avoid double counting of the outputs of the hatchery and the outputs of the processing plant)
P = price at which fish and products are sold

In order to include only fish produced within the crocodile Catchment the following formula were used to calculate the inputs for formula (1):

(2) $$Tl = Fp + (Fb \times \%C)$$

Where,
Tl = tonnes live fish
Fp = tonnes of fish produced locally at the enterprise within the Crocodile Catchment
Fb = tonnes of fish bought from other enterprises and processes locally
%C= percentage of the fish purchased from other enterprises that are within the Crocodile Catchment

And:

(3) $$Tp = Fp + (Fb \times \%C)$$

Where,
Tp = tonnes of processed fish

Fp = tonnes of fish produced locally at the enterprise within the Crocodile Catchment

Fb = tonnes of fish bought from other enterprises and processes locally

%C= percentage of the fish purchased from other enterprises that are within the Crocodile Catchment

7.2.2 Assumptions

Very few of the enterprises operate solely within the boundaries of the Crocodile Catchment, but rather depend on inputs from aquaculture enterprises established outside the catchment. Calculations are therefore based on assumptions of what percentage of the aquaculture production originates from enterprises within the Catchment.

7.2.3 Inputs used in calculations

Raw data such as values per kilogram, tonnes produced were very difficult to obtain during the surveys. Enterprise operators were largely only prepared to provide indications of total values of various production activities. Inputs into the calculations were therefore primarily summaries of values rather than detailed values of different aspects of the operations. The summary values that were provided included:

- Value of live fish produced (fingerlings for stocking dams)
- Value of live fish purchased for processing
- Estimated percentage of live fish purchased from other enterprises within Crocodile Catchment
- Value of processed fish products for retail to restaurants etc.
- Value of associated enterprises, eg trout lodges, restaurants etc.
- Total wage bills

7.2.4 Limitations

- The calculations do not take into consideration input costs; they are simply an estimate of the value of turnover.
- Enterprise operators were often hesitant to provide economic details of there operations and only a limited amount of information was therefore obtained.
- Interviews often did not provide a full range of vital information, for example tonnes of fish produced, but rather only provided the value of production, or total wage bill rather than number of people employed and wage rates. The estimated values are therefore generalized amounts rather than specific values.

7.3 RESULTS

The value of aquaculture production, sales of processed trout and associated enterprises based within the Crocodile Catchment is estimated at R10.7 million.

Table 25 : Data capturing and calculations for aquaculture production

	Record 1	Record 2	Record 3	Record 4
Presence of processing plant	yes	yes	no (live sales)	no (live sales)
Tonnes of fish produced by enterprise annually	78	4	50	35.5
Tonnes of additional fish bought from inside CRC (annually)	34 (from record 3)	0	0	0
Value of additional fish bought from hatchery inside CRC and then processed	R510 000	0	0	0
Tonnes of additional fish bought from outside CRC (annually)	8	2.5	0	0
Annual value of production (R)	R 6 000 000	R 360 000	R 750 000	R 743 000
% Turnover resulting from other catchment resources	6.66%	38.5%	0%	0%
Turnover attributed from production from inside CRC	R 5 122 170	R 221 538	R 750 000	R 743 000
Turnover from associated enterprises	R 4 000 000	R 250 000	R 0	R 145 000
Less fish values already counted	R510 000			
Total Turnover arising from inside CRC	R 8 612 170	R 471 538	R 750 000	R 743 000

CRC = Crocodile River Catchment

Table 26: Summary of results from aquaculture production

Record No.	Value of processed fish	Value of live sales	Value of associated enterprises	Total turnover
1	R5 122 170	- R510 000	R4 000 000	R 8 612 170
2	R 221 538		R 250 000	R 471 538
3		R750 000		R 750 000
4		R743 500	R 145 000	R 888 500
Estimated value of aquaculture production in Crocodile Catchment				R10 722 208

Of the four aquaculture enterprises within the Crocodile Catchment, two have processing plants where they process trout into food products for sales to restaurants etc. These two enterprises have their own hatcheries where they produce trout and in addition buy in additional trout from other hatcheries, both inside and outside of the Catchment (for the purpose of these calculations, only those produced within the Catchment were considered). The remaining two enterprises produce only live trout at hatcheries and do not have processing plants. The one hatchery (record 3) supplies the majority of their trout to the largest processing plant (record 1) while the second hatchery primarily supplies live trout for restocking dams at trout lodges. To avoid double counting, the value of the trout purchased by record 1 from record 3 is subtracted from the total value. The values of associated enterprises refer to additional activities run at the hatcheries for example, restaurants, and bed and breakfast cottages on the trout farm.

8 EXPORTS TO MARINE ECOSYSTEMS

8.1 INTRODUCTION

Estuaries are the meeting-places of rivers and the sea and their character is determined by the interplay of the inputs from these systems. These dominant influences govern the physical, biological and chemical processes that take place in estuaries and which in turn, provide the habitat for the organisms that live there. Various invertebrate and vertebrate species utilise estuaries as nurseries, relying on the nutrients rich environment and habitat provided by river and marine input, before returning to the marine environment.

Of the estuarine reliant biota, prawns provide the basis for one of the most commercially lucrative fisheries. Although it has not been possible to determine the exact contribution of the Crocodile River's input to the value of these fisheries, an attempt is made to highlight the significance of their influence. Broad conclusions have also been draw regarding their potential contribution to the value derived from fisheries dependant on estuarine systems.

According to De Freitas (*pers comm*), the Mozambique prawn fishery associated with species that are estuarine dependant at a certain stage of their life-cycle, is currently worth R 720 million/annum. This figure is based on annual catches and an average price of \$9/kg (R75). Deep water prawns, which undergo their entire development in the ocean depths, contribute another R 90 million to this industry.

8.2 THE INFLUENCE OF RIVER SYSTEMS ON THE VALUE DERIVED FROM MARINE FISHERIES

8.2.1 Life cycle of Prawns (Penaecoidea)

Shelf prawns spawn and undergo several moults at sea. The initial larval stages are planktonik in nature and are therefore driven by wind and currents. During postlarval stages they move into the estuaries where they become omnivorous bottom feeders. They soon change into juveniles and grow rapidly before moving in a pre-adult stage back into the ocean where they finally mature and reach the spawning grounds.

The backwater and mangrove areas in estuaries therefore provide a critical habitat in the development of commercially important species of shelf prawns.

8.2.2 The influence of Rivers on Estuarine Habitat and Mangroves

The abundance of shelf prawns found off the Mozambique coast is closely related to the abundance of suitable nursery areas, especially those afforded by mangrove swamps (De Freitas, 1984).

The mangrove communities occur in mudflat areas which are influenced by inputs from river systems, "*There are small patches of mangroves at the south end of St Sebastian Bay, Pomene and at Inhambane. The mangal at this last locality is found* *on a substratum poor in mud due to the lack of river borne silt. Further, the rivers of this region are poor in nutrients as they arise in leached, acidic sands. As a result the mangroves are stunted in growth.*" (De Freitas, 1984) . This example shows the influence of river sediment on the mangrove communities occurring along the South-east African coast.

Rivers not only provide the substrate and nutrients for the development of mangrove communities, but also influence other aspects of the estuarine habitat.

- Although certain species occur in freshwater, other species of prawn can only tolerate certain levels of salinity. The mixing of fresh and marine water influences these gradients which support biota dependant on the different salinity levels. Estuarine waters can either be mixed, where salinities occur in ranges between bottom and surface waters, or stratified, where there may be freshwater at the surface and the bottom levels may be saline. There seems to be little doubt therefore that in general the Maputo Bay complex, including the estuaries, can be considered virtually homogenous due to the mixing efficiency of the tidal prism (De Freitas 1984). With the exception of those stratifications in river mouths, little, if any difference in surface and bottom salinity was found between high and low tides in the Bay of Maputo.
- Similarly, freshwater inputs also influence temperature, which in the Bay of Maputo was found to vary little between surface and bottom waters.
- As discussed in De Freitas (1984) turbidity of water in the whole Delgoa Bay is related more to the movement of water masses than to wet or dry seasons. De Freitas (*pers comm*), however suggests that prawns are found in higher turbidities because these are associated with areas of finer (muddier) sediments, which form their preferred habitat.
- Although opinion varies, freshwater flows influence the movement of prawns in and out of estuaries. Certain estuarine ecologists contest that prawns respond to the chemical condition i.e. salinities, temperature of water which drives their migration into estuaries and influences their return to marine systems at critical stages in their life cycle. Alternative opinion is that, because their initial stages are planktonic they are at the mercy of the tides and winds in their movement towards and into estuaries at post-larval stages. Regardless of the influence of movement into the estuary, the second line of thinking argues that freshwater is important, albeit that it is not due to the influence on the physico-chemical condition of the water, on the return of prawns to the marine environment. They argue that large flows are required to flush the prawns out of the estuaries and nursery areas into the marine environment.
- Freshwater flow is also responsible for influencing the physical structure of estuaries. Significant decreases in flow may alter the status of the estuary mouth. Where the estuary changes from e.g. a permanently open estuary to a temporarily closed one, this has implications for the salinities, water levels and depths i.e. habitat, and the associated biota. Of significance, migratory species such as prawns that utilise estuaries may no longer be able to gain access to the nursery areas.

River input is therefore important in creating and maintaining the extent and condition of mangrove and estuarine habitat that serve as nursery areas and thereby an important component of the life cycle of certain commercially important marine species.

8.2.3 The Komati Estuary

Most of the work done on the commercially important shelf prawn species has taken place in Maputo Bay where a fairly substantial tonnage of prawn is caught by small trawlers and seiners every year (de Freitas 1984). The habitat in the bay is influenced by a number of rivers, namely the Komati, Maputo, and the Espirito Santo Estuary, which is formed by the confluence of the Tembe, Umbeluzi and Matola Rivers.

The Komati, of which the Crocodile is a major tributary, contributes to an estuary 13km in length and with a surface area of 20.4 km^2 of which 10.4 km^2 its area is formed by mudflats exposed during spring low tides. In the river Mangroves occupy about 3 200 hectares. According to De Freitas (*pers com*), this estuary provides extensive areas of good habitat for prawns.

8.3 EVALUATION

Two options are proposed for calculating the value of river input to the prawn fishery as an example of the value of river exports to marine environments.

8.3.1 Calculation 1

This calculation focuses on deriving a value for each estuary based on the actual numbers and species of prawns which it supports. It is therefore more accurate than the second option, which merely aims to derive rough estimates, and requires that greater assumptions be made.

$VREME = STPS_1 * KGVS_1$

Where VREME = Value of river exports to the marine environment for a specific estuary (Rands)

$STPS_1$ = Sustainable tonnage of prawn $species_1$ supported by an estuary

$KGVS_1$ = Kilogram value of prawn $species_1$ as determined by market price (e.g. \$9/kg). This will vary from species to species so that in order to be accurate, the equation will need to read:

$FV = (STPS_1 * KGVS_1) + (STPS_2 * KGVS_2) + ...$

8.3.2 Calculation 2

According to De Freitas (*pers comm*), the shelf prawn industry in Mozambique is currently worth R 720 million/annum (\$ 90 million). This is based on an average value of \$9/kg. In De Freitas (1984), 28 estuaries that support mangrove communities along the Mozambique coast are listed. The proposed calculation is:

$VREME = TVI / E$

Where TVI = The total value of the Mozambiquan prawn fishery
E = Number of mangrove supporting estuaries

VREME = R720 000 000 /28
= R25 700 000 per mangrove supporting estuary

This figure would need to be rationalised in terms of the relative contributions by the different estuaries to the total value of the industry. The most simple way would be to compare the size, status and density of the mangrove communities supported by each estuary. This approach would depend on the assumption that the status and size of the mangrove plants and their health reflected the relative contribution of the river system, and that this information was available.

8.3.3 Assumptions and limitations

- Owing to the complex relationship between different catchment inputs and marine influences on the different aspects of the estuarine habitat, e.g. salinity, turbidity, nutrients levels, sediment deposition and the creation of intertidal area, it would be almost impossible to place any confidence in attributing a proportion of the total value of the industry to the input of the river. This relationship requires that a major assumption therefore be made i.e. that without the rivers there would be no prawn fishery due to the dependence of the prawns on the estuaries. Consequently, the whole value of the fishery prawns may be attributed to the existence and influence of rivers.
- For equation 1, establishing the composition and numbers of prawn species supported by an estuary would require thorough surveys. According to De Freitas (*pers com*) such surveys are both time consuming and costly.
- Despite the first assumption, that rivers are a critical to the existence of estuaries and therefore the entire value of the fishery can be attributed to them, the situation is complicated by the fact that the Crocodile is a tributary of the Komati. It is therefore difficult to determine the percentage of the value derived from an estuary that can be attributed to the input from the Crocodile River into the Komati River. A possible means of overcoming this limitation may be to attribute value based on the contribution of the Crocodile River to the total sediment and nutrient load of the Komati River. This would be a very rough estimate due to the effect of nutrient dilution, deposition of sediment and the input from the catchment and other tributaries between the confluence of the two rivers and the Komati Estuary. These influence would further blur the contribution of the Crocodile River to the final output of the Komati River to the estuary.
- Although an estuary may support a certain tonnage of prawns, it would be necessary to know what the limit would be for ensuring sustainable harvests. This 'sustainable' tonnage would represent the realistic value that would be

obtainable from the estuary. De Freitas (*pers comm*) commented that such studies had been undertaken, the evaluation of which would need to be applied.

- The values obtained reflect only the value of the prawns harvested from marine environments and do not take into account harvests of other fish and crustacean species which are reliant on estuarine habitat for periods of their life cycle.
- The value calculated for the prawn fishery does not take into account the value of the subsistence fishing, which takes place in all estuaries in Mozambique (De Freitas, *pers comm*). The value of these annual harvests may be significant when viewed in terms of the protein value to those benefiting from it.

8.4 SUMMARY

Although it is possible to establish the value of prawns specific to individual estuaries, the surveys required to determine the number and species present are time consuming and costly.

The link between the influence of rivers in terms of sediment, nutrients and freshwater itself on creating and maintaining estuarine habitats is a strong one. However, the degree to which the current river inputs determine the composition and density of the prawn populations utilising an estuary are difficult to quantify due to the input of marine influences e.g. tides, currents, salinities, nutrients and the position of the estuary in the coast which dictates the extent and significance of marine influences.

In the case of the Crocodile catchment, the fact that it is only a tributary of the Komati River, further complicates the issue of associating a percentage of the potential value of the Komati estuary. The influence of the Crocodile on the estuary is reduced via various processes discussed, between the juncture of the two rivers and the estuary itself.

The figure obtained from applying calculation 2 is significant. Even if approximate and out by an order of magnitude i.e. 10 times less than the calculated value, every estuary would still support a fishery worth R 2.5 million per year. Such a figure is still worthy of consideration when determining the allocation of water resources within a catchment which contributes to such fisheries.

As noted these values exclude other marine fisheries that involve the harvesting of other estuarine dependent invertebrates and fish species. Including the values of these fisheries would increase the total value associated with estuaries and the inputs provided by the catchments that sustain them.

9 WASTE TREATMENT

9.1 INTRODUCTION

The term "assimilative capacity" is based on the concept that all water bodies posses a finite ability to absorb, dilute, modify or transform waste products or contaminants, to levels which prevent the quality of the water from being degraded. The assimilative capacity for one constituent in one part of a water body may be exceeded (and thereby impact a sensitive user), whilst all other measured constituents are within the allowable concentration ranges and show no effect on any water users. Assimilative capacity must therefore be defined separately for each water quality constituent of interest and for each water user.

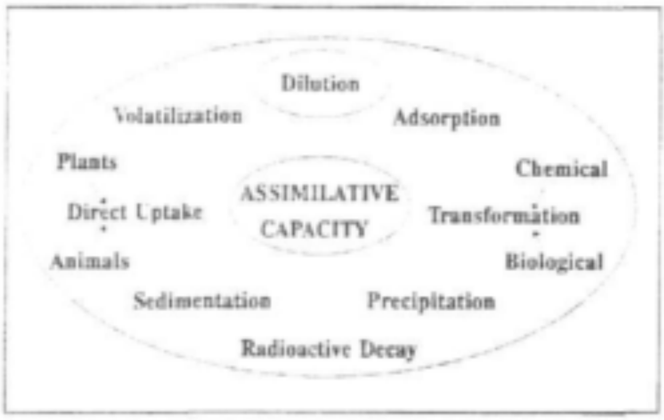

Figure 27.1: The different component processes that contribute to assimilative capacity in a water body. The assimilative capacity for a conservative substance is controlled by dilution alone. (Redrawn from Ashton, 1993).

These maximum concentrations, or water quality standards are set by the Department of Water Affairs and Forestry (DWAF) who require that all activities within a catchment that generate effluent apply for a permit. Permit holders are required to treat their effluent to a maximum concentration that may be returned to the system. In order to reduce the effluent to the prescribed standards, permit holders incur costs required to establish and operate treatment plants.

The value of the assimilation capacity of the river is expressed as, the costs the permit holders would incur if they were to reduce the concentration of the various constituents in the effluent they produce to zero before returning it to the receiving system.

9.2 DATA COLLECTION

9.2.1 Methods of data collection

- A list of all permit holders in the catchment was obtained from the DWAF.
- Each permit holder was contacted via telephone to introduce the project. This was followed by written correspondence using fax or e-mail to formalise a request for the following information:

- The volumes of effluent treated annually, including input and output concentrations for the various constituents treated, and the flow volume capacity of the treatment plants.
- The original capital costs and predicted life span of their treatment works.
- The annual operating costs for the works, including salaries, chemicals, maintenance etc.

9.2.2 Limitations of method and data collected

- Despite assurances from permit holders over the phone that the data requested was available, the actual delivery was both slow and incomplete. In almost all cases, only certain aspects of the data required were provided. This resulted in the need to contact all permit holders a number of times, a process which proved both frustrating, time consuming and costly. Overall, the process was ineffective as a stage was reached where no more time or money could be spent, despite the fact that only 2 of the 28 permit holders contacted had provided all the data required to populate the proposed methodology.
- The data provided was not all immediately compatible. This was due to permit holders using different scales of measurement e.g. mg/l, tons/annum, mega-litres. This required that all the information be converted to a common scale for each of the various data sets. As a further example, some treatment works only functioned over certain periods of the year e.g. citrus canning and juice plants that operate during the harvesting season, which required that the data be annualised.
- Various types of treatment works are employed by different permit holders, which made certain data difficult to derive e.g. many of the systems irrigate the treated effluent – the concentrations of the irrigated constituents can therefore not be taken as those that eventually seep through to the river system. In an attempt to overcome this, the DWAF were consulted regarding monitoring points in the river below such systems. The readings at such points however, include concentrations from further upstream and which required that distinction be drawn between the input from the irrigated area and upstream input. This was too complex an undertaking to prove an effective solution.
- In a number of instances certain data was not available at all e.g. the original capital costs for constructing the treatment works, or their predicted life span.
- A significant limiting factor to the proposed method was the fact that none of the permit holders were able to break down the total removal costs (annual operating plus operation costs) into the costs for removing the masses of the individual constituents. Consequently it was not possible to establish a 'treatment cost/per volume' for the different constituents. This value/ratio is fundamental to establishing a value for the mass assimilated by the river in the proposed method. Costs could only be linked to the volumes of wastewater treated.

  The situation is further complicated by the fact that although a plant may treat a wide range of constituents, some of the processes remove more than one constituent.

9.2.3 Development of a Model to Calculate the Value of Waste Assimilation of a River System

In view of the difficulties encountered in collecting, and the type of data available, to test the proposed methodology, assistance was sought from Umgeni Water's wastewater scientists who are responsible for managing the Darvill works in Pietermaritzburg and for the design of treatment plants throughout Africa. A model was developed based on the expertise of the Umgeni Water staff and the costs, volumes and concentrations associated with the Darvill Treatment works.

In order to reduce the complexity of the valuation process, it was decided to focus on those main constituents for which treatment plants are normally designed. The processes employed in treating these 'main' constituents account for some of the other constituents removed. In accordance with this decision, the following constituents were selected:

COD - Chemical oxygen demand
TKS - Total Kjeldahl Nitrogen
SRP - Soluble reactive phosphate
SS - Suspended solids

In order to overcome the problem of attributing percentages of the total annual removal costs to the various constituents, it was proposed that the total costs be divided between the constituents based on the percentage of the total treated mass associated with each of the constituents. A model was developed to convert the data into values for the assimilation capacity returned to the system.

The resulting evaluation is given below, along with tables showing the examples of values from the Darvill example at different stages of the calculation. These are followed by the assumptions and limitations necessary to place the results in context.

9.3 EVALUATION

9.3.1 Approach to the formula

The proposed formula was designed to establish a value for the assimilative capacity of the entire system.

Proposed Formula

$TVSAC = (CSPH_1 + CSPH_2 + CSPH_3 + ...)$

Where $TVSAC$ = The total value of the system's assimilative capacity

$CSPH$ = The costs savings provided by the system to permit holder $_{1, 2, 3....}$

Inputs to the formula

(1) $CSPH = (CSC_1 + CSC_2 + CSC_3 + ...)$

Where CSC_1 = Cost savings for constituent $_{1, 2, 3.....}$

(2) $CSC_1 = CRC_1/Kg * MC_1AS$

Where $CRC_{1/}/Kg$ = Cost to remove a kilogram of constituent$_1$

MC_1AS = Mass of constituent $_{1, 2, 3...}$ assimilated by the river

(3) $CRC_1 /Kg = TARCC_1 / TAMRC_1$

Where $TARCC_1$ = Total annual removal cost for $constituent_1$

$TAMRC_1$ = Total annual mass removed for $constituent_1$

(4) $TARCC_1 = [(TAMRC_1 / TAMRAC) * 100] * TAC$

Where $TAMRC_1$ = Total annual mass removed for $constituent_1$

TAMRAC = Total annual mass removed for all constituents (apply step 5 to all constituents and sum)

TAC = Total annual cost

(5) $TAMRC_1 = (ACRC_1 * DFV * Y)$

Where $ACRC_1$ = Average concentration removed for $constituent_1$

DFV = Daily flow volume (given)

Y = 365 (days in a year to annualise mass removed)

(6) $MC_1AS = ACRFC_1 * DFV * Y$

Where $ACRFC_1$= Average concentration of return flow for $constituent_1$

DFV = Daily flow volume

Y = 365 (days in a year to annualise the mass of the constituent assimilated by the system)

(7) TAC = ACC + AOC

Where ACC = Annual capital cost

AOC = Annual operating cost

(8) ACC = (CCC * TPC) / PLS

Where CCC = Current capital cost per Megalitre capacity – given as R2 million

TPC = Treatment plant capacity (given as 72 Megailtres per day in the case of Darvill

PLS = Predicted life span of the treatment works (specialist input assumed average of 20 years)

(9) AOC = (AOCperV * TPC)

AOCperV = Average operating cost per volume (specialist input assumed average cost of 0.33 million per megalitre/year

(10) $ACRFC_1 = AACIC_1 - AACOC_1$

Where $ACIC_1$ = Annual average concentration of inflow for $constituent_1$

$ACOC_1$ = Annual average concentration of outflow

Both of the above were calculated from annual records for the Darvill treatment works.

Table 9.1 Values and costs used as inputs to the calculation

Values/costs	
Daily Flow Volume for Darvill (Ml/day)	72
Capital Cost (Rm/Ml/day) - current average cost to construct a treatment works per million cubic litres processed per day	R2 million
Operating Cost (Rm/Yr/Ml/day) – current average cost according to expert opinion	R 0.33 million
Gross Capital Cost (Rm)	R 144 million
Annual Capital Cost (Rm) – gross capital cost divided by the operational life of the works	R 19.28 million
Annual Operating Cost (Rm/yr)	R 23.76 million
Total Annual Cost (Rm/yr)	R 43.04 million

Table 9.2 Stages of the calculation developed to determine a removal cost per/Kg for the different constituents

Constituent	Average Concentration Influent (mg/l)	Average Concentration Effluent (mg/l)	Average Concentration Removed (mg/l)	Mass Removed/ Annum (Kgs)	Percentage of Total Annual Costs (Rm)	Removal Cost/Kg (Rm)
COD	500	27	473	12,430,440	26.4	R 0.0000021238
TKN	33	3	30	788,400	1.67	R 0.0000021182
SRP	5	0.8	4.2	110,376	0.23	R 0.0000020838
SS	271	7	264	6,937,920	14.73	R 0.0000021231

Table 9.3 Steps of calculation showing application of removal cost/kg to mass returned to the system to arrive at a value for the total mass assimilated by the system

Constituent	Mass Returned to the System (Kgs/Annum)	Value of Mass Assimilated by System (Rm/yr)
COD	709560	R 1.51
TKN	78840	R 0.17
SRP	21024	R 0.04
SS	183960	R 0.39
Totals	**993384**	**R 2.11**

9.3.2 Assumptions and Limitations for the Evaluation

The above evaluation relies on a number of assumptions and limitations that are required to address the complexities associated with the removal and assimilative processes.

- The capital cost of R2million/Megalitre/day and operating costs of R0.33million/Ml/day/annum are based on expert input from the Umgeni Staff who consider these the current average costs for constructing and operating a wastewater treatment works. As there are variations of treatment works, the capital costs may vary as may the associated management and operating costs.
- The annual average for the flows and concentrations of the constituents are used. In reality these vary with season. Similarly the assimilation and dilution capacity of the system vary, increasing in summer when there is more water in the system and decreasing in winter low flows. It must also be noted that the seasons influence the concentrations of certain organic constituents which increase during the warmer months of the year. In view of the above, water quality guidelines should vary through-out the year in relation to the varying assimilation capacity.

- By focussing the evaluation on key constituents as opposed to the full range of constituents removed, the distribution of costs does not reflect the actual situation.
- In using the 'percentage of the total mass removed' to establish a cost for the different constituents used, it is assumed that the cost to remove a constituent is directly proportional to the mass removed. In reality it is significantly more costly and sometimes impossible to remove the final fraction for certain constituents e.g. ammonia where a limiting lower concentration is experienced. This is important to note because the cost per mass relationship for removing a constituent is multiplied by the mass returned to the system in order to derive the assimilation value for that constituent, and that which is returned may constitute the proportion which can only be broken down by treatment and cost which is un-proportional to the mass which has already been removed by the treatment works. In this case, the assimilative capacity may be significantly undervalued. The would however only prove true where the remaining mass returned to the system proved a threat to certain users.
- The assimilative capacity of a water body for a specific substance depends on whether or not it can be considered conservative, or non-conservative. Conservative substances are not lost through biological transformations or chemical reactions, but accumulate along the length of water body. Strictly speaking, the substance is not assimilated, but is its concentration is reduced through dilution. In contrast, non-conservative substances decay with time due to a variety of biological, chemical and physical reactions as discussed in 9.1. Amounts (loads) of non-conservative substances decrease with time and distance from the point of input. In attributing a value to a mass returned to the river it is assumed that the entire mass can be assimilated.
- Where a large pollution event has occurred in the catchment, a situation may arise where the concentrations of the effluent returned to the river system are lower than those in the river. In such a case the treatment plant is actually providing a service to the system which is a reversal of the situation which is being evaluated in the above process.

9.4 Application of the Results to the Crocodile Catchment

The value of the assimilation capacity of the river (R2.1 million) calculated by applying the model to the Darvill Treatment works equated to approximately 5% of the total annual costs to run the plant (R43 million). The fact that the removal cost/kg of the different constituents did not vary much can be attributed to the simplified approach to establishing this ratio i.e. percentage of the total mass removed. This resulted in the mass assimilated also being 5% of the total mass removed. The Umgeni Scientists were confident that these relationships could be refined significantly with a additional investigation.

In order to get a broad understanding of the potential value of the waste assimilation capacity of the Crocodile catchment, the following calculations were made.

In order to translate the results of the Darvill example to the catchment the following is assumed: For Darvill,

(1) Annual return flow= Daily return flow * 365
= 72Ml * 365
= 26 208 Ml

(2) Cost saving per / = Annual return flow / Annual cost saving
= Ml 26 208 000 / R 2 100 000
= R80 per *megalitre*

The cost saving to the Darvill works is R80 per megalitre returned to the system over on an annual basis.

The total volume of effluent allocated for the 28 permits authorised by the DWAF for the Crocodile catchment is 24 726 Ml/year. To put this in perspective, the Crocodile catchment's largest centre, Nelspruit, is serviced by 3 treatment plants which together have approximate capacity of 18 Megalitres per day. This capacity is significantly smaller when compared to Darvill which has a return flow of 72 Megalitres per day.

Applying the cost savings per megalitre established i.e. R80 per megalitre, the potential savings for the entire catchment would be:
24 726 Ml * R80 = R 1 978 080

In order to keep this result in perspective, the following assumptions and limitations must be considered:

- the same major constituents are removed by the treatment plants in the crocodile catchment as by the Darvill works
- the treatment works operate at a similar efficiency i.e. remove 95% of the total mass throughput
- the same basic processes for removal are employed
- the Crocodile catchment volumes are based on permitted volumes, not actual volumes, which may vary either way
- according to Umgeni Water scientists, sewerage treatment works are 'over-designed' by up to 1.5 times the probable capacity to ensure that they are able to meet standards and to allow for additional development in a catchment over the plants lifetime. Sewerage treatment plants are therefore effective in removing the majority of the effluent throughput. Of the 28 permit holders from which the Crocodile catchment annual volume was calculated, several produce industrial effluent. The treatment process required for such effluent may not be as effective in reducing the concentrations returned to the river.

In conclusion, confidence in the estimated value of the assimilation capacity of the Crocodile catchment can not be considered high due to a number of major assumptions, made due to a lack of data and difficulties in obtaining other information. The results do however provide an order of magnitude figure and the model provides the basis for further development and refinement. What must be considered, is that although the total financial savings to industry do not appear that high in a catchment context, the R2 million does not take into account the costs to users associated with disease which may result from that effluent which returned to the system and which exceeds the assimilation capacity of the river.

10 CONTROL OF PESTS AND PATHOGENS

10.1 INTRODUCTION

Aquatic environments host water-borne and water-associated pests and pathogens, which can cause disease. Abiotic factors are influencing the distribution of these pests and pathogens. For example, suitability of habitat for Bilharzia intermediate host snails is a function of water temperature and substrate type and composition. More water in the River will result in a higher velocity, which will lead to a potential decrease in suitable habitat for hosting the snails.

A study was done on the Gladdespruit stream, 1620 m above sea level on the edge of the highveld plateau and flows to its confluence with the Crocodile River at 655m (2 km northwest of Nelspruit). This 40 km perennial stream flows from a non-endemic bilharzias area to one of high endemicity (Appleton, 1975). A discussion follows on influencing factors occurring from this study.

- Geology and the distribution of Mollusca

Most Mollusca species occur in the granite zone (900m to 655m). This zone is exposed buy stream action, from the 900m altitude which form the bed of the Gladdespruit for the remainder of its flow to the Crocodile River. Eroded and exposed granite contains pools (which are blocked with reeds and sedges), backwaters, potholes and a calmer habitat. Riverine trees shade the stream and aquatic plants are common.

Bilharzia intermediate host snails occurred in detached and semi-detached pools and backwaters from an altitude of 823m to 655m. An absence of distribution occurs in the heavily shaded areas and faster current flows (faster than approximately 0.3m/s).

Weirs built in the stream created artificial lentic (standing or calm) habitats, which extended the distribution of snails beyond the normally calm lowers reaches into upstream zones.

- *Current speed*

Host snails are only tolerant with stream velocities of 0.3m/s or less.

10.2 DATA COLLECTION

10.2.1 Data collection method

The scope of the project did not allow for the primary collection of health care data. This survey therefore made use of expert opinion, key informant interviews and information from other studies covering issues such as:

- Most prevalent waterborne diseases in the Crocodile Catchment
- Incidence rates of infections
- Treatment costs

While data was available for infection rates of the two most prevalent diseases (Bilharzia and diarrhoea), valuing the cost of these infections was difficult. A method had been developed in a study to assess the cost of diarrhoea in KwaZulu-Natal and South Africa (Pegram *et al.* 1998). This study used the following criteria in the evaluation of moderate infections of diarrhoea (obtained from Table 7: Productivity, health services and transport costs at different levels of morbidity severity).

Description	Estimated cost
Cost of lost productivity of adult patients	R30/day
Cost of lost productivity of adult care givers	R15/day
Health practitioner and clinic costs	R20/visit
Hospital out-patients	R180/visit
General ward (clinic or hospital)	R375/day
Diarrhoea medicine: health care Self treatment	R50/incident R20/incident
Local transport	R8/trip
Hospital transport	R20/trip

While this model provided a basic framework for the calculation for the cost of bilharzia and diarrhoea in the Crocodile Catchment, it was not directly applied due to a limitation in collecting inputs factors, ie:

- Limitation in demographic and health care data which made it difficult to calculate the incidence of diarrhoea among the adult population in the Crocodile Catchment.
- The number of patients visiting hospitals infected with bilharzia or diarrhoea was not available.

In the case of diarrhoea, infections tend to be acute, ie. manifest and then clear up. However in the case of bilharzia, infections tend to be chronic, with many infected people not going for treatment at all, but rather suffering continuously with lower productivity and poorer health. Furthermore, even if the patient does receive treatment they could become re-infected by coming into contact with the parasite in infected water. Bilharzia is reported to be particularly prevalent among children, who tend to play and swim in rivers. Infection rates tend to be lower among adults. These factors therefore make the valuation of the cost of bilharzias infections particularly difficult. In the case of bilharzia it was reported that few infected people are believed to receive treatment.

Low confidence was placed in the results of estimating the value of lost productivity (both of the patient and care-giver) or the cost of hospital treatment for either bilharzia or diarrhoea. Using basic information that was available on infection rates, it was however possible to estimate the following costs:

- Potential cost of medication
- Potential cost of health care (clinic) treatment
- Potential transport costs

10.2.2 Survey area

In terms of health issues the Crocodile Catchment can be divided into two primary areas, viz. the highlands (western catchment) and the low-lying lowveld areas to the east.

The most prevalent waterborne diseases that were reported were:

- Bilharzia
- Diarrhoea

Less common diseases included typhoid, dysentery, and outbreaks of cholera had been recently reported. While diarrhoea was widely reported throughout the catchment, the incidence of waterborne diseases was notably higher in the lowveld area, particularly bilharzia, which was seldom reported in the highland areas.

10.2.3 Target group

Water borne diseases such as diarrhoea, dysentery and bilharzia are prevalent primarily in areas where people do not have access to clean and safe drinking water. Within the Crocodile Catchment these areas are mainly the former homeland areas within the lowveld areas in the east of the Catchment. Data collection and calculations of costs therefore focussed on the rural communities living within these areas.

10.2.4 Limitations

- While a number of studies are currently being undertaken on infection rates and social costs of these diseases with Mpumalanga, there has been very little output from the research to date, and there is currently very little data available to use in this study other than infection rates, e.g. there is little break down in data in terms of infection rates within different age groups particularly adults.
- Limited census data was available for the Crocodile Catchment area, as it is not a census district on its own. Estimates therefore had to be made on population size of different race groups within the catchment, which were then used to estimate the number of people potentially infected by the different waterborne diseases. The accuracy of these estimates is therefore limited by the accuracy of the assumed growth rates from the dates of the census. Furthermore, bilharzia is primarily prevalent among children who play in rivers and is not as prevalent among the adult population. However prevalence data was only expressed as a percentage for different regions of the province and not with breakdowns among age groups within these regions. In addition the census data accessed did not have age category breakdowns. The accuracy of assumed infection rates was therefore affected by these limitations and resulting generalizations.
- Limited information was available only for bilharzia and diarrhoea, it was difficult to find information on infection rates of typhoid and cholera within the Crocodile Catchment. The potential costs of these diseases were therefore omitted from these calculations.

10.3 EVALUATION

10.3.1 *Approach to the equation (formula)*

The costs of bilharzia and diarrhoea were calculated separately, based on estimates of costs of treatment, transport, health care costs and incidence levels. The cost of bilharzia was calculated using the following formula:

(1) $TB = (Tc + t + HC) \times (P \times \% I)$

Where,
TB = Total costs of treating bilharzia
P = Rural population in Crocodile Catchment
%I = Estimated infection rate for bilharzia
Tc = Treatment costs
t = Transport costs (to clinic)
HC = Health practitioner and clinic costs

The same formula was used for calculating the estimated cost of treating diarrhoea

(2) $TD = (Td + t + HC) \times (P \times \% I)$

Where,
TD = total cost of treating diarrhoea
Td = treatment costs of diarrhoea
P = Rural population in Crocodile Catchment
%I = Estimated infection rate for diarrhoea
Tc = Treatment costs
t = Transport costs (to clinic)
HC = Health practitioner and clinic costs

10.3.2 *Assumptions*

- Infection rates

Bilharzia and diarrhoea mainly affect communities without access to clean and safe drinking water and sanitation services, however rates vary:

(1) Diarrhoea infection rates are particularly high among communities who have no access to treated water supply.
(2) Diarrhoea rates are lower among those with access to RDP water supply or sanitation infrastructure.
(3) Diarrhoea is still prevalent among those with a reliable supply of water directly to the house and with on-site water borne sewerage or septic tanks.

These conditions largely characterise the black rural population across the Crocodile Catchment. It was therefore assumed that the average incidence of diarrhoea in South Africa (57%) could be applied to the Crocodile Catchment, and that as in the national average, 12% of these infections would also require treatment. It was assumed that the range of habitat types and socio-economic conditions across the Catchment were representative of the Mpumalanga Province in general, and the prevalence data for bilharzia in Mpumalanga was therefore averaged (31%) and applied to the Catchment.

- Treatment costs

In the case of diarrhoea, it was assumed that the medication costs (R20 for self treatment of a moderate infection) reported in the Pegram *et al.* report (1998) would still be relevant although potentially an underestimation of cost. Medication costs for bilharzia would vary according to body weight, and would therefore be quite different between adults and children, however it was assumed that R20 per treatment represents average cost.

- Relationship between water quality / quantity and diarrhoea

The link between the water quantity and quality in rivers and the prevalence of diarrhoea is not a widely investigated or understood relationship. There are a wide range of factors that affect the prevalence of diarrhoea. The three primarily factors contributing to infection are;

- Sanitation (Sewerage or septic tanks, washing of hands when handling water etc.)
- Water storage (Containers used, time frame of storage, etc.)
- Water quality (Infected water with pest and pathogens)

Households for example, can have access to infected water but by purifying it they may not necessarily be infected with diarrhoea. On the other hand, households might have access to clean and good quality water, but by storing it incorrectly they might become infected. Due to these influences, it has been difficult for researchers to isolate the effect the quality and quantity of water in the rivers has on the incidence of diarrhoea within a community dependent of river water for household use (Archer *pers comm. 2001).* For the purpose of this study it was assumed that there is a direct relationship, although it is only one of the three contributing factors.

10.3.3 *Inputs used in calculations*

- Estimate of size of rural black population in Crocodile Catchment

Census data, from 1991, on the size of the black population living in the Crocodile Catchment was available from a report on the water quality and management in the Crocodile Catchment produced by the Department of Water Affairs and Forestry (DWAF1995). This data was extrapolated using the reported growth rate, to obtain an estimate of the size of the rural black population in the Crocodile Catchment in 2001 (Appendix 2).

- Infection rates

Infection rates for bilharzia were obtained from a parasite prevalence survey in Mpumalanga Province, undertaken by the Mpumalanga Department of Health (Mngomezulu, N. Govere, J. and Durrheim, D.). Diarrhoea rates for Mpumalanga were extrapolated from a study that estimated costs of diarrhoea in KwaZulu-Natal and South Africa (Pegram, G., Rollins, N. and Espey, Q. 1998)

- Treatment costs

The cost of medicines for treating bilharzia was obtained from a contract price that a pharmaceutical company (Bayer) had secured a government contract on for supplying Bitricide to local health departments. This cost varies for disages for adults and children but was averaged at R20. The medicine costs for diarrhoea were obtained from the study by Pegram *et al.* (1998) which was given as R20. The costs of health practitioners (who would be consulted by patients at clinics) who would administer the medication was R20, and was also taken from the study by Pegram *et al.* (1998).

- Transport costs

The average cost of public transport, eg taxis, was obtained from reports obtained during questioning on the consumptive use of aquatic resources survey (R10). The average was taken for all costs reported by households on accessing public transport to the clinic for treatment.

10.4 RESULTS

10.4.1 Cost of treating bilharzia

DESCRIPTION	VALUE
Size of rural population with poor access to clean drinking water and sanitation services	356 086
Average Bilharzia infection rate	31%
Number of population infected	110 387
Cost of medicine	R20/infection
Cost of medicines to treat all infected people	R2 207 734.68
Cost of transport	R10/trip
Total cost of transport for all infected people to reach clinics	R 1 103 867.34
Cost of health practitioners services	R20/infection
Total cost of health practitioners' services to treat infected patients at clinics	R2 207 734.68
Estimated potential cost of treating bilharzia	**R5 519 336.69**

The cost of R5 519 336.69 is not an estimate of current treatment costs, but rather an estimate of what it would potentially cost to treat all infected individuals in the Catchment in a bilharzia control programme.

10.4.2 Potential loss of productivity

Treatment costs represent only a part of the cost of diseases such as bilharzia. The debilitating effects of the diseases also result in a loss of productivity which result in a social cost to the households. A scenario is therefore also developed, to estimate the cost of lost productivity, using results obtained in a review that was done on the evidence of household water resources and rural productivity in Sub-Saharan Africa (Development Discussion Paper No 673, February 1999, Harvard University). An average of the time lost in productivity was derived from the results of studies undertaken five locations (two sugar estates in Sudan, Tanzania and Ghana). These studies indicate that on average four healthy workdays are lost/capita/year due to water-based diseases - *Schistosomiasis* (Bilharzia). By assuming a comparable situation for the rural population within the catchment, the loss of productivity is costed as follows:

Scenario for the lost of productivity

DESCRIPTION	VALUE
Size of rural population with poor access to clean drinking water and sanitation services	356 086
Average Bilharzia infection rate	31%
Number of population infected	110 387
Average life days lost per year	4
Potential lost of income per day[1]	R25
Potential cost of lost productivity per year	**R11 038 700.00**

10.4.3 Cost of treating diarrhoea

DESCRIPTION	VALUE
Size of rural population with poor access to clean drinking water and sanitation services	356 086
Diarrhoea infection rate	57%
Number infected	202 969
Percentage of those infected requiring treatment	12%
Number of infected population requiring treatment	24 356
Cost of medicine	R20/infection
Cost of medicines to treat all infected people	R487 125
Cost of transport	R10/trip
Total cost of transport for all infected people to reach clinics	R243 562.99
Cost of health practitioners services	R20/infection
Total cost of health practitioners' services to treat infected patients at clinics	R 487 125.97
Estimated potential cost of treating diarrhoea	**R1 217 814.93**

The cost of R1 217 814.93 is an estimate of what it potentially costs to treat individuals with diarrhoea in the Catchment per annum.

10.4.4 Potential loss of productivity

As with bilharzia, treatment costs represent only a part of the cost of diarrhoea. The debilitating effects of the diseases also result in a loss of productivity which result in a social cost to the households. Again a scenario was developed to estimate the cost of lost productivity using results obtained in a review that was done on the evidence of household water resources and rural productivity in Sub-Saharan Africa (Development Discussion Paper No 673, February 1999, Harvard University). The results from this study indicate that 0.97 healthy workdays are lost/capita/year due to severe diarrhoea in Ghana. By assuming the same situation for the rural population within the catchment, a lost of productivity is costed as follows:

[1] Assuming an average value of R25 per day for unskilled labour in rural areas.

Scenario for the lost of productivity

DESCRIPTION:	VALUE
Size of rural population with poor access to clean drinking water and sanitation services	356 086
Diarrhoea infection rate	57%
Number infected	202 969
Percentage of those infected requiring treatment	12%
Number of infected population requiring treatment	24 356
Average life days lost per year	0.97
Potential lost of income per day[2]	R25
Potential cost of lost productivity per year	**R4 921 998.25**

10.5 DISCUSSION

10.5.1 Bilharzia

The estimated cost of treating bilharzia in the Crocodile Catchment represents only the costs of medication, health care practitioners and transport costs of getting patients to clinics. It does not reflect the social and economic costs of decreased productivity of patents or caregivers. This lost productivity would be experienced, for example, in terms of less labour hours spent working in fields, collecting firewood and water, or preparing meals. The lost productivity would therefore not necessarily be felt as a loss of income to the household but rather as a decrease in well being or social welfare. Additional potential costs that have been raised by researchers (Kvarlsvig *pers comm.* 2001) include the debilitating effects the disease has on children, for example their lower energy and concentration levels which impact significantly on their ability to attend and perform at school. While there is not information or research to support this theory, researchers are suggesting that bilharzia could potentially be affecting failure rates of children at school.

Furthermore, relatively few infected individuals actually seek treatment for the disease, and instead live with the debilitating side effects e.g. low energy levels and reduced mental and physical. In addition due to the nature of transmission of the disease (ie water borne) many people could receive treatment and become re-infected again, unless the source of the infections (ie bilharzia parasite host snails in the water systems) are simultaneously destroyed. The estimated value provided in this study is therefore believed to be a basic cost of what a programme to attempt to significantly reduce the infection and associated debilitating effects would be in the Crocodile Catchment.

10.5.2 Diarrhoea

As with bilharzia, it is believed that the calculation of the cost of diarrhoea is an underestimation of the social cost as it does not include the social and economic costs of decreased productivity of patient and caregiver. It is also potentially and over-simplification of the treatment costs as it is based on averaged medication and health practitioner costs only and does not include costs hospitalisation etc. However it is believed that the estimate does provide an indication of what costs are being incurred by both the state and rural households given the prevalence of the disease.

[2] Assuming an average value of R25 per day for unskilled labour in rural areas

10.5.3 Other water borne diseases

No estimations were made of the of other waterborne diseases such as typhoid and cholera. Therefore the estimates calculated for bilharzia and diarrhoea could represent the minimum costs potentially incurred as a result of water quality in the Catchment, and could increase significantly when a full costs are calculated for the range of water borne diseases prevalent in the Catchment.

11 SUMMARY OF VALUES

A summary of values are provided in Table11 to illustrate the range and size of impacts of the Crocodile River ecosystem on household and regional economy. This illustrates the 'orders of magnitude' value of the water that currently remains within the river. Importantly this excludes the value of water abstracted from the river.

While the benefits of the services supplied by the river are self-explanatory in terms of maintaining an environmental reserve, the costs require some discussion. Flooding control and pest control are measured as costs as the river generates significant dis-benefits. However, the environmental reserve can play a significant role in reducing these dis-benefits. Greater water flow volumes and improved water quality may have a significant impact in reducing the potential habitat for pathogens, thereby generating a cost savings. Similarly, the impact of flooding may be reduced by a well functioning river ecosystem that relies on an environmental reserve.

Some of the values have not been calculated as most of the effort has been directed at developing approaches to make estimates. These methods will need to be tested in future research.

The values and costs associated with the Crocodile river show that the volume of water in the river has significant implications to broader society, especially to households and disadvantaged groups.

Table 11 : Summary of benefits and costs associated with the Crocodile River

Services supplied by the Crocodile River	**Benefits of services supplied**	**Costs associated with the Crocodile river**
Fish consumed by black rural households	R10.2 million per annum in cost savings	
Total expenditure on recreation activities associated with the river	R75.7 million expenditure per annum	
Flood regulation	Cost savings of flood management not calculated	R100 million damage through flooding in 2000
Maintenance of river banks	Cost savings not calculated	
Sediment trapping	Negligible value in this catchment	
Revenue generated by aquaculture activities	R10.7 million per annum in gross turn-over	
Exports to marine ecosystems	Contributes to a R25 million per annum prawn fishery in Mozambique	
Tourism value of Crocodile river and tributaries in KNP	R19 million per annum in on-site and off-site expenditure	
Industrial and municipal waste treatment by the Crocodile catchment	Cost savings of R2 million per annum to municipalities and industry Benefits of clean water to consumers not estimated	
Control of pests and pathogens – particularly bilharzia	Cost saving associated with greater flows not estimated	R5.5 million costs associated with treatment R11 million costs in terms of lost productivity to households

APPENDIX 1: CONSUMPTIVE USE QUESTOINNAIRE

FISH HARVESTING SURVEY SHEET

RESOURCE DESCRIPTION . . . QUESTIONNAIRE NO.: . .
LOCALITY District: . . . GPS READING . .
Village . . .
INTERVIEWEE NAME . . .

1.When do you fish
(a) time of the year
(b) any special conditions

2.What fishing equipment do you use?

3.What did you pay for the equipment?

4.If you made these things how much time did it take?

5.How often do you replace your equipment?

6.Who in your family catches fish?

7.How many fish does a person catch in peak fishing season?

FISH TYPE	FREQUENCY CAUGHT	NUMBER CAUGHT	AVERAGE SIZE / WEIGHT	SEASON

1.Time spent fishing

	NO. PEOPLE	NO. DAYS / WEEK	NO. HOURS / DAY
PEAK SEASON			
OFF SEASON			

1.How far do you travel to catch fish (most used sites)?
(1) (2) (3)

2.Where do you catch your fish? [river] [dams] [estuaries]

3.What proportion of your catch did you sell last year? . . .
To whom do you sell the fish? . . . . .
4.What is the price of the fish you sell? per kg . . . or per fish .
5.How often did you buy fish . . . .
How much do you normally buy? . . . . .
6. How much do you pay for the fish you buy? per kg . . . or per fish

APPENDIX 1 (Continue)

RESOURCE HARVESTING SURVEY SHEET

RESOURCE DESCRIPTION . . QUESTIONNAIRE NO.: . .
LOCALITY District: . . GPS READING . .
Village . . .
INTERVIEWEE NAME . . .

1. *FREQUENCY HARVESTED*

When is it usually harvested in the year (list months)? . . . . .
How often do you harvest the resource? [ ] times per [ ]
Are there times when you may harvest more or less?
More harvested . . . .
Less harvested . . . .

2. *QUANTITIES HARVESTED*

How much do you collect each time you harvest? Number of units [ ]
Mass/unit[ ]
If your harvesting changes, how much do you harvest for these periods?
More harvested . . . .
Less harvested . . . .

3. *LOCATION HARVESTED*

Where do you harvest the resource?. . . . . . .
How far do you travel? . . . . (km)
How long does it take to harvest? . . . . (time)
How much do you pay for transport per trip?. . . (Rands)

4. *VALUE*

Who uses the resource [yourself] or [sell it] or [both]?
What do you use it for? . . . .
Are there other resources or products you can use for this purpose instead?
If there are, what are they? (1) . (2) . . (3) . .
Where do you get them? (1) . (2) . . (3) . .
How much do they cost? (1) . (2) . (3) . .
When selling as a raw material – what units do you sell it in (eg bundle, /kg) .
At what price per unit? . . . .
How much of your harvest do you sell ? [. %]
Do you process the material before selling it? . . . . .
What do you make? . . . .
How long does it take to make . . . .
How much do you sell it for? . . . .
Did you buy this resource last year – how much did you buy . . .
For what price? R............/....................
Where did you buy it from? . . . .

APPENDIX 2: POPULATION ESTIMATES

Population data
Population estimate for the black rural populations in the Crocodile Catchment in 1991 was 278 174 (DWAF 1995). A population growth rate of 2.5% was used to provide an estimate of the population size in 2001 as follows:

Year	Estimated population	Estimated growth in population at a rate of 2.46%
1991	278,174	6,843
1992	285,017	7,011
1993	292,029	7,184
1994	299,212	7,361
1995	306,573	7,542
1996	314,115	7,727
1997	321,842	7,917
1998	329,759	8,112
1999	337,871	8,312
2000	346,183	8,516
2001	354,699	

APPENDIX 3: FISHING CLUBS AND LICENCES

Fishing clubs

Club (highlands)	Members	Questionnaires sent
Dullstroom Flyfishers	450	Yes
Machadodorp Flyfishing Club	208	yes
Nelspruit Angling Club	124	yes
Mondi Forests Trout Angling Club	100	yes
Ngodwana (Elands River)	70	no
Belfast Flyfishing Association	650	yes
	1602	
(Lowveld)		
Crocodile Valley Fishing Club	15	no
SAW (defence force)	24	no
ITSG	45	no
Total	1686	no

Fishing licences

Population Mpumalanga (2001) = 3122 644
at 2.2% annual increase per year (Statistics South Africa – user enquiries).

Population census 1996 = 2 800 711
1997 = 2 862 326
1998 = 2 925 297
1999 = 2 989 653
2000 = 3 055 425
2001 = 3 122 644

Crocodile River Catchment (CRC) population = ±20.4% of Mpumalanga's population. (1991 census – Department of Water Affairs and Forestry.)

$= 3\ 122\ 644 \times 20.4\% = 637\ 019$

$$\frac{637\ 019}{3\ 122\ 644} \times \frac{100}{1} = 20.4\%$$

CRC Fishing Licences

Fishing Licenses issued in Mpumalanga = R 250 000 @ R20/license = 12 500 licences
(Mpumalanga Parks Board – J.S. Engelbrecht)

12 500 × 20.4% = 2550 licences

APPENDIX 4: RECREATIONAL USE QUESTOINNAIRE

FISHING SURVEY

Institute of Natural Resources

NAME. . . . . CONTACT TELEPHONE NUMBER. . . .
ADDRESS . . . .

Cost of equipment

Value of Rod (1). . . . .Replacement frequency (years). . .
(2). . . . .Replacement frequency (years). . .
(3). . . . .Replacement frequency (years). . .

Line (estimated total value). . . .Replacement frequency (years). . .

Hooks/flies/etc(estimated total value) . .Replacement frequency (years). . .

Boats. . . . . . Replacement frequency (years). . .

Boat motors. . . . . Replacement frequency (years). . .

Floatation tubes (list) . . . Replacement frequency (years). . .

Other equipment (1). . . Replacement frequency (years). . .
(2). . . Replacement frequency (years). . .
(3) Replacement frequency (years)

Cost of fishing expeditions

Frequency of trips: Most trips per year. . . . .
Fewest trips per year. . . . .

Accommodation (either your individual cost or cost of family if they all accompany you)
(a) Individual costs (Most spent per trip). . . . .
(Least spent per trip). . . . .
(b) Family (Most spent per trip). . . . .
(Least spent per trip). . . . .

Transport costs (petrol etc) (Highest). . . (Least). . . .

Cost of fish caught (per kg) (Most paid). . . . .
(Least paid). . . . .
(Average per trip) . . . . . .
Additional costs eg food etc (list average per trip) . . . . .
Other water sprot activities undertaken while on fishing expeditions
(1). . . . . . . Cost. . . . .
(2). . . . . . . Cost. . . . .

Cost of fishing licences per year. . . . .

Cost of membership to associations / clubs per year
(1) Name of association. . . . Membership cost . . .
(2) Name of association. . . . Membership cost . . .
(3) Name of association. . . . Membership cost . . .

Places most often fished
(1) . . . .
(2) . . . .
(3) . . . .

APPENDIX 5: RECREATIONAL USE QUESTOINNAIRE
RECREATIONAL VALUE OF FISHING AND WATER BASED ACTIVITIES

Name of Operation : ....
Owner : .... **contact no :** ....
Manager : .... **contact no :** ....
Address : ....
....
....

1. Description of water based **enterprises**,
(ie. Which of your enterprises directly or indirectly depend on water based activities eg. Accommodatio
....
....
....

2. **Infrastructure** (eg. number of chalets etc)

Main Lodge (please state whether these are contained within the main lodge or are separate buildings.)

Yes/No

Restaurant ....

Bar..

Conference centre..

Other..

Guest Accommodation

Self Catering units (please specify the number and capacity of each)

Number (of units)	Sleeps (number of people)	cost pp per night
....	....	....
....	....	....
....	....	....

Non self catering units (please specify the number and capacity of each)

Number (of units)	Sleeps (number of people)	cost pp per night
....	....	....
....	....	....

Q2. Continued....

Staff Accommodation (housing and capacity)

....

....

....

Other (Yes/No)

Stables..

Boma...

Tennis Courts..

Other (specify)..

Dams & Weirs

Number of Dams...

Size	Cost of Development	Cost of Maintenance
....	....	....
....	....	....
....	....	....

Number of Weirs...

Size	Cost of Development	Cost of Maintenance
....	....	....
....	....	....

Total value of enterprise infrastructure, (the individual values can be written next to infrastructure listed above)

....

....

Annual turnover per annum

....

3. Guest

Occupancy rates

Occupancy	Empty	25%	50%	75%	Full
Months per Annum	....	....	....	....	....

Local vs foreign guest ratio..

4. You provide employment and generate an income for

Skilled employees

Number...

% of Wage bill..

Unskilled employees

Number...

% of wage bill...

Total wage bill..

5. Water based activities (please list)

Description of associated water-based **activities**, (eg. Fishing, rafting etc)	% of total turnover generated through water based activity
....	....
....	....
....	....
....	....
....	....

Fishing & Restocking

Fish species (golden, brown, bass etc.)	Stocked (annually, monthly)	Cost of restocking (at that rate)
....	....	....
....	....	....
....	....	....
....	....	....

Fish Caught

Value of fish caught per year / month ....

Income received from fish caught per year / month...

What percentage of the value of fish caught is recovered......................................

6. Non-water based activities offered to guests

Activity	Income generated	Is the support for this activity dependant on water based activies. (Yes/No)
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

7. Are there any other resorts/lodges in your area?..

APPENDIX 6: STAFF EMPLOYED: WATERBASED LODGES

Number of employees and Wage bills

REC NO	Skilled	% of Wage Bill	*subtotal wage bill*	Unskilled	% of Wage Bill	*Subtotal wage bill*	**Total wage bill (PA)**
1	2	40	20000.00	5	60	30000.00	50,000.00
2	4	80	57600.00	1	20	14400.00	72,000.00
3	2	75	0.00	2	25	0.00	0.00
5	0	0	0.00	6	0	40000.00	40,000.00
6	5	70	0.00	3	30	0.00	0.00
7	0	0	0.00	0	0	0.00	48,000.00
8	0	0	0.00	2	0	12000.00	18,000.00
9	0	0	0.00	6	0	36000.00	360,000.00
10	15	25	450000.00	34	75	1350000.00	1,800,000.00
11	2	55	4950.00	5	45	4050.00	9,000.00
12	0	0	0.00	0	0	0.00	0.00
13	2	75	0.00	0	0	0.00	0.00
14	2	50	0.00	0	0	0.00	0.00
TOTAL	34			64			

APPENDIX 7: RETAIL OUTLETS QUESTIONNAIRE

Retail Value of Fishing Equipment

Name (Retail) :...
Manager/Owner:...................................... **Contact number**: ....
Address :...
....

1. Your monthly/annual turnover

....

2. Staff

- Number of employees...

Skills Levels	No. of Staff	Estimated Wage Bills
....	....	....
....	....	....
....	....	....

- Total Wage Bill ....

3. The ratio of imported as apposed to locally produced goods

	% of stock	Value
Local:	....	....
Imported:	....	....

4. Foreign vs local customer ratio...

1. Value of Infrastructure

- What is the value of your Infrastructure ....
- Is the premises owned/ rented by you...
- If rented what is your monthly rental...

APPENDIX 8 : AQUACULTURE QUESTIONNAIRE

VALUE OF FISH PRODUCTION/AQUACULTURE

Name:...................................... Enterprise Name ....

Telephone Number ....

Location (district): ....Inside Crocodile catchment? ....

1. Production

Species (Golden, Brown etc.)	No. Produced annually	Value
....	....	....
....	....	....
....	....	....

Market	Number	Value	% bus. inside catchment
Table (restaurant)	....	....	....
Lodges (stocking)	....	....	....

2. Staff

Number of employees and skills level	estimated wage bill
....	....
....	....
....	....

3. Additional / complementary enterprises (eg trout lodge)

Description	Annual Turnover
....	....
....	....

4. Production trends? Eg medium term (5 years) long term (10 years)

....

5. Motivation for location of hatchery

(eg. access to conducive water conditions,access to markets for trout)

....

....

6. What volume of water do you require (eg m^3/day) for the hatchery to operate

....

7. Do you purify the water in any way?

Before entering hatchery? *Yes/No* How? .... Cost? ....

Before re-entering river? *Yes/No* How? .... Cost? ....

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Assessing the ecological relevance of a spatially-nested geomorphological hierarchy for river management

JM King & DM Schael

The research focused on a site in each of 28 headwater streams in the Western Cape. These were all in the mountain and foothill zones of perennial rivers, in order to standardise study sites as much as possible. Sites were designated "mountain" or "foothill" based on prior biological knowledge of which they were likely to be. All fieldwork was done during summer low flows, when flow and other physical conditions are most stable and the rivers most comparable in hydraulic terms. Eighteen of the rivers had minimal disturbance, and were used to detect underlying trends in physical-biotic links. The remaining ten had specific disturbances, and were used to assess how disturbance affected the trends.

At each of the sites, up to 12 biological samples were collected from the widest possible range of physical conditions, and these conditions were measured in detail. The sites, which ranged from 30-100 m in length, were mapped using eight categories of substrata and 14 categories of flow type, and the location of every biological sample shown (Tables E1 and E2). Aquatic invertebrates were used to provide the biological input to the study, as different species are known to seek different kinds of flow or substrata and by this selectivity should illustrate clear physical-biotic links.

The sampling programme as a whole was designed to assess the ecological relevance of all levels of the hierarchy.

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