# AN ACTION PLAN FOR WATER QUALITY RESEARCH AND TECHNOLOGY TRANSFER IN THE RIVERS FLOWING THROUGH THE KRUGER NATIONAL PARK

HJ Smith • AJ van Zyl • H Bouwman

WRC Report No 988/1/00

Water Research Commission

# An Action Plan for Water Quality Research and Technology Transfer in the Rivers Flowing Through the Kruger National Park

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Report to the Water Research Commission

by the

Institute for Soil, Climate and Water

and the

Plant Protection Research Institute

of the

Agricultural Research Council

**WRC Report No 988/1/00**

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AN ACTION PLAN FOR WATER QUALITY RESEARCH AND TECHNOLOGY TRANSFER IN THE RIVERS FLOWING THROUGH THE KRUGER PARK

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Report by the Agricultural Research Council to the Centre for Water in the Environment, University of the Witwatersrand, on the Water Research Commission Project

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# EXECUTIVE SUMMARY

## 1. BACKGROUND AND MOTIVATION

The sub-programme of the Kruger National Park River Research Programme (KNPRRP) on research has identified two priority research and technology transfer needs for the remainder of Phase III of the programme. One of these is to generate an explicit thrust to improve our understanding of water quality issues in the catchments of perennial rivers of the Kruger National Park (KNP) and to transfer existing knowledge on water quality to catchment fora. The strategy of the Kruger National Park Rivers Research Programme and Park management to engage other parties in the catchment in explicit Integrated Catchment Management (ICM) requires that there is a solid grasp of what the issues are, what can be done with existing information and where future research should focus.

Despite the fact that there are many pressing water quality problems in the perennial rivers flowing through the Kruger National Park, the KNPRRP has not effectively engaged water quality issues. However, the extension of the programme to include other rivers and the upper catchments opened the door for renewed thrust.

The **objectives** of the project were as follows:

- Review the existing knowledge of current water quality issues of the perennial rivers flowing through the KNP, and the available technology for dealing with water quality issues.
- Compile an annotated list of the main interested and affected parties and their information and management needs.
- Develop a strategy for effective transfer of existing knowledge and technology on water quality for managing the rivers of the KNP.
- Develop a strategy by which the KNPRRP can effectively contribute to the enhancement of the knowledge base and its application on water quality issues in the rivers.

## 2. A STRATEGY FOR THE EFFECTIVE TRANSFER OF KNOWLEDGE AND TECHNOLOGY IN THE KNPRRP

Links between research institutions and their clients (water users, land users, research managers, catchment management forums, policy makers, etc.) are vital for successful technology development and delivery. A number of initiatives were recently launched in South Africa, which provide an 'enabling environment' wherein these essential links could be established. These initiatives are Integrated Catchment Management (ICM) of the Department of Water Affairs and Forestry, the Landcare Programme of the National Department of Agriculture, and the Integrated Environmental Management (IEM) of the Department of Environmental Affairs and Tourism.

A multi-level (hierarchical) stakeholder approach holds promise to serve as a framework for technology transfer and to serve as a platform from which to launch current and future research and decision support products on water quality. A proposed multi–level stakeholder framework for application in water quality management and based on the framework for Landcare, is shown in **Figure 2.1.** The components of this framework are *The Top-Down Leg* and *The Bottom-Up Leg*, which are the most prominently integrated on the *Catchment* level.

Government, national- and international research organisations usually take a lead role in the 'top-down' approach. In response to the failures of applying only a top-down approach, the development process in general has literally been turned upside down by using a bottom-up approach in addition to a top-down leg during the last decade. The key aspect to this approach has been to place people at the centre of their own development.

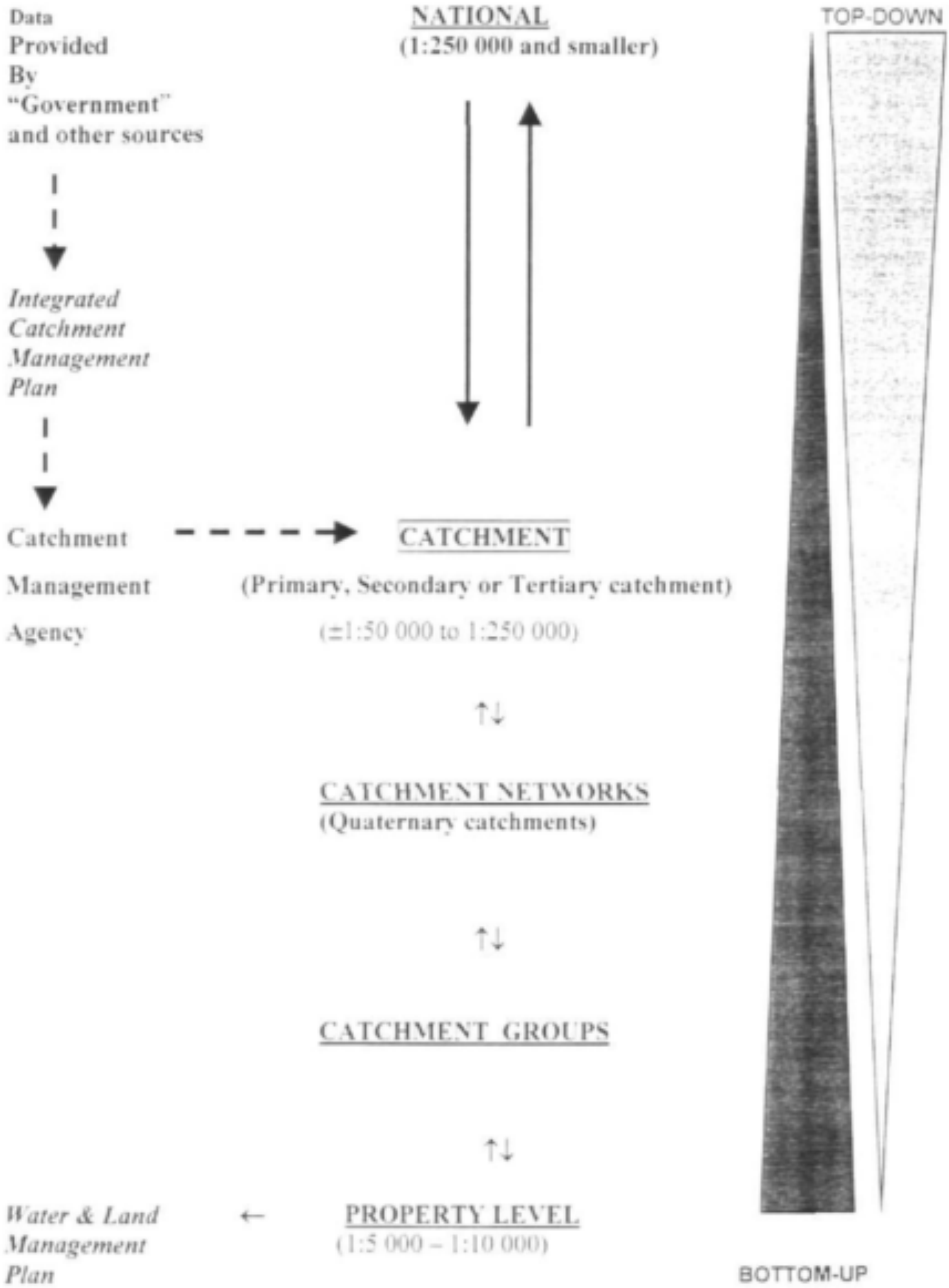


Figure 2.1. Multi-level stakeholder framework.

The bottom-up leg represents the individual stakeholders (water and land managers or users), the stakeholder groups and the stakeholder networks. It accommodates the will, wishes, and wants of the people and indicates that the key to sustainable water and land management lies with the people.

The main initiative at the *catchment* (primary, secondary and tertiary) level, is the development of a strategic *or* integrated catchment management plan, which is usually done on a 1:50 000 to 1:250 000 scale. **This is the level where the integration of the top-down and bottom-up legs is the most prominent and forms an important link between the technology development and technology transfer activities.**

Water resource modelling is one technology fundamental to the concept of integrated catchment management. Together with the goals of water resource modelling, the process of horizontal integration will be appropriate in terms of broadening participation (Dent, 1996). The process of horizontal integration would help to extend and strengthen the processes of technology development and transfer within the multi-level stakeholder framework (MLSF).

**The new approach to sustainable and integrated water and land resources planning and management which includes the multi-level stakeholder framework, stresses three things: Information, involvement and joint decision making by all stakeholders.** When people are informed and involved, they are halfway to being satisfied. When they participate in decision-making, they are three quarters of the way to being satisfied. When they understand that they have negotiated the best result possible, they are almost always satisfied. When they are part of a development partnership, they are usually enthusiastic and more than satisfied (FAO, 1996).

Therefore, the key to the successful transfer of technology lies in an effective link between the bottom-up and top-down processes. The mechanisms of integration, communication and participation, which form the effective links between the various dimensions of the multi-level stakeholder framework, are consequently seen as essential building blocks for technology transfer.

The idea that a system perceived as 'hard' (such as water resource modelling) requires a 'soft' platform to manage it sustainably, have led to the application of 'coupled systems'. Consistent with the notion of a coupled system, is the notion of **adaptive management**, which is viewed as of crucial relevance for sustainable water and land management. Coupled with the MLSF approach, which could be viewed as a 'soft system platform' for water resource management and technology transfer in the KNPRRP, is the 'water resources modelling approach in pursuit of enabling technology for adaptive management in integrated catchment management'. The application of a coupled system approach means that computer-enhanced modelling, including such tools as GIS, GPS, simulation models, remote sensing and so forth, become tools for interactive learning, i.e. they are not only models for learning by scientists with some vague assumed impact on policy or public opinion, they are first and foremost tools for learning by water and land users themselves, and thus serve as a basis for technology transfer.

## 3. A STRATEGY FOR WATER QUALITY RESEARCH AND THE ENHANCEMENT OF THE KNOWLEDGE BASE

The strategy for WATER QUALITY RESEARCH AND TECHNOLOGY TRANSFER is proposed in Figure 3.1. The numbers of the sub-headings are keyed to the numbers in Figure 3.1.

### 1. Multi-level stakeholder framework (MLSF)

A "multi-level (hierarchical) stakeholder approach to sustainable natural resource management holds promise to serve as a platform from which to launch current and new research, decision support products and initiatives and to serve as a framework for technology transfer.

2. **Needs assessment**

Needs assessment has been defined as "the systematic process whereby relevant needs are documented'' (Etling and Smith, 1994; as quoted by Dorward, Shepherd and Wolmer, 1997). This definition applies to development or research interventions. Needs assessment for research involves the identification, definition and prioritising of water and land users' problems, risks and opportunities that appear susceptible to intervention. The process can thus be thought of as having two distinct stages: the diagnosis of researchable constraints and the evaluation of research opportunities (Dorward *et al.*, 1997).

3. **Stakeholder needs**

The stakeholder needs are the products of the needs assessment process. The process applied in this study identified not only the specific water quality issues within the KNPRRP catchment areas, but also determined the research and technology development needs of the various stakeholders.

4. **Research and development**

Research and development (R&D) in natural resources management can be classified into five broad categories in terms of the relationships to science / technology development and to knowledge / dissemination / adoption. These categories, ranked according to its ability to meet the requirements of a systems approach, are participatory research, adaptive research, applied research, diagnostic research and basic research.

5. **Appropriate technology**

The "demand driven" approach (based on the stakeholder needs assessment) requires, for its success, the development and availability of appropriate (relevant) and improved (new) technologies. In this connection the linkage with research is critically important, and over the last twenty years has led, in particular, to the evolution and adoption of systems based and participatory research.

6. **Decision support & information systems**

In order to make the newly developed technology user-friendly and to ensure that it is used and implemented, it has to be integrated in decision support and information systems. This integration will also link the newly developed technology with other technologies already in use and with existing information.

For the newly developed technology to assist in improving sustainable water and land use and catchment management, it must be made target-orientated, client-oriented, process-oriented and multidisciplinary through decision support and information systems (Hurni, 1997).

7. **Technology transfer**

Embodied in the proposed multi-level stakeholder framework (MLSF) strategy, is the transfer of new and appropriate technology. The integration of top-down and bottom-up actions is one of the prerequisites for technology transfer. This is needed for the empowerment of different stakeholders with knowledge, skills and technology, i.e. to transfer appropriate technology. By using a range of suitable mechanisms (e.g. facilitation, representation, participation, demonstration, etc.), an active and open communication environment is created which is conducive to the successful transfer of technology. According to Martin and Sherington (1997), approaches involving these mechanisms changed the model of technology development from a linear transfer of technology model to an iterative approach based on learning and modification.

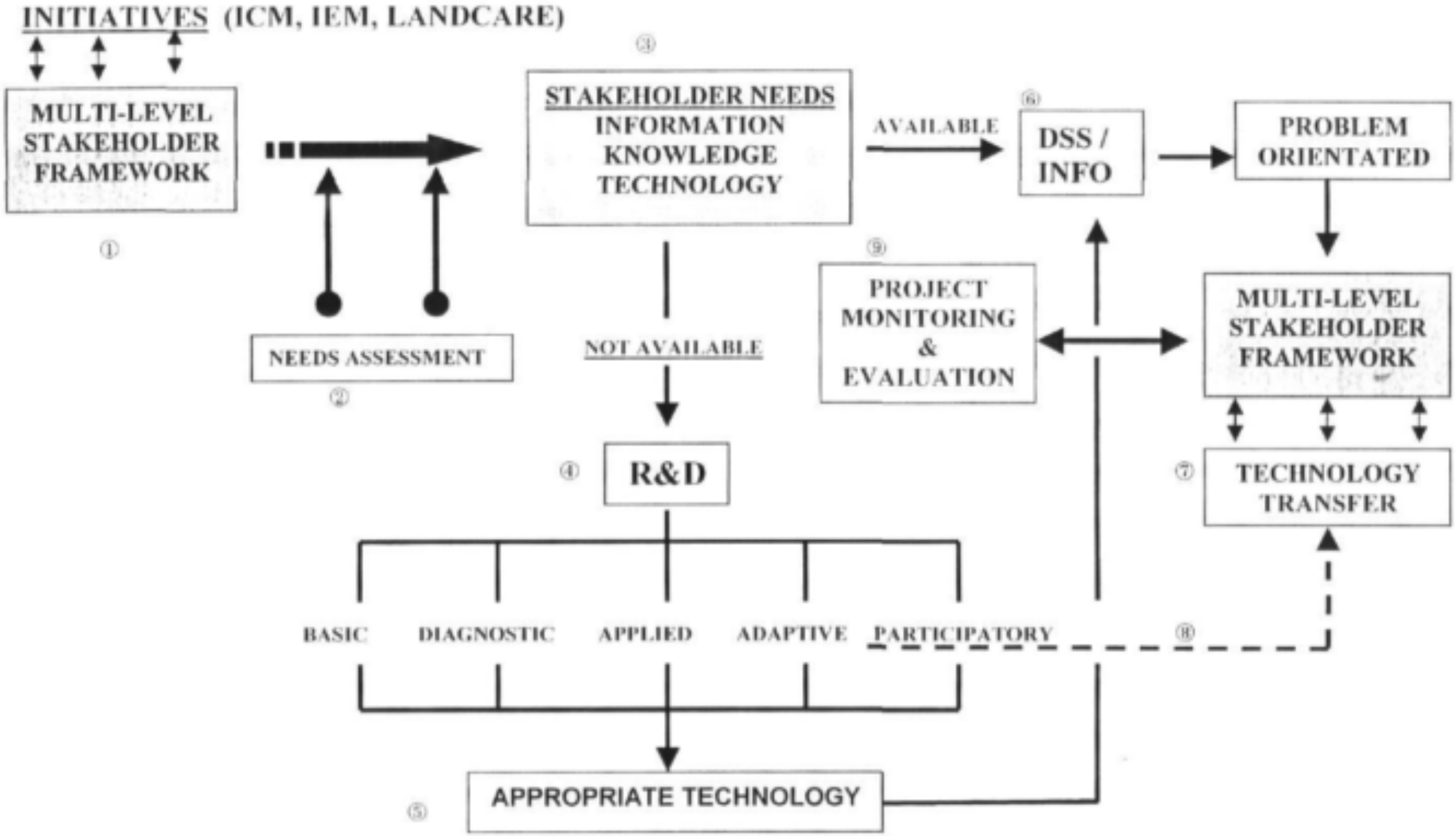


Figure 3.1 A strategy for water quality research and technology transfer

8. **Participatory research**

There is now widespread recognition, in name at least, that participatory R&D is critical for achieving sound natural resource management (Allen, 1997; Dent, 1999). It is considered important especially because it directly involves the process of technology transfer.

Participatory research is underscored by an educational and political philosophy which claims that the more people are involved in an activity, the more they will appreciate, understand and take responsibility for it. The whole process is cognisant of the principles of adult learning (Knowles, 1990), action learning (Kolb, 1986) and good facilitation processes. Group processes, in particular, become very important.

9. **Project monitoring and evaluation**

The primary aims of *monitoring* are to provide a basis for decisions on subsequent stages of the research, to formulate judgements on performance and to contribute to accountability for the use of resources. *Evaluation* assesses how far research has achieved its objectives and examines any unplanned outcomes.

## 4. SURVEY OF PERCEIVED WATER QUALITY INFORMATION AND RESEARCH NEEDS: WATER USERS

A survey of perceived water quality information and research needs was conducted via questionnaires, completed during interviews with a selected group of representatives from all levels of stakeholders. Seven questionnaires were completed. The perception scores for various categories and aspects of water quality were tabulated.

Because the respondents were not required to motivate or further prioritise their answers, comments cannot be made on the reasons and considerations behind their perceptions. The results do indicate that the differences between the level of knowledge and availability of technology on the one hand, and the urgency and importance of information needs as identified by the respondents on the other, show a strong research and implementation need for most of the categories.

Within the categories used in the survey, the greatest need was found by the respondents to be the implementation of validated and catchment-relevant prediction tools. A great deal of research was also judged to be needed to refine water quality criteria for river reaches, to determine the impacts on water quality, to manage the quality of water, and to find effective ways to transfer and communicate water quality issues to all the different stakeholders. Other water quality issues were also rated as important and presented in Chapter 4.

Even though this survey was based on a limited number of respondents, the results indicate that such a survey method, administered to more respondents from each of the different levels of stakeholders, will produce useful information to guide future research strategies for the KNPRRP, and also on a national scale. Such surveys can also serve to introduce the concepts of ICM and CMAs to many of the respondents, and establish the beginning of a communications network or 'soft system platform' as indicated in Chapter 2.

## 5. CONCLUSION AND RECOMMENDATIONS

The multi-level (hierarchical) stakeholder approach to sustainable natural resource management that we propose, holds promise to serve as a platform from which to launch new research, decision support products, initiatives, as well as to serve as a framework for integration, communication and participation and consequently technology transfer. A prominent and important part of the multi-level stakeholder framework (MLSF) is the addition of, or more widely employment of a bottom-up approach. The key to this is to place people at the centre of their own development by employing various 'soft system' methodologies, such as participatory approaches, mediation and methodologies for the facilitation of social learning. The MLSF approach, as proposed in this study, could consequently be viewed as a 'soft system platform' for water resource management and technology transfer in the KNPRRP.

Integrated catchment management planning plays an important role within the MLSF. The catchment (primary, secondary and tertiary catchments) is seen as the level where the integration of the top-down and bottom-up legs is the most prominent and forms an important link between the technology development and technology transfer activities.

Networks are a major key in the development and implementation phases in water and land management plans. The main reason for this is that they would usually be more advanced than the rest of the community in *inter alia* the dissemination and transfer of technology.

Participatory and systems-based models of research will help scientists to give water and land managers useful answers for integrated water and land management planning in the KNPRRP catchments. It can play a key role in "the integration of knowledge and purposeful action" by creating an effective learning environment for those involved.

The idea that a system perceived as 'hard' (such as water resource modelling) requires a 'soft' platform to manage it sustainably have led to the formation of 'coupled systems'. Consistent with the notion of a coupled system, is the notion of adaptive management, which is viewed as of crucial relevance for sustainable water and land management.

The introduction of a 'coupled system' approach means that computer-enhanced modelling become tools for interactive learning, i.e., they are not only models for learning by scientists; they are first and foremost tools for learning by water and land users themselves, and thus serve as a basis for technology transfer. Models (such as the installed modelling system for integrated water resources management on a catchment basis) are ideal catalysts and indeed vehicles to engage teams in deeper set systems of learning and allow them to experiment with the consequences of their thinking.

It is clear that a series of changes in the practice of R&D within the KNPRRP is required if the adoption of new and appropriate technology by all stakeholders is to become a reality. Group learning in practical settings, in particular, is now what is required on a greater scale.

To achieve this, we recommend the following:

**Recommendation 1.** We propose that a multi-level (hierarchical) stakeholder approach to sustainable natural resource management be considered (Figure 2.1) as the basis for further activity, as it shows promise for finding feasible, acceptable, viable and ecologically sound solutions at different scales.

**Recommendation 2.** We propose a strategy by which water quality research, but also other water issues, can be addressed within the KNPRRP. This strategy is presented in Figure 3.1, and it features the MLSF as a focus for needs assessment and technology transfer.

**Recommendation 3**. We recommend that surveys via questionnaires be used to derive a needs assessment.

Our limited survey showed that Criteria, Prediction Technology, and Technology Transfer are perceived to be priorities for research.

We do, however, recommend that a more "streamlined" questionnaire for interviews be used, based on the present one, as well as taking account of the needs identified by this survey. A section on prioritising needs relative to each other, should also be included at the end of each interview. Different questionnaires can be developed to survey the needs of users at different levels of the MLSF. We also recommend that a sociologist be included as part of the team in future needs surveys. Although the focus of this project was on water quality issues, we feel that many other water related issues can also be addressed with the proposed MLSF and research strategy.

## 6. OBJECTIVES AND CUSTODIAN OF DATA OF THIS PROJECT

All the objectives of this project were met. The objective to compile an annotated list of the main interested and affected parties and their information and management needs was decided not to be exhaustive due to time and financial constraints. Due to the rapid ageing of the information, this section is not included in this report, but is available from the WRC.

Appendix 1 of this report shows the average ratings of the water quality issues in general and of the different catchments. The results for different stakeholder groups are not included in this report, but are available from the WRC.

# ACKNOWLEDGEMENTS

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- Dr Heather MacKay of the Institute for Water Quality Studies, DWAF
- Mr. Mike Silberbauer of the Institute for Water Quality Studies, DWAF
- Dr Mark Dent of the Computing Centre for Water Research, University of Natal

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## REPORT

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| | |
|---|---|
| **CMA** | Catchment Management Agency |
| **DSS** | Decision Support System |
| **DWAF** | Department of Water Affairs and Forestry |
| **EIM** | Environmental Impact Monitoring |
| **FAO** | Food and Agricultural Organisation (United Nations) |
| **GIS** | Geographic Information System |
| **GPS** | Global Positioning System |
| **HSPF** | Hydrological Simulation Program Fortran |
| **ICIS** | Integrated Catchment Information System |
| **KNP** | Kruger National Park |
| **KNPRRP** | Kruger National Park Rivers Research Programme |
| **MLSF** | Multi-level stakeholder framework |
| **M&E** | Monitoring and Evaluation |
| **NGO** | Non-governmental Organisation |
| **ICM** | Integrated Catchment Management |
| **IEM** | Integrated Environmental Management |
| **PRA** | Participatory Rural Appraisal |
| **R&D** | Research and Development |
| **SDA** | Sustainable Development Analyses |
| **TOT** | Transfer of Technology |
| **TPC** | Threshold of Potential Concern |
| **WOCAT** | World Overview of Conservation Approaches and Technologies |

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# CHAPTER 1

## INTRODUCTION

### 1.1 BACKGROUND AND MOTIVATION

Despite the fact that there are many pressing water quality problems in the perennial rivers flowing through the Kruger National Park, the Kruger National Park River Research Programme (KNPRRP) has not effectively engaged water quality issues. However, the extension of the programme to include other rivers and the upper catchments opened the door for a renewed thrust.

The sub-programme of the KNPRRP on research has identified two priority research and technology transfer needs for the remainder of Phase III of the programme. One of these is to generate an explicit thrust to improve our understanding of water quality issues in the catchments of perennial rivers of the Kruger National Park (KNP) and to transfer existing knowledge to catchment fora. The strategy of the KPRRP and Park Management to engage other parties in the catchment in explicit Integrated Catchment Management (ICM) requires that there is a solid grasp of what the issues are, what can be done with existing information and where future research should focus.

### *1.2 OBJECTIVES*

The project had four specific objectives:

1. To review the existing knowledge of current water quality issues of the perennial rivers flowing through the KNP, and the available technology for dealing with water quality issues.

2. To compile an annotated list of the main interested and affected parties and their information and management needs.

3. To develop a strategy for effective transfer of existing knowledge and technology for managing the rivers of the KNP.

4. To develop a strategy by which the KNPRRP can effectively contribute to the enhancement of the knowledge base and its application.

## 1.3 APPROACH

We addressed the objectives by examining the links between research organisations and their clients, in this case the water users of the KNP. A number of approaches and principles to sustainable natural resource management, which would foster and strengthen these links, were investigated and discussed. Information, involvement and joint decision-making was taken as the basis for a sustainable strategy for the transfer of knowledge and technology (Chapter 2). We then linked this with a strategy for water quality research and the enhancement of the knowledge base (Chapter 3). Needs assessment is the link between the two, and this was demonstrated by a small-scale survey by questionnaire of seven respondents to illustrate the viability of this concept, as well, as to gain experience with this communication technique (Chapter 4).

# CHAPTER 2

# A STRATEGY FOR THE EFFECTIVE TRANSFER OF KNOWLEDGE AND TECHNOLOGY IN THE KNPRRP

## 2.1. INTRODUCTION

Implicit in research and development (R&D) is the transfer of new or improved technologies that are:

a) relevant to the stakeholders' needs and production objectives, and
b) appropriate to the stakeholders' operational circumstances and resources.

Marsh (1998) mentioned that the theory underlying the adoption of new or improved technologies suggests that it is important for research to be able to:

- demonstrate a need, or respond to an expressed need;
- demonstrate an observable difference in on-site situations; and
- demonstrate a measurable benefit in line with individual objectives.

Marsh (1998) stated that if these criteria are not met, the research products will unlikely be adopted voluntarily. For technologies that have slow and indirect effects, Pannel (1999) strongly emphasised the importance of the second point, stating that: "*Scientists need to consider ways to increase the observability of results from trials of such technologies, ways to help water and land users recognise that the technology is what is causing the results, and ways to allow results to be observed sooner*".

Research effort is wasted if it does not lead to wide scale adoption by the stakeholders at whom it is directed. By wide-scale adoption is meant the sustained use of new or improved technologies by a large portion of the specific stakeholder group or community. Links between research institutions and their clients (water users, land users, research managers, catchment management forums, policy makers, etc.) are vital for successful technology development and delivery.

To build effective links with the various clients and / or stakeholders, a combination of various mechanisms need to be applied at various levels of the institutional hierarchy. It is obvious that links are about people. No links will work unless staff working at research institutions, in the field and in technology transfer agencies are motivated to collaborate (Stillwell, 1992).

A number of initiatives were recently launched in South Africa, which provides an 'enabling environment' wherein these essential links could be established. These initiatives are Integrated Catchment Management (ICM) of the Department of Water Affairs and Forestry, the Landcare Programme of the National Department of Agriculture, and the Integrated Environmental Management (IEM) of the Department of Environmental Affairs and Tourism.

Although these three initiatives may differ in their origin and application, they all have a common element, namely the wise and sustainable use of water and land. Their main purpose is to select and put into practice those water and land uses that will best meet the needs of the people while safeguarding these resources for the future. Another dimension of these initiatives is community involvement. The involvement of water and land users with the planning, development, management and implementation processes of water quality conservation must therefore receive special attention. It therefore makes sense to use the 'mechanisms' advocated by these three initiatives, together with the existing structure of the KNPRRP (including existing knowledge and technology), as a point of departure in proposing and describing a strategy for the effective transfer of knowledge and technology in the KNPRRP. A few 'mechanisms' appear to be of particular importance for the successful transfer of new or improved technologies. They are:

- integration, communication and participation; and
- a multi-level stakeholder framework.

## 2.2. INTEGRATION, COMMUNICATION AND PARTICIPATION

According to Pieri (1997), centralized top-down methods for technology development and transfer (i.e. a public research and extension driven model) have significant weaknesses in dealing with diverse production systems with a high level of biological interaction as well as a high level of social integration. There is a need to move from a prescriptive approach towards an integrated approach of the physical planning and the social and institutional dimensions of catchment management. According to Dent (1995) 'dis-integrated' scientific efforts are an ineffective base from which to contribute to water resources modelling, and hence to integrated management of catchments. It is well recognised that the most serious problems in achieving the integration of catchment planning and management are not technical, but social. It is also acknowledged that this integration should be developed and maintained at the lowest possible level (grass-roots), using demand-based approaches and involving all stakeholders in decision making. For example, in rural areas individual farmers, residents, and catchment groups should be the engine of this integration. But crop and stock farmers are not the only users, and at district, sub-national and national levels, different stakeholders may have conflicting views about best water and land management practices (Pieri, 1997).

Many authors in South Africa stressed the need for proper participation, communication and integration in natural resources research and management. Among these are Dent (1995, 1996, 1998), Maaren and Dent (1995), MacKay (1994), Rabie (1996), Van Zyl (1995), Versfeld (1995), Walmsley (1992) and Department of Water Affairs and Forestry (1996). Dent (1995) warned that there was a perception in management circles that water resource modelers and managers have failed to contribute meaningfully to integrated water resources (or catchment) management in South Africa. Such perceptions could affect the public support and funding for the research required to improve our water resource modelling efforts, and therefore our ability to contribute, through basic and applied research.

Breen, Biggs, Dent, Görgens, O'Keeffe and Rogers (1995) identified four critical determinants for success, which provided the rationale for the structure of the KNPRRP into four sub-programmes. These are:

- Information Systems Development and Management – information must be accessible and there must be a free flow of data and information between and among researchers, managers and stakeholders.
- Decision Support Systems Development and Management – information and expert opinion should be structured into decision support systems directed at achieving the best possible answers at the time, and at informing researchers of the information needs required to improve answers in the future.
- Research Development and Management – research should be directed at developing understanding and providing relevant information for researchers, stakeholders and resource managers.
- Training, Information and Technology Transfer – communication, among others, is central to effective management of the use of resources, particularly when there are conflicts of interest. A concerted effort is required to promote and sustain communication.

The KNPRRP (Breen, Quinn and Mander, 1997) already produced a number of products, examples of which are the integrated catchment information system (ICIS), the DSS proposed by MacKay (1994) and the DSS of Rogers and Bestbier (1997). Rogers and Bestbier (1997) stated that we face an enormous challenge to convert the complex products of science into achievable goals and implementable solutions for practical conservation. MacKay (1994) emphasised that a DSS should provide a framework for the KNPRRP, so that researchers, managers and stakeholders can see where their expertise and information are complementary to the programme goals, and how they might contribute to the achievement of programme goals. The DSS should therefore aim to:

a) facilitate communication between managers, researchers and stakeholders;

b) assist managers to make decisions regarding short and long term management of aquatic ecosystems in general;

c) provide protocols for communication between managers, researchers and stakeholders in order to allow all to participate in the setting of long-term conservation and/or management goals for rivers, in local, provincial, national and international contexts;

d) allow the identification and prioritisation of research activities which will meet information requirements either in advance or during decision-making.

This DSS approach represents a way to structure the involvement of researchers, specialists, stakeholders and managers in integrated river management issues. This would allow the most appropriate (or problem orientated) methodologies, information, people and expertise to be accessed and utilised in river management decision-making. It therefore forms an integral part of the KNPRRP research strategy on water quality (See Figure 3.1).

Dent (1995) referred to the widespread agreement on the view that successful integrated catchment management for sustainable development will require broad participation by all stakeholders and intensive communication in order to facilitate the compromises, trust and faith which are necessary in such a process. The process will require bargaining or negotiation on an ongoing basis. The quality of the negotiations will depend largely on the quality of the information available to all parties, and the levels of understanding of the issues.

*It is clear that the ultimate success of technology transfer initiatives in integrated catchment management depends on meaningful participation and communication of all stakeholders. This is difficult to achieve and currently presents a formidable challenge to the KNPRRP.*

## 2.3. A MULTI-LEVEL STAKEHOLDER APPROACH

A multi-level (hierarchical) stakeholder approach holds promise to serve as a framework for technology transfer and to serve as a platform from which to launch current and future research and decision support products on water quality. Today, many international programmes and co-operation projects have started using such approaches, either explicitly or at least implicitly (Hurni, 1997). According to Burrough (1997), hierarchies are a convenient mental or conceptual model for organising complex information. The great advantage is that each level has about the same amount of detail (seven classes ± two). The hierarchy of *library – book – chapter – paragraph – sentence – word – letter* is a good analogue. A hierarchy for water quality management could be *global – region (e.g. Africa) – sub-region (e.g. southern Africa) – national - primary catchment (e.g. Olifants) / provincial – secondary & tertiary catchment (e.g. Loskop) / district – quaternary catchment / community / networks – catchment groups – property (e.g. farm / household / mining- /industrial site).* Rogers and Bestbier (1997) already introduced the hierarchy concept to the KNPRRP to provide a context for management problems, as management actions may be different at different scales.

According to Dent (1995) any strategy must be guided by a clear vision. In this case (i.e. the MLSF) the vision is one of people working together to achieve goals that would be impossible to achieve by the same people working in isolation. It is important to develop an integrated water resource management system through a vigorous process of interaction with all stakeholders. Furthermore, it makes no sense to speak of integration without fundamentally considering the whole issue of communication for the purposes of integration and technology transfer.

Smith (1997) proposed a multi-level stakeholder framework (See Appendix 4) for application in the South African Landcare initiative. This framework is based on the Australian Landcare framework and consists of both a ***'bottom-up'*** leg and a ***'top-down'*** leg. A proposed multi–level stakeholder framework for application in water quality management and based on the framework for Landcare, is shown in Figure 2.1. The components of this framework will now be discussed in more detail.

**The Top-down leg** (Fig. 2.1)

Government, national- and international research organisations usually take a lead role in the 'top-down' approach. Technology, information, legislation, catchment plans and / or decision support systems (information systems), monitoring and auditing, etc. are provided and / or supported from 'the top' at any scale or level. In reality, it usually happens on scales of 1:100 000 to 1:1 000 000 mainly due to a shortage of applicable data on larger (more detail) scales and to the inability of institutions to produce bottom-up initiatives. Although this approach is common to many forms of geo-information handling, it is not particularly suitable for integrated water and land management and technology transfer for several reasons. The main reasons according to Burrough (1997) are:

- good decision-making requires specific data and not data resulting from spatial generalisation, reclassification and translation;
- generalised top-down methods ignore local conditions;
- the hierarchies and classifications used for aspects of the natural world do not necessarily have direct counterparts in the socio-economic fabric of water and land users.

Continuous and active communication and exchange of information between researchers and policy-makers is essential to show that the research programmes are congruent with the development plans, and that the realisation of development targets is largely dependant on the effective implementation of the results of this research. The need to convince policy-makers of the potential inherent in applying the results of research on a national scale is as important as publishing papers. Doing good research is not enough, it must be perceived as an effective tool in promoting development (Arnon, 1989).

Secondly, the participation of the bottom-up stakeholder levels or representatives thereof, is important at all stages and levels of research planning and prioritisation in the top-down leg (Fig. 2.1). Even if we assume that the specialist members of the research panels have the competence and motivation to ensure that the research reflects the real needs of any client community, a major way to convince them is by involving them in the process of defining research goals, problems and priorities. Arnon (1989) paraphrased a well-known adage of justice into saying that "*research must not only be appropriate, it must also be perceived to be appropriate*".

Examples of research products in the top-down leg (Fig. 2.1), which are currently a hard prerequisite for the calculation of environmental indicators on these levels, are the availability of national and primary catchment / provincial scale reference databases. At present, environmental managers and planners can derive few replicable indicators from existing data. Furthermore, the Internet offers creative and strategic opportunities to communicate and exchange information between researchers, managers and planners, especially on these levels of decision-making.

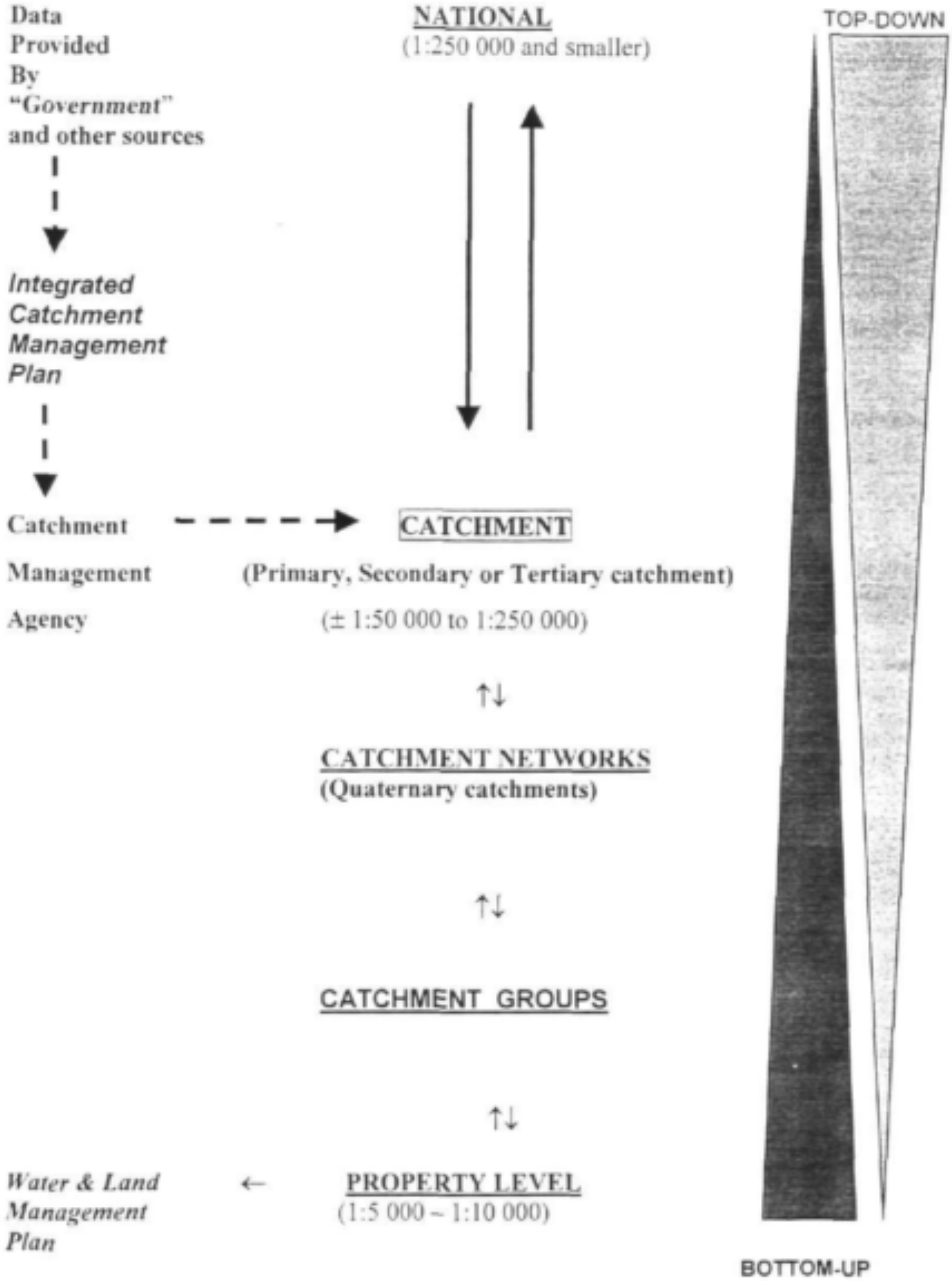


Figure 2.1. Multi-level stakeholder framework.

**The Bottom-up leg** (Fig. 2.1)

*The "art" of community consultation is more important than the "science" of river management.*

*J. Burston (1997)*

In response to the failures of applying only a top-down approach, the development process in general has literally been turned upside down by using a bottom-up approach, or adding a top-down leg during the last decade. The key aspect to this approach has been to place people at the centre of their own development. This approach therefore places people at "*the starting point, the centre, and the end of each development intervention...and constructing development projects around the mode of production, cultural patterns, needs, and potential of the populations in the project area*" (Cernea, 1985; as quoted by Hutchinson and Toledano, 1993).

The bottom-up leg (Table 3.1 and Fig. 2.1) is a people-centred process and represents the individual stakeholders (water and land managers or users), the stakeholder groups and the stakeholder networks. It accommodates the will, wishes, and wants of the people and indicates that the key to sustainable water and land management lies with the people. It focuses on real problems and the need for improvement. It furthermore emphasises the 'empowerment' of the water and land user by direct involvement with decision-making and responsibility towards the environment. It emphasises the 'ownership' of actions and technology in order to manage their resources in a sustainable manner. These activities are executed on farm / local (community) / site levels on scales of 1:50 000 to 1:5 000. It is generally known as *integrated (tertiary and quaternary) catchment planning and land management planning.*

***Property (farm / site) level : water and land management planning***

Water and land management planning provides the opportunity for water and land users at the property level (Fig. 2.1) to plan its integrated management in a productive and sustainable way. According to Pieri (1997), this approach requires that indigenous and community–based knowledge and actions to be prioritised in relation to new knowledge and technologies entering from outside. Outside sources are still needed for solving specific problems or for understanding the basic processes at the field and / or catchment scale and beyond.

The best base on which to prepare the physical land management plan is an aerial photo. The planning process focuses on simplicity and flexibility with a bottom-up approach as its most important feature. This means that the land user takes 'ownership' of the planning of his land (meaning soil, water and plants). The land users, usually with the assistance of an expert (e.g. a planner or facilitator), do their own thinking or planning (i.e. the mapping of natural resources together with film overlays). These overlays normally include the natural resource capabilities (land classing), envisaged layout of land use improvements, fencing and contouring. In some cases GIS can be used to prepare and display the land management plan. The land users are consequently involved in 'on-farm / site' research and are seen as co-researchers in the development of land management practices. Local (and indigenous) knowledge and scientific knowledge (technology) are integrated in the search for applicable practices.

***The Group level: Stakeholder (Catchment / Landcare / Waterwatch) group activities***

A typical catchment group (Fig. 2.1) would consist of actual stakeholders, or stakeholder representatives. At grassroots level the group would collect the necessary information for decision-making and negotiate its own management plan. At the same time the group would be able to pass information upwards, either to the appropriate government institution, or to the next higher group or network (Fig. 2.1). Where the group finds that it faces constraints or problems due to lack of information, or due to the existing social or legal framework, the difficulty, indicating the need for change, is passed upwards to the next institutional level (FAO, 1997).

The structure and organisation of individual groups at grassroots level should be appropriate to the customs and cultural norms of the country and the area. It is essential to allow local people the freedom to organise themselves, to debate and to contribute (FAO, 1997). **Dynamic group extension and communication processes are seen as an important basis for the communication and transfer of new or improved technology.**

*The Community level: Catchment & Landcare Networks*

Groupings of groups, i.e. catchment networks (Fig. 2.1), create the opportunity to address management issues over quaternary catchments and / or large tracks of land. Communication, or the lack of it, is another catalyst for groups to form together, to exchange ideas and learn from one another. In some cases it could result in the formation of such a structure, e.g. a Landcare association, which concentrates on improving communication links within and between groups, or to promote the dissemination of knowledge and technology within and between groups.

Networks can grow in stature and importance through their planning strategies and can form a strong association with catchment management agencies (CMA's). This process puts pressure on catchment management agencies, as the community looks at issues in a broader context – thereby forcing specialists to work in a wider sphere with clients.

Networks are a major key in the development and implementation phases in water and land management plans. The main reason for this is that they would usually be more advanced than the rest of the community in *inter alia* the dissemination and transfer of technology. Ideally, according to Ryan and Bray (1997), networks will:

- Look at the causes rather than the issues in isolation;
- Develop a community plan that will be attractive for partnership agreements and funding by several sources;
- Focus the agencies on the whole catchment process;
- Ensure that the community and CMA work together;
- Provide effective feedback to government through CMA's;
- Validate government responses;
- Involve all in the community;

- Provide a forum for conflict resolution;
- Establish real needs instead of perceived needs;
- Ensure effective use of funds.

**The Catchment level**

The main initiative at the primary, secondary and tertiary catchment (district) level (Fig. 2.1), is the development of a strategic *or* integrated catchment management plan, which is usually done at a 1:50 000 to 1:250 000 scale. **This is the level where the integration of top-down and bottom-up legs is the most prominent and forms an important link between the technology development and technology transfer.** Tainton (1995; as quoted by Dent, 1996) describes integrated catchment management as follows:

> *"Integrated Catchment Management (ICM) involves the holistic use of the resources of an area, using the whole catchment as a unit in its own right or as an integration of its sub-catchments. Central to this concept is the co-ordinated use and management of land, water, vegetation and other physical resources and activities within the area of the catchment. Because of the importance of water to man and because water integrates many aspects of land use on any system, it is logical that the water catchment should form the basis of the geographical units used in land-use planning. Such arguments rest on the recognition of the river as the natural unit of management, and that other man-made and administrative boundaries are inherently unnatural. All the interactive activities within a catchment need to be drawn together in any such exercise, with water quality and quantity being used as the yardstick by which the success of the catchment management (including land use and management) is evaluated."*

If integrated catchment management is to be effective, all the institutions with their different initiatives (Landcare, ICM and IEM) and all the stakeholders in the catchment must support the catchment management initiative and agree on the objectives which need to be set for the catchment. Implementation of a catchment management plan, which could include various research products and results, must thus rely heavily on a partnership between government, statutory organisations and water and land users such as mining, industry, agriculture, civil society and conservationists. The needs and aspirations of the various user groups are key considerations in the establishment of water quality and yield.

The catchment management agencies (CMA's, see Fig. 2.1) must, in terms of the White Paper (DWAF, 1996) draw up catchment plans and ensure the ongoing implementation and audit of the plan. In addition, local authorities, industries and agricultural boards must integrate their activities with the overall objectives and goals of the plan (Howard, 1998).

Community input into catchment plans is essential. The best way to motivate water and land users and communities to take an active part in participatory and integrated catchment management initiatives, is through the identification of simple and user-friendly technical interventions, which enhance the efficiency, rentability, and sustainability of the local water and land use systems. In the Australian Landcare movement, catchment groups assess the capabilities of the land and then plan their activities according to the priorities within their catchment. Ignoring individual property boundaries, they plan, manage and monitor land and water activities strategically within the overall catchment. Success is usually measured by improvements in water quality at the outlet of the catchment and in catchment productivity. A catchment management agency (CMA) is responsible for the Integrated Catchment Plan (ICM, see Fig. 2.1) and the members of this board represent all the different levels of the multi-level stakeholder framework (Roberts, 1994).

Fundamental to the concept of integrated catchment management is the pursuit of enabling technologies for adaptive management (Breen *et al.*, 1995). Water resource modelling is one such technology. There are others which may be harnessed to assist the adaptive form of management which is essential in the dynamic social and bio-physical environment within which integrated natural resource (especially land and water) management takes place. Based on this, it becomes obvious that dis-integrated scientific efforts are an ineffective base from which to contribute to integrated management (Dent, 1996).

Dent (1996) stressed that through the wise use of installed modelling systems, society could begin to move towards the goal of integrated catchment management. Such a process would seek to achieve a level of interaction between individuals, organisations and disciplines such that we can collectively, timeously, wisely and cost effectively visit the consequences of our past and present, and anticipate the consequences of proposed actions. These models will enable us to compress time and space sufficiently for us to visualise and quantify these consequences.

The parallels in water resource modelling are whether to develop or assimilate expertise that is outside of a scientist's core competencies (vertical integration). Alternatively, a scientist may decide to co-operate with persons from other groups in order to integrate the different core competencies (horizontal integration). This is the classic 'make or buy' dilemma. If we consider the goal of all water resource modelling efforts to be to provide meaningful contributions to integrated natural resource management, then the lessons and skills learned through the process of horizontal integration will be appropriate. They will be appropriate in terms of broadening participation which is necessary to foster the process of integrative bargaining which attempts to achieve win-win situations (Dent, 1996). The process of horizontal integration would help to extend and strengthen the processes of technology development and transfer within the multi-level stakeholder framework (MLSF).

## 2.4. INTEGRATING THE MLSF APPROACH WITH WATER RESOURCES MODELLING: A SYSTEMS APPROACH

According to Röling (1997), the introduction of systems thinking has had major benefits in the practical world of purposive change. This has allowed an integration of disciplines such as hydrology, climatology, soil science, physiology, agronomy and even economics into 'theoretical production ecology' and useful simulation models, which commands international attention. However, it is relevant to this study to make a distinction between hard and soft systems. Hard systems thinking, such as computerised simulation models, assumes that real systems exist independently of the human observer. One can therefore make models of existing systems. Hard systems are generated when you map a real system against a chosen space-time scale.

Hard system models of the life sciences, such as ecology, pinpoint human activity as the cause of our predicament. They indicate the criteria for the kind of management required for a sustainable global society. However, they must leave begging the question how the implicit transformation of society can come about. Hence they seek to develop interdisciplinary collaboration with economists in exciting new approaches which challenge the disciplinary organization and management of academia. **Soft systems thinking provides a useful basis for such interdisciplinary collaboration.**

Soft systems, which deal with purposive human activity systems, differ from natural (e.g. plants) or designed (e.g. computer models) systems in two major ways. First, they are guided by *reasons* and not driven by *causes*. Second, they do not have assumed goals; instead, the major issue is how they arrive at shared system goals (Röling, 1997).

Röling (1997) described how soft systems thinking are used to form a 'platform for water (and land) use management', i.e. to construct a soft system among the stakeholder groups based on shared learning, negotiation and accommodation. The platform perspective implies attention to soft system methodology, participatory approaches, mediation and methodologies for the facilitation of social learning so as to take stakeholders along a learning path towards effective platform development. The MLSF approach could consequently be viewed as a 'soft system platform' for water resource management and technology transfer in the KNPRRP. **The idea that a system perceived as 'hard' (such as water resource modelling) requires a 'soft' platform to manage it sustainably leads us to 'coupled systems'.**

Consistent with the notion of a coupled system, is Holling's (1995; as quoted by Röling, 1997) notion of **adaptive management**, which is viewed as crucial relevance for sustainable water and land management. The essence of adaptive management is that it treats management actions as potential learning opportunities that can feed back more reliable information to improve decision-making (Lancia, Nudds and Morrison, 1993; as quoted by Rogers and Biggs, 1999). The coupled system is relevant because water and land use can be considered as a system that couples a) *a system perceived as hard* and b) *a platform*. Coupling occurs through adaptive management which is based on:

- learning
- making visible the state of the water and the land
- monitoring the impact of human activity
- negotiating agreement with respect to the norms for sustained use of the land
- collective action, for example, with respect to resolution of distributive conflicts.

Such a coupled system seems essential for sustainable water and land use, because it is only in such coupled systems, at different system levels, that negotiated self-restraint of human greed seems possible (Röling, 1997). It supports the strategy proposed by Rogers and Biggs (1999) that the integration of value systems, endpoints and indicators of ecosystems health or ecosystem integrity forms the cornerstone of a consultative management process for the rivers of the KNP. According to Beek, De Bie and Driessen (1997), the latest land use planning strategies recognise the importance of a multi-stakeholder approach. Furthermore, it recognises that decisions have a *bio-physical component*, dealing with the bio-physical performance of specific land use systems (at various scales); and a *socio-economic component*, the decision-making process itself.

Coupled with the MLSF approach, which could be viewed as a 'soft system platform' for water resource management and technology transfer in the KNPRRP, is the water resources modelling approach. Water resources modelling is in pursuit of 'enabling technology for adaptive management in integrated catchment management'. This 'hard system' paradigm views models (including rule based reasoning systems) as living repositories for the knowledge which the collective scientific community has about the specific catchment. According to Garforth and Usher (1997) the merit of systems models lies partly in their abandonment of unilinear metaphor – flow, transfer, 'downstream' – and their portrayal of elements mutually influencing each other, with control mechanisms operating at various levels. They also deal more effectively with the complexity and diversity of information sources and channels.

It is important to pause for a moment to consider these forces and likely responses by the top level scientific consultant groups which will inevitably emerge to advise various stakeholder groupings. It is here that the scientific, computer, business and social science worlds will integrate to form the new paradigms. On the one hand, the above-mentioned paradigm shifts have been made possible by high speed computer processing, large data bases, geographic information systems, wide area networks and high quality graphics including multi-media, images and animation. The development and existence of such computer software installations mean that we can begin to think in terms of new paradigms when we consider the challenges of multi-disciplinary scientific teams working on these catchments. The goal of broadening participation is thus brought a step closer. (Dent, 1996).

Following international trends, there is a growing number of modelling systems being installed for integrated water resources management on a catchment basis in southern Africa. Such systems are being installed for operational use in ongoing learning, research, strategic planning and consensus building amongst role players in the Catchment Management Agencies (CMAs). These installed systems are poised to change fundamentally the way modelling is approached in southern Africa. They are a logical and irreversible response to the enormous forces which have led to the revision of the South African Water Law and the water resources management paradigms (Dent, 1999). The Hydrological Simulation Program Fortran (HSPF) is a key component of a number of successful installed modelling systems in the world today. According to Dent (1999), installed modelling systems like HSPF will be a significant contribution towards making the implicit mental models of the stakeholders explicit and hence contribute to management, change and resolution of conflict in the social process (soft system) of water allocation.

Dent (1999) argued that being able to program the IF, THEN, ELSE type Conditional Special Actions in the user control input, HSPF is able to model feedback consequences of human interventions in the natural water resources systems in catchments. Röling (1997) stated that modelling has become the basic methodology to bring the human element into natural science. It profits from the expansion of human cognative ability by computer technology. Computer-assisted modelling however, cannot deal with the human factor. This has meant that people have not been taken into consideration. Röling (1997) went further by saying that the masses of words of the social scientists and the models of the natural scientists remain separate and without operational linkage. Participatory approaches which involve people in constructing their own reality (possibly with the aid of models) and in agreeing on their own reasons for collective action promise to be much more powerful.

What is left is shared learning, negotiation, accommodation of conflicting goals, building rich pictures from multiple perspectives, consensual approaches to the resolution of distributive conflicts, covenants among stakeholders in natural resources, *but above all agreement to do things differently and collective action based on shared learning at different levels of social aggregation, i.e. different stakeholder levels*. In other words, what is left are solutions which emerge from interaction. From these comes a different portfolio of interventions, including mediation to resolve conflicts, facilitation of learning and participatory approaches that involve people in negotiating collective action. The future emerges from interaction.

What does this (coupled system) mean for the natural sciences (including water resource modelling, agriculture, etc.)? According to Röling (1997), it means that computer-enhanced modelling, including such tools as GIS, GPS, simulation models, remote sensing and so forth, become tools for interactive learning, i.e. they are not only models for learning by scientists with some vague assumed impact on policy or public opinion,

**they are first and foremost tools for learning by water and land users themselves, and thus serve as a basis for technology transfer. According to Dent (1999), models are ideal catalysts and indeed vehicles to engage teams in deeper sets of systems learning and allow them to experiment with the consequences of their thinking.**

The strategy proposed by Rogers and Biggs (1999) compares well with the coupled system, especially if a deliberate effort is made to include these above-mentioned issues. The strategy has been to develop a consultative management process in which interactions between stakeholders, managers and researchers are facilitated by a decision support system (DSS) (Breen, Quin and Deacon, 1995; as quoted by Rogers and Biggs, 1999). The process consists of three subsets of activities. One subset is the Operational Framework, which relates fairly well with the 'soft systems platform' of the coupled system. It has two functions: a) To set and evaluate attainable and acceptable goals which reflect the desired future state for the rivers. Attainability must be judged on the basis of ecologically realistic targets and the operational capabilities of management. Acceptable goals will meet the various stakeholders' broad aims. b) To select and implement appropriate management actions.

The second and third subsets of activities are a Predictive Modelling Framework and a System Response Framework, respectively. These subsets correlate well with the 'hard system' component, i.e. the water resources modelling approach and the installed modelling approach. This second subset is for prediction of the consequences of management actions and of system changes in general. It aids in evaluating the acceptability of the consequences of management actions. The System Response Framework is for monitoring system response to management actions and natural disturbance or change, and for auditing the attainment goals (desired state).

## 2.5. DISCUSSION OF KEY CONCEPTS, DEFINITIONS AND ELEMENTS OF A MULTI-LEVEL STAKEHOLDER FRAMEWORK

### 2.5.1. Stakeholders

A 'stakeholder' is anyone who has an interest in or is affected by an issue or activity or transaction and therefore has a natural right to participate in decisions relating to it. A farmer may have a 'stake' in the management of irrigation water from a common source, or in decisions about grazing rights on communal land. A group, or several groups, may have an interest in the use of particular resources, such as a forest or a river.

According to Pieri (1997), there are many categories or types of water and land users. All these must be identified to establish the respective hierarchy of needs. These users vary from place to place, but collectively they make up the major stakeholders in the process of water and land use planning and management.

Table 2.1. The different stakeholder groups within the context of the KNPRRP.

| LEVELS | MAIN INTERESTED AND AFFECTED PARTIES |
|---|---|
| NATIONAL | National Departments of Water Affairs and Forestry (DWAF), Environmental Affairs and Tourism (DEAT) and Agriculture and Land Affairs (NDALA); National, regional and international research organisations ; Universities; SA National Parks |
| PROVINCIAL | Provincial Departments of Environment and Tourism and of Agriculture; Provincial Park Boards; research organisations |
| CATCHMENT | Catchment forums; research institutions and movements (KNPRRP, Working for Water, River Health); NGO's; Landcare |
| NETWORKS | Communities; community associations; Working for Water; Landcare networks; NGO's; |
| GROUPS | Land user (farmer) groups; discussion groups; private research and development groups; NGO's; |
| INDIVIDUALS | Land users (commercial and small-scale farmers, private game farm and -park owners; private land owners; mines; industries |

The multi-level stakeholder framework (MLSF) can be used to identify the groups and provides a suitable basis for further investigations (such as needs assessments, identification of appropriate technology, information systems, technology transfer methods, etc.). Tables in Appendix 5 gives a broad overview of how the MLSF could be used in practice: for example to direct certain processes and activities in order to transfer new and improved technologies to specific stakeholder groups.

**2.5.2. Participation**

Most things 'happen' better if the recipients are involved in the process. Working with people forces researchers (and extension workers) to recognise that their goals may be different from the water and land users' goals, to recognise this as a constraint and to adapt their research or extension accordingly.

As the issue of sustainable and integrated natural resource management becomes more and more urgent in R&D, it is also clear that the 'message' of sustainability is closely linked to participation of communities who are living in close association with these natural resources. As described above, the multi-level stakeholder framework, among several other approaches today, focuses on the need to involve communities and individual water and land users in the research, planning and management of natural resources through the implementation of applicable technologies. For the purposes of the KNPRRP and in the context of integrated catchment management, the definition of participation, as proposed by Adolph and Kelly (1998), is relevant:

> *"Participation is the active involvement of all user groups of a catchment in the identification of problems and solutions, the planning and implementation of these solutions, and the monitoring and evaluation of their performance. Full participation includes joint decision making, based on mutual agreement, of the project implementing agency and the*

*people in the project area, and incorporates an element of accountability on behalf of the implementing agency to the people concerned."*

According to Hutchinson and Toledano (1993), the incorporation of the intended users or clients as part of the project team will contribute to the transfer of knowledge in two ways. Firstly, client participation will help to improve the overall quality of the activity by defining an important problem to address. Incorporation of the client or potential user in the design, execution and evaluation of the activity ensures that an actual problem is addressed and that solutions are presented in an institutionally acceptable form. Secondly, giving the clients a vested interest in the success of the activity helps to ensure their full participation. Once familiar with the activity, they are in a position to see that it will be continuously used.

**In summary, the new approach to sustainable and integrated water and land resources planning and management, which includes the multi-level stakeholder framework stresses three things. Information, involvement and joint decision-making by all stakeholders.** When people are informed and involved, they are halfway to being satisfied. When they participate in decision-making, they are three quarters of the way to being satisfied. When they understand that they have negotiated the best result possible, they are almost always satisfied. When they are part of a development partnership, they are usually enthusiastic and more than satisfied (FAO, 1996).

### 2.5.3. Landcare

Landcare is about managing land, water, plants and animals sustainably and productively. In essence Landcare aims to have all land used according to its capability, to plan management on a catchment or district basis, to involve all land users in the community and to encourage the adoption of a land ethic by the community nation-wide (Roberts, 1994). As such, integrated catchment management and planning forms one of the pillars of Landcare.

### 2.5.4. Where should the 'top-down' and 'bottom-up' process meet?

As proposed by the multi-level stakeholder framework, the catchment level is a suitable, reasonably decentralised level where top-down and bottom-up processes can meet within an institutional planning approach. This means that representatives of all the different stakeholder levels or groups form part of this planning group and process, which is usually in the form of a catchment forum. **However, to facilitate and strengthen the integration process in view of technology transfer, top-down and bottom-up processes are needed at all the levels of the MLSF in various degrees of intensity.** Representatives from the top-down leg would come from national and provincial departments and research organisations, extension staff, universities, etc. These people are typically involved with national, primary and secondary catchment and provincial water and land use planning and R&D programs and projects. When operating on these levels, it is not possible to deal with individuals or water and land user groups. However, it is necessary to involve representatives of client groups and / or communities from these early stages of water and land use planning processes. This will ensure that the client has already taken ownership of the process and product, which could probably be an integrated catchment management plan, or part of it, once it is delivered to the catchment management forum. The process proposed by Rogers and Bestbier (1997) would be appropriate.

Representatives from the bottom-up leg would be members of tertiary and quaternary catchment and farmer groups, water boards, community networks, NGO's, community based research groups, riverwatch / streamwatch groups, water and land user associations, individual land users, etc. One major objective of this dynamic, people-centred process is to empower local people with knowledge, skills and technology (i.e. to transfer appropriate technology).

Therefore, the key to the successful transfer of technology lies in an effective link between the bottom-up and top-down processes. The mechanisms of integration, communication and participation, which form the effective links between the various dimensions of the multi-level stakeholder framework, are consequently seen as essential building blocks for technology transfer.

# CHAPTER 3

## A STRATEGY FOR WATER QUALITY RESEARCH AND THE ENHANCEMENT OF THE KNOWLEDGE BASE

In the previous chapter we introduced the concept of MLSF as the basis of effective transfer of knowledge and technology in the KNPRRP. In this chapter we integrate the MLSF concept into a larger framework that deals with research and technology transfer, based on the needs as identified by the MLSF. Water quality, one of many water related issues, is used as an example. The strategy we propose is summarised in Figure 3.1. This chapter discusses this strategy in detail. The numbers of the sub-headings in this chapter are keyed to the numbers in Figure 3.1. **Examples of the practical application of this strategy are given at the end of this chapter.**

### 1. MULTI-LEVEL STAKEHOLDER FRAMEWORK (MLSF)

A "multi-level (hierarchical) stakeholder approach to sustainable natural resource management shows promise for finding feasible, acceptable, viable and ecologically sound solutions at different scales. It also holds promise to serve as a platform from which to launch current and new research and decision support products and initiatives and to serve as a framework for technology transfer.

This approach would greatly assist in facilitating participation of and communication between all stakeholders in a catchment that could conceivably affect or be affected by water quality. It relies on building partnerships for the development and delivery of innovative technologies, drawing upon an interactive establishment of major stakeholders' needs that stem from their perceptions and priorities regarding water quality issues. It requires a high level of social infrastructure and networking, which includes the participation and empowerment of water and land users, the development of partnerships among institutions, and policy and political support (Pieri, 1997).

When adopting the multi-level stakeholder approach to water quality research and technology transfer in the KNPRRP, the various dimensions of sustainability have to be weighed against one another in a negotiated, *i.e.*, participatory approach that does not discriminate against, or favour particular actor categories. For example, scientific information must be coupled with indigenous knowledge to offer a better basis for decision-making in the negotiation processes. Here, applied geo-information may *inter alia* serve as an appropriate tool to facilitate communication in negotiation processes. Experience worldwide has already demonstrated the multi-level dimensions that have to be considered in order to attain long-lasting solutions. The real strength of the multi-level stakeholder approach is that it does not provide a predetermined concept, but offers a framework and a procedure for working towards a common point of view and defining the next steps to take (Hurni, 1997).

## 2. NEEDS ASSESSMENT

Needs assessment has been defined as "the systematic process whereby relevant needs are documented" (Etling and Smith, 1994; as quoted by Dorward, Shepherd and Wolmer, 1997). This definition applies to development or research interventions. Needs assessment for research involves the identification, definition and prioritising of water and land users' problems, risks and opportunities that appear susceptible to intervention. The process can thus be thought of as having two distinct stages: the diagnosis of researchable constraints and the evaluation of research opportunities (Dorward *et al.*, 1997).

Institutional arrangements should exist through which all stakeholders are represented in an informed negotiating process which leads to an agreed water quality research and development plan that is in the long-term interest of all of them. The essence of negotiation among stakeholders is that all the groups who will be affected are fairly represented in the discussions. This helps to ensure that all interests are catered for, and also that the results will be accepted by all the actors. However there are many cases where it is impossible for all stakeholders to participate personally in all aspects of the negotiating process. Up to the present time the only way that such situations have been handled is through some form of representation (FAO, 1997). Identifying stakeholder needs on water quality issues is not a static and intellectual exercise, but involves a dynamic conflict resolution process among actual and potential stakeholders (Pieri, 1997). **A successful decision-making process on water quality issues can be seen as a negotiated agreement in which all stakeholders feel that they have achieved maximum possible satisfaction of their needs and objectives. The process must also result in resources being used in an efficient way in order to maintain or improve the water quality in the catchment.**

The first requirement of effective stakeholder representation during the process of needs assessment is that the person selected should represent an identified group of stakeholders of a particular type. All the stakeholder groups must therefore be represented in the negotiating process. This also ensures that decision-making is not taken over by one particular economic or social group. The second requirement is for some form of forum or framework within which negotiations will take place. Different forms of conflict resolution are appropriate at different levels.

Another requirement for the enhancement of needs assessment is to select an appropriate approach or technique to be used for the assessment of stakeholder needs on different levels. Participatory rural appraisal (PRA) or -assessment is becoming increasingly popular in many people-centred (bottom-up) projects, where individual stakeholders, groups or networks are the target audience. Other forms of participatory processes, such as workshops and brainstorms, are used with the activities of catchment management forums or with the planning of research programmes and projects. The latter approach is designed to involve all interest groups and to facilitate interactions between researchers and research users. In so doing, it addresses one of the major criticisms of research, namely that research does not sufficiently respond to users' needs (Collion and Kissi, 1995).

## 3. STAKEHOLDER NEEDS

The stakeholder needs are the products of the needs assessment process. The process applied in this study not only identified the specific water quality issues within the KNPRRP catchment areas, but also determined the research and technology development needs of the various stakeholders.

In order to determine the R & D needs for each water quality issue, a review of the following was needed:

- The state of existing knowledge for decision-making and implementation
- The available technology for dealing with it
- The need (how important is it?) to fill the knowledge and technology gaps

The gaps in knowledge and technology that should be filled would be the research and development needs that can be addressed by the KNPRRP. These research and development needs have to be prioritised. To prioritise the R & D needs, it needs to be scored in terms of how important and urgent is it to get the necessary knowledge and technology in place by the different stakeholders.

**The results of this survey are presented in Chapter 4.**

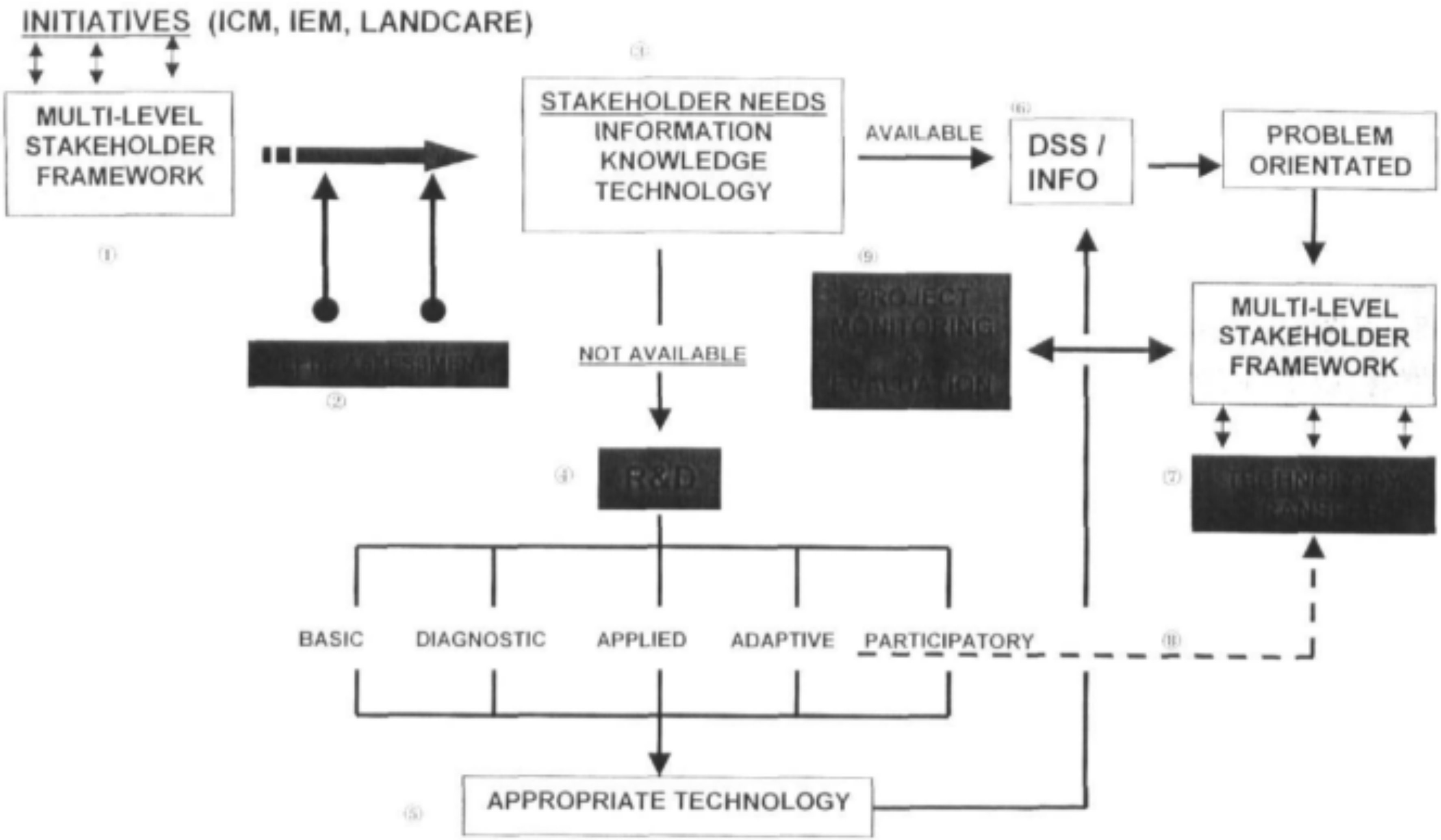


Figure 3.1. A strategy for water quality research and technology transfer.

# 4. RESEARCH AND DEVELOPMENT

The shortage of research information in general, is further complicated by the fragmented nature of some of the research efforts, making it difficult to relate the results of individual research projects to whole systems. The sooner that a ***systems approach is*** used to determine research priorities, the earlier scientists will be able to give water and land managers useful answers for ***integrated water and land management planning*** (Dent, 1999; Roberts, 1994). There is a serious lack of understanding on fundamental processes in the catchment (e.g. sediment transport in rivers and hillslope soil-water budgeting) and how land management affects these. This can be ascribed to a fragmented approach and includes: not solving specific problems; not solving priority problems; not answering fundamental questions; and not transferring information in the appropriate way (Walmsley, 1992).

Research and development (R&D) in natural resources management can be classified into five broad categories in terms of the relationships to science / technology development and to knowledge / dissemination / adoption, as shown in Table 3.1. The nature of the five categories of research, ranked according to its ability to meet the requirements of a systems approach, is the following:

**Participatory research.** Is directed at applying the technology within a specific system, often called a recommendation domain; is multidisciplinary, on-site and participatory; creating a learning situation for the end-user. **It implies that technology transfer is inherently a result or product of this process.** An example of participatory research is the development of a community 'waterwatch' system for improving catchment water quality.

**Adaptive research.** Is directed at the testing and adaptation of new technology and is focussed on specific environments and considers the interaction of the technology with the specific environment. It assumes that some elements of technology transfer already exist. An example is that of the adaptation and testing of existing predicting technologies under local conditions / catchments.

**Applied research.** Draws on the world body of scientific knowledge in developing new technology in response to identified problems; for example the development of a riparian plant variety free of a specific disease or the development of a specific prediction technology.

**Diagnostic research.** Focuses on the acquisition of new understanding and is problem directed; for example the identification of disease causing agents in a river fish population.

**Basic research.** Focuses on acquisition of new understanding, but is not problem-directed; for example the mechanism of absorption of a toxic element through the gills of a fish species.

**Table 3.1.** Relationship of research components to science / technology development and to knowledge dissemination / adoption.

| SCIENCE / KNOWLEDGE | Types of research | Basic > Diagnostic > Applied > Adaptive > Participatory | | DISSEMINATION | ADOPTION |
|---|---|---|---|---|---|
| | Products | Science development | Technology development | | |
| | | Disciplinary | Multidisciplinary | | |
| | | Single location | Multi locational | | |
| | | Controlled environment | Environmental interaction | | |
| | | Highly reproducible | Environmental specific | | |
| | Orientation to user | Remote | Proximate | | |
| | | Non participative | Highly participative | | |

## 5. APPROPRIATE TECHNOLOGY

The "demand driven" approach (based on the stakeholder needs assessment) requires, for its success, the development and availability of appropriate (relevant) and improved (new) technologies. In this connection the linkage with research is critically important, and over the last 20 years has led, in particular, to the evolution and adoption of systems based and participatory research.

## 6. DECISION SUPPORT & INFORMATION SYSTEMS

In order to make the newly developed technology user-friendly and to ensure that it is used and implemented, it has to be integrated in decision support and information systems. This integration will also link the newly developed technology with other technologies already in use and with existing information.

For the newly developed technology to assist in improving sustainable water and land use and catchment management, it must be made target-orientated, client-oriented, process-oriented and multidisciplinary through decision support and information systems (Hurni, 1997).

A key objective of the people-centred (bottom-up) approach to assess the needs and perceptions of water and land users is to capture and store local property user's knowledge. On the other hand, project managers and national policy makers require information at higher levels of organisation. Different levels of information and experiences now become documented and available, showing the applicability and cost-effectiveness of decision support and information systems technology. The integration of developed technology with decision support and information systems has an additional advantage in that collection of data through decision support and information systems could be easier, quicker and more cost effective, because of the involvement of the multi-level stakeholder framework.

Hutchinson and Toledano (1993) examined some of the elements of technology transfer as it determines the sustainable application and adoption of information systems technology to problems in water and land management. They *inter alia* discovered that, while a project team was fully capable of undertaking the computing aspects of demonstration, they had few links to the "real world" where the technology would be used. As a result, the research institutions could not define suitable problems to be addressed in demonstrations and had no mechanism for transferring the technology to the groups that would ultimately use it. The authors stressed the necessity of client (read stakeholder) involvement in the transfer of information systems technology in a participatory manner.

While information technologies are available to address most of the information needs, including the modelling approach, some basic questions still have to be resolved, such as the congruence between socio-biophysical boundaries (the *terrors* or resource management domains) and administrative boundaries (Pieri, 1997). The congruence between two initiatives (Landcare and ICM) that both have an impact on water quality, as identified in this investigation, have been discussed in Chapter 2.

## 7. TECHNOLOGY TRANSFER

Embodied in the proposed multi-level stakeholder framework (MLSF) strategy, is the transfer of new and appropriate technology. The integration of top-down and bottom-up actions is one of the prerequisites for technology transfer. The main aim of the MLSF strategy is to empower different stakeholders with knowledge, skills and technology, i.e. to transfer appropriate technology. By using a range of suitable mechanisms, methods and principles (e.g. facilitation, representation, participation, demonstration, etc.), an active and open communication environment is created which is conducive to the successful transfer of new and appropriate technology. According to Martin and Sherington (1997), approaches involving these mechanisms changed the model of technology development from a linear transfer of technology model to an iterative approach based on learning and modification.

Within the scope of technology transfer and user groups one can, according to Röling (1995), distinguish three very different, though internally consistent approaches to the way scientists interact with clients, namely (1) Transfer of Technology (TOT), (2) Consultancy and (3) Facilitation. TOT is the most prevalent, conventional type with which scientists are all familiar. It fits bureaucratic systems like a glove and delivers technology in 'packages' (e.g. reports). Consultancy involves most subject matter specialists in South Africa (e.g. soil scientists and hydrologists) who can deal with any aspect of a certain field and have a large repertoire of expertise, which they can draw upon according to the intake with the stakeholder (client) in question.

It is clear that a paradigm shift is needed in the direction of more facilitation and less consultancy and TOT. Facilitation is emerging in many countries as a distinct set of highly cohesive elements. Its focus is necessarily on recognising water and land users as experts in managing complex, diverse and variable agro-ecosystems and businesses. Unlike the other two types (TOT and consultancy), the facilitating process allows such policy goals as equity and sustainability to be addressed in addition to productivity and competitiveness.

*The demonstrated achievement of facilitation is that it can change water and land users from passive receivers of packages and routine appliers of chemicals into active and creative movers, and passive water and land user groups into vibrant hubs of self-help, learning and innovation.* Practices, learning, institutions and policy are the four elements of facilitation. Descriptions of the four elements of success of facilitation are:

1. **Practices**. Based on a system approach to mining / industrial site, cropping field, farm / forest / park or catchment. Use of natural processes and controls

e.g. community streamwatch. Low external input management of local resources. Building on diversity. Active resource development. Locality-specific application of general principles.

2. **Learning**. Water and land user takes expert decisions based on observation and agro-ecosystem analysis, using indicators and equipment that make things visible. Anticipation based on observation and understanding. Emphasis on discovery learning and collective local learning. This type of learning is very different from adopting add-on innovations and requires more time. An example is that of Participatory Rural Appraisal (PRA).
3. **Institutions**. Decentralised local learning networks of farmers and facilitators. Local property owner organisations, Landcare movements or catchment forums 'in charge' of process. Linkage to existing body of scientific knowledge, but not necessarily through research.
4. **Policies**. Financial support for labour intensive facilitation and for local networking (e.g. meeting and transport). Regulation of use of harmful chemicals. Market development for ecological products. Support of 'alternative actor networks'. Acceptance of multiple policy goals and trade-offs among them.

Röling (1995) sounds some warnings however. Many extension officers, managers and researchers persist in wanting to 'run' groups in stead of facilitating. Similarly some professional researchers regard Landcare or catchment groups as amateur competitors for scarce research funds. As a result, these researchers would be less than enthusiastic about co-operating in regional research programme planning to meet the needs identified by the community groups (Röling, 1995).

## 8. PARTICIPATORY RESEARCH

There is now widespread recognition, in name at least, that participatory R&D is critical for achieving sound natural resource management (Allen, 1997; Dent, 1999). It is considered important especially because it directly involves the process of technology transfer. Participatory research calls for a creative blend of traditional methods and new approaches aiming at the development of critical knowledge, i.e. technology transfer. By including unconventional techniques (such as 'learning by doing', 'discovery learning', 'group extension and – communication', 'facilitation', 'demonstration trials', etc.), the research methodology is demystified and put into the hands of the people. They can consequently use it as a tool of empowerment and emancipation by *inter alia* making new technology or the knowledge of experts, part of their own. According to Smith (1990; as quoted by Songh, 1995) participatory research is thereby directed at *both* the understanding *and* the practical transformation of these conditions. If, on the one hand, the regulative ideal of natural sciences is objectivity, for participatory research on the other it is "the integration of knowledge and purposeful action". Therefore, participatory and systems-based models of research can play a key role in this process by creating an effective learning environment for those involved.

Participatory research is underscored by an educational and political philosophy which claims that the more people are involved in an activity, the more they will appreciate, understand and take responsibility for it. The whole process is cognisant of the principles of adult learning (Knowles, 1990), action learning (Kolb, 1986) and good facilitation processes. Group processes, in particular, become very important.

Participatory research is supported by its advocates by two arguments: an ethical argument and a 'better research' argument. The ethical argument states that people have a right to be involved because:

- research which has the potential to impact on the social and financial fabric of a community requires stakeholder input and involvement;
- research carries the expectation that people / producers have to take on the innovations / recommendations; and

- involvement is inherent recognition that the recipients of research products have valid knowledge as well.

The argument that people participation results in 'better', more relevant research says that water and land users (including the local communities) have a much better understanding of constraints. Hence research which acknowledges these constraints can help to increase the chance that local operators remain willing to adopt outcomes. It therefore follows that it is possible to get stakeholder involvement in contentious issues, better research credibility, better research adoption and broader research perspectives (Marsh, 1998).

Participatory research has advantages and disadvantages, can operate at different levels of participation, is more appropriate in some circumstances than others and requires an 'enabling' environment (i.e. the three South African initiatives) to be effective.

A participatory process in research is a very effective way to turn research into an engine for development. Collion and Kissi (1995) described such a process, which was designed to bring research closer to users and other interest groups. All those involved in implementing the program (product) or in using its results will be represented in the group: researchers and research managers, users, development staff and ministry officials, input suppliers, etc.

Hurni (1997) introduced the sustainable development analysis (SDA) (Table 3.2) as supportive tools that can be potentially used to achieve participatory water and land management solutions at community level. SDA is preferably carried out by interdisciplinary teams, working with local and external stakeholders, in a transdisciplinary manner (i.e., using both scientific and local knowledge), to arrive at shared views on needs, options and constraints in order to be able to collaborate in efforts to promote sustainable development.

**Table 3.2.** Overview of the steps to be taken in analysing sustainability in a regional context, using sustainable development analysis according to Hurni (1997)

**Part 1: Participatory assessment**

- Problem formulation
- Definition of development goals
- Spatial typology (water and land use, ownership, resources, etc)
- Interactions between and among units and actors
- Dynamics of change (population, degradation, improvements, etc.)
- Assessment of sustainability (according to selected social, ecological and economic indicators)

**Part 2: Participatory development evaluation**

- Development visions as seen by different stakeholders
- Needs, options and constraints as seen by stakeholders
- Development synthesis
- Recommendations

While the SDA process has to start from the level of perceived problems, a crucial question is: Who defines the problem? There are a number of challenges and opportunities for research at problem-oriented levels. Better integration and co-ordination of these activities would greatly enhance the potential to improve the efficiency and avoid duplication of effort in strategy and applied research. Here, enhanced communication of all available information will be an important prerequisite. Multiple decision support systems, including GIS and technology databases such as the World Overview of Conservation Approaches and Technologies (WOCAT) database for soil and water conservation, provide excellent tools for negotiation processes at community levels and beyond.

The SDA is thus a tool for better land management in a specific case study and can be applied in situations where external and scientific groups are invited to assist local groups in developing their areas in a more sustainable way (Hurni, 1997).

## 9. PROJECT MONITORING AND EVALUATION

The primary aims of *monitoring* are to provide a basis for decisions on subsequent stages of the research, to formulate judgements on performance and to contribute to accountability for the use of resources. *Evaluation* assesses how far research has achieved its objectives and examines any unplanned outcomes.

Monitoring and evaluation (M & E) can be applied at numerous levels of natural resource research and fits well into the MLSF approach. The conventional hierarchies in developing countries, of projects within programmes within institutes within the national research service, represent a vertical dimension. Each of these levels may have horizontal links, for instance with donors or international research organisations, development programmes, NGO's, property owner organisations and so on. Projects and programmes can have a number of *purposes*, each requiring different M & E approaches (Farrington, Thirtle and Henderson, 1997).

What would be one of the greatest challenges within the MLSF, is, according to Allen (1997), to build mechanisms into this process to allow for learning, correction and adjustment by all parties concerned. To do this will require the development of clear sets of objectives and *indicators of success*, which will promote accountability and participation and which can be monitored and evaluated by the relevant decision-makers at all levels. For example, if we are serious about community-based, adaptive R&D approaches we will require clear sets of indicators of success which promote accountability and co-operation and which can be monitored and evaluated. For this purpose, Allen (1997) proposed and described participatory and systems-based evaluation models, which can help society to facilitate the implementation of monitoring and evaluation processes. Although these models are mentioned here as part of the context of this investigation, it must be pointed out that these models will need refining before it can be adopted by the KNPRRP. The work done by *inter alia* Dent (1995, 1996, 1998) showed that there is already a strong thrust of using systems-based models in, amongst other applications, monitoring and evaluation processes in South Africa.

# EXAMPLES OF THE PRACTICAL APPLICTION OF THE PROPOSED STRATEGY FOR WATER QUALITY RESEARCH AND TECHNOLOGY TRANSFER, BASED ON FIGURE 3.1

## PRACTICAL EXAMPLE 1

### 1. MULTI-LEVEL STAKEHOLDER FRAMEWORK

It is envisaged that the impetus of technology development and transfer must be born out of the different stakeholders. This 'need' for new or improved technology can be effectively assessed and negotiated within a framework, which link and integrate all the relevant stakeholders.

***Possible negotiation forum (horizontal integration):***
Catchment Management Agency (CMA)

### 2. NEEDS ASSESSMENT

| | |
|---|---|
| *Focus:* | Water quality issues |
| *Diagnoses:* | Researchable constraints (Technological gaps) |
| *Evaluation criteria:* | Research opportunities with highest priority |
| *Method:* | Negotiated agreement among all stakeholder representatives in the CMA; workshop using the Rogers and Bestbier (1997) approach. |

### 3. IDENTIFIED STAKEHOLDER NEEDS

| | |
|---|---|
| *Issue:* | Physical water quality – sediment yield |
| *Researchable constraint:* | Lack of accurate sediment yield values under different land management practices at the outlet of specific catchments. |
| *Best research opportunity:* | Prediction of sediment yield by means of an applicable erosion model. |

## 4. RESEARCH AND DEVELOPMENT

Important is the involvement of the relevant 'client' stakeholders during the identification of the category of research and the research aim and objectives.

***Applicable category of research:*** Adapted research (systems based)

***Research aim:***

To predict accurate sediment yield values under different land management practices for selected catchments, by means of systems based erosion model.

***Research objectives:***

- To evaluate and validate a suitable model for sediment yield prediction.
- To implement the model under various land management practices in selected catchments.

## 5. APPROPRIATE TECHNOLOGY

***Relevancy to stakeholder needs:*** Provision of accurate, quantitative sediment yield data.

***New and improved technologies:***

- Provision of a validated, process-based modelling system
- Provision of environmental management criteria on physical water quality, e.g. benchmarks, tolerance and threshold values, indicators, etc.

## 6. DECISION SUPPORT AND INFORMATION SYSTEM

***Applicable technology:*** Geo-information systems available on Internet or on request

## 7. TECHNOLOGY TRANSFER

***Suitable framework:*** Multi-level stakeholder framework

***Suitable structures:*** Catchment management agency, extension services, research programmes

***Suitable mechanisms:*** Interim feedback, workshops and demonstrations

## 8. PROJECT MONITORING AND EVALUATION

***Indicators of success:***

- Accuracy of prediction results
- Applicability and flexibility of modelling system under local conditions
- Provision and utilisation of quantitative sediment yield results
- Adoption by stakeholders

## PRACTICAL EXAMPLE 2

## 1. MULTI-LEVEL STAKEHOLDER FRAMEWORK

***Negotiation forum (horizontal integration):*** Catchment Management Agency (CMA)

## 2. NEEDS ASSESSMENT

***Focus:*** Water quality issues

***Diagnoses:*** Researchable constraints (technological gaps)

***Evaluation criteria:*** Research opportunities with highest priority

***Method:*** Negotiated agreement among all stakeholder representatives in the CMA

## 3. IDENTIFIED STAKEHOLDER NEEDS

| | |
|---|---|
| *Issue:* | Water quality |
| *Researchable constraint:* | Lack of awareness and knowledge of water quality conservation aspects among water and land users. |
| *Best research opportunity:* | Awareness campaign and the transfer of skills and information (knowledge) to water and land users. |

## 4. RESEARCH AND DEVELOPMENT

***Applicable category of research:*** Participatory research (systems based)

***Research aim:***

To implement effective water quality conservation practices by means of the transfer of skills and knowledge to water and land users.

***Research objectives:***

- To establish functional water and land user groups in the relevant catchments, i.e. 'Waterwatch' groups.
- To implement effective participatory research (demonstration "trials") and group extension actions to transfer knowledge and skills to the groups.

## 5. APPROPRIATE TECHNOLOGY

***Relevancy to stakeholder needs:*** Provision of skills and knowledge.

***New and improved technologies:***

- New information and skills that would improve the water quality conservation practices of water and land users, e.g. control of the dumping of harmful effluents in rivers, contouring of cultivated fields under row crops, etc.

## 6. DECISION SUPPORT AND INFORMATION SYSTEM

***Applicable approach:*** Pamphlets; "Waterwatch toolboxes"; newsletters, school curricula

## 7. TECHNOLOGY TRANSFER

***Suitable framework:*** Multi-level stakeholder framework

***Suitable structures:*** Waterwatch, catchment and other functional groups; water and land user associations; community networks and groups; Catchment management agency, extension services, research programmes

***Suitable mechanisms:*** Dynamic group extension activities, participatory research actions ad demonstrations, etc.

## 8. PROJECT MONITORING AND EVALUATION

***Indicators of success:***

- Rate of adoption of new skills and information by water and land users
- Degree of awareness, co-operation and involvement by water and land users
- Improvement of water quality in rivers.
- Improved participation in CMAs.
- Improved identification of water issues.
- 'Maturity' in discussion of issues.

# CHAPTER 4

## SURVEY OF PERCEIVED WATER QUALITY INFORMATION AND RESEARCH NEEDS: WATER USERS

### 4.1. INTRODUCTION

In the preceding chapters, a strategy for research and technology (knowledge) transfer in the KNPRRP has been proposed and two examples dealing with water quality have been provided. As part of the stated aims of this project, the team was required to determine the R & D needs of water users, by conducting a survey of their perceptions regarding: 1) the state of knowledge upon which decision-making is based, 2) the availability of technology to assist in decision-making, and, 3) to assess the perceived need to address the knowledge and technology gaps. It is therefore clear that the results of this survey will reflect the perceptions of the water users, regarding the water quality issues.

To accomplish the above within the ambit of the project and time available, the following approach was adopted. Using the strategy for water quality research and technology transfer, as proposed in Figure 3.1, steps 1, 2 and 3 (MLSF, Needs assessment and Stakeholder needs) was identified as relevant to accomplish this aim. Water quality issues were then identified, pertaining to KNPRRP and national rivers, and categorised (4.1.1). A questionnaire was designed based on the identified issues, and piloted within the team. A short list of names, comprising interested and affected parties from national down to individual levels (Table 2.1) was compiled, based on suggestions from within the team, as well as on discussions with other individuals (4.1.2). These seven individuals that we identified were then interviewed, using the questionnaire. This activity also served as an evaluation of this kind of survey, and the questionnaire itself.

Since the aim was to determine the perceptions of a small group of selected stakeholders regarding identified water quality issues, the results will reflect these perceptions (whether right or wrong), and the tables and responses should be interpreted in this context. These results might therefore differ from a survey of the true level of knowledge and availability of technology conducted by experts in their field. The results will indicate however (even though based on a sub-set of stakeholders), to what extend communication, as discussed in the previous chapters, will need to be considered if the proposed strategy for water quality research and technology transfer is adopted.

## 4.2. MATERIALS AND METHODS

The project team decided to design and administer a questionnaire to characterise the perceptions of various levels of stakeholders in order to derive a needs assessment.

### 4.2.1. Design of the questionnaire

To determine the perceptions of water users regarding water quality, a questionnaire was designed to survey the following:

- Existing knowledge of the water quality issues
- Available technology for dealing with the water quality issues
- Need for information and technology on the water quality issues.

It was not the aim of this exercise to compare and contrast the scored perceptions of the respondents with the real state of affairs regarding available technologies, policies or management infrastructure.

To identify water quality issues, South African literature was screened to identify all possible current issues concerning water quality of the perennial rivers flowing through the Kruger National Park (KNP). Some international literature was also screened to identify additional water quality issues not identified in South African literature, which could be applicable to the KNP rivers. The questionnaire was also designed to address the perceptions specific to the Sabie / Sand, Olifants and Crocodile River catchments. Appendix 1 provides an example of a questionnaire with the average scores entered.

The identified current issues concerning water quality of the perennial rivers flowing through the Kruger National Park were classified into categories (indicated by numerals) and aspects (indicated by bullets) within each category:

1. Desired state of rivers
   - Procedures / protocols to define the desired future state of a river in terms of water quality

2. Zoning of river reaches
   - Identification of representative reaches for research, monitoring and extrapolation of water quality conditions

3. Criteria (guidelines / thresholds / tolerance values)
   - Desired instream water quality criteria
   - Region-specific water quality criteria
   - Water quality tolerance and threshold values for selected biota
   - Thresholds of potential concern
   - Applicability of water quality criteria from elsewhere to local conditions
   - Water quality index (number and the period of variables higher than criteria)

4. Prediction technology
   - Responses of instream biota to changing water quality
   - Effect of water quality on wetlands
   - Likely impacts of catchment activities on water quality
   - Effect of flow modification on water quality
   - Effect of wetlands on water quality
   - Linking of terrestrial and aquatic systems
   - Factor based / empirical models for use in information- and decision support systems
   - Conceptual models for water quality processes in the river and catchment

- Simulation models to describe present water quality conditions and to predict future conditions

5. Monitoring of water quality
   - Monitoring system of biological, chemical and physical characteristics of water
   - Monitoring database of biological, chemical and physical characteristics of water
   - Identification of trends of biological, chemical and physical characteristics of water from monitoring database

6. Impacts on river water quality
   - Point source pollution as a result of mining, power generation, wood / paper milling, agricultural, aquacultural, construction and domestic activities
   - Non-point source pollution from agriculture, forestry and air pollution
   - Aquatic weeds / Alien invaders / seed pollution
   - Land use type and pressure
   - Alteration in land use and management practices

7. Management of water quality
   - Water quality situation assessment
   - Risk assessment
   - Water quality management plans
   - Managing water reserve with regard to water quality
   - Use of whole catchment-scale approach in managing water quality
   - Use of indigenous / traditional practices in managing water quality

8. Policy on water quality
   - Policy regarding protection and rehabilitation of aquatic ecosystems in relation to water quality

9. Technology transfer / training / communication
   - Dissemination of knowledge and skills to all stakeholders (empowerment)

- Information systems – catchment / applied / geographic
- Decision support systems
- Workshops
- Conferences
- Effective functioning of catchment forums
- A multi-level stakeholder framework (bottom-up and top-down)
- Use of community based programmes (e.g. Landcare, Streamwatch, Riverwatch)
- Use of participatory learning and / or technology transfer methods (e.g. "on-site research" and PRA)

### 4.2.2. Completion of the questionnaire

The questionnaire was piloted among the members of the project team and informal consultation with few interested parties. According to the comments received, the questionnaire was refined. The scope of the questionnaire was such, that it became obvious to the team that a postal distribution would unlikely result in an acceptable return rate. It was decided that team members would administer the questionnaires in contact interviews, especially in the light of some of the technical aspects that would need further explanation to non-technical respondents.

*Selection of respondents*

The multi-level (hierarchical) stakeholder framework as proposed in **Table 2.1** was used to identify stakeholders on all the levels of decision-making. A list of candidates was compiled from various sources, as well as through communication with some members of the Steering Committee. Because of the scope of the project, seven questionnaires were completed, based on recommendations, availability of individuals, and availability of time and financial resources. These respondents may represent one (preferably) or more stakeholder groups.

Appointments for interviews were made with the respondents. In most cases at least two members of the project team were present during the completion of the questionnaire. An introductory discussion was held, and the purpose of the questionnaire explained. It was stressed that this was a survey of the perceptions of the respondents, and as such, there were no "right" or "wrong" answers. The respondents were also made attentive of the option "not qualified to comment" throughout the interview. During the interview explanatory comments were provided whenever interpretation of the categories and aspects were needed, and to ensure consequent use and interpretation of terminology between respondents, but care was taken not to force a specific rating. The presence of at least two team members ensured continuity. One member was mostly occupied with entering the ratings, while the other was guiding the respondent through the questionnaire.

*Perception rating system*

The respondents' perceptions of the different categories and aspects were rated as follows. The abbreviations in brackets will be used in the relevant tables, reflecting the mean perception scores of the respondents for the categories and aspects.

**Existing level of knowledge:**

(Knowledge and / or information which give insight into the specific issue)

0 = not qualified to comment

1 = no work done (NOWO)

2 = some work commenced (COMM)

3 = some work completed (COMP)

4 = substantial work completed (SUBST)

**Availability of technology**:

Technology (e.g. models, instruments, methods, techniques, criteria) to investigate the specific issue)

0 = not qualified to comment

1 = none

2 = some

3 = moderate

4 = abundant

**Information need:**

0 = not qualified to comment

1 = not important, no need

2 = limited importance, nice to have

3 = important, not urgent

4 = important and urgent

The difference between 3 and 4 above was explained to the respondents such that 4 include an immediate needs requirement.

Additional water quality aspects could be listed in open lines after each category. Comments could be made in the open lines for comments. Appendix 1 is an example of a completed questionnaire.

NOTE: The respondents were not required to motivate their answers.

4.2.3. Processing of questionnaire results

*Data analysis of perception scores: catchments and stakeholder groups*

The ratings of the seven respondents were summarised by calculating the mean of the ratings (1 – 4) for each category per catchment and per stakeholder group. The means were rounded of to the nearest 0.5. A rating of 0 (not qualified to comment) was not included in the calculations (See Appendix 1 and 2 for means of the category responses per catchment and per stakeholder group, respectively). Means that are in *italics* indicate categories where more than half of the respondents scored a 0.

The means of the categories were calculated by using the means of the aspects of that specific category. This was done to evaluate the perceptions of the respondents in general and to compare between catchments and stakeholder groups with regard to water quality.

The scores were reflected in the relevant tables by using abbreviations of the perception rating system (4.2.2) as used in the questionnaire. Means scores of 0.5 will for example be reflected by NOWOR/COMM.

## 4.3. RESULTS AND DISCUSSION

For discussion purposes, stakeholder perceptions will be addressed first, irrespective of catchments, in order to examine the level of agreement between the stakeholder levels regarding different categories. This will provide an overall profile of the respondents, which will be useful when evaluating the detailed perceptions of the respondents for the various catchments. This will then be followed by a discussion on the scored perceptions of the respondents, regarding categories and aspects, relating to the different catchments.

### 4.3.1. Stakeholder groups

The mean scores between the different stakeholder groups showed good agreement (Appendix 2, all categories), with no major or notable differences or exceptions. The representatives of the different stakeholder groups, based on our sample, therefore seemed to share the same perceptions of the existing knowledge, availability of technology and the need for information on the various water quality issues. A possible reason for this apparent congruity is the limited number of respondents. Ways to obtain information from more respondents will be discussed in 4.4.

### 4.3.2. Catchments

#### 4.3.2.1. Categories

Table 4.1 is a summary of the results obtained from the questionnaire for the water quality categories in general and for the Sabie / Sand, Olifants and Crocodile catchments.

The ratings of the main issues were comparable between the catchments, except for the Olifants catchment that scored lower for the level of knowledge on *Methodology to define desired state of rivers; Policy formulation; and Technology transfer / training / communication on water quality.* The perceptions of water quality problems, and the need for water quality information and implemented catchment relevant technology, possibly the result of the more complex spectrum of water and land use in the Olifants catchment, might thus be reflected.

The perceived level of knowledge and availability of *Water quality prediction technology* scored higher overall when compared with the scores for the specific catchments. This could for instance reflect models that are available, but might not yet have been evaluated and / or adapted for the specific catchments.

Table 4.1. Mean perception scores of the KNPRRP water quality categories in general and for the different catchments. Note that more detailed evaluation of the aspects under the different categories follows in Tables 4.2 – 4.10. See text for more detailed explanations of the categories.

| Categories | Level of Knowledge | | | | Availability of Technology | | | | Information Need* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Desired state of rivers | COMP | COMP | COMM / COMP | COMP / SUBS | MOD / ABUN | MOD | MOD | MOD | URG | URG | URG | URG |
| 2. Zoning | COMP | COMP | COMP | COMP | MOD | MOD | MOD | MOD | URG | URG | URG | URG |
| 3. Criteria (guidelines / thresholds / tolerance values) | COMM / COMP | COMM / COMP | COMM / COMP | COMM / COMP | SOME / MOD | SOME / MOD | SOME / MOD | SOME / MOD | IMP/ URG | IMP/ URG | IMP/ URG | IMP/ URG |
| 4. Prediction technology | COMM | NOWOR / COMM | NOWOR / COMM | NOWOR / COMM | SOME | NONE / SOME | NONE / SOME | NONE / SOME | IMP/ URG | IMP/ URG | IMP/ URG | IMP/ URG |
| 5. Monitoring | COMP | COMP | COMP | COMP | MOD | MOD | MOD | MOD | URG | IMP/ URG | URG | URG |
| 6. Impacts on water quality | COMM | COMM | COMM | COMM | SOME / MOD | SOME / MOD | SOME / MOD | SOME / MOD | URG | URG | URG | URG |
| 7. Management of water quality | COMM | COMM | COMM / COMP | COMM / COMP | SOME / MOD | SOME / MOD | MOD | MOD | URG | URG | URG | URG |
| 8. Policy | COMP | COMP | COMM / COMP | COMP | MOD | MOD | MOD / ABUN | MOD / ABUN | URG | URG | URG | URG |
| 9. Technology transfer / training / communication | COMM / COMP | COMM / COMP | COMM | COMM / COMP | MOD | SOME / MOD | SOME / MOD | SOME / MOD | URG | IMP/ URG | IMP/ URG | IMP/ URG |

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* See text for discussion on tendency of respondents to rate many of the issues as "Urgent".

The perceived level of knowledge scored the lowest for *Prediction technology on water quality*, where little research seemed to have been done to evaluate, verify and adapt models and procedures for the conditions pertaining to the rivers flowing through the KNP. For none of the categories substantial research had been completed, but some research for categories such as *Methodology to define the desired state of rivers*, *Zoning of river reaches*, *Monitoring of water quality* and *Policy formulation* were perceived by the respondents to have been completed.

Few evaluated, verified and adapted *Prediction technologies* for water quality in the perennial rivers flowing through the KNP were perceived to be available. Some criteria and methods to determine *Impacts* on water quality, as well as methods to manage water quality were deemed available. A moderate amount of procedures and protocols were deemed available for defining the desired state of rivers and zoning of river reaches. Respondents nowhere indicated abundant technology for any of the categories.

The need for "Information, knowledge and technology" was scored as important for all the categories. However, the perceived need for "Information, knowledge and technology" on categories such as *Criteria*, *Prediction technology* and *Technology transfer / training / communication* was regarded as less urgent (i.e. important, not urgent) when compared with *Methodologies to define desired state of rivers*, *Zoning of river reaches*, *Monitoring and Management of water quality*, *Impacts and Policy on water quality*.

4.3.2.2. Aspects of categories

*Desired state of rivers*

Table 4.2 is a summary of the mean scores of the aspects on the *Desired state of rivers* category of the KNPRRP in general and for the different catchments.

There was a moderate amount of *Procedures, protocols and information* deemed to be available to define the desired future state of a river in terms of water quality for the Crocodile and Sabie / Sand catchments. However, for the rivers of the Olifants catchment, the respondents felt that additional research was urgently needed to obtain the necessary knowledge and information to define the desired state.

*Zoning of river reaches*

Table 4.3 is a summary of the mean scores of the aspects on the *Zoning of river reaches* category of the KNPRRP in general and for the different catchments.

The respondents felt that the identification of representative (benchmark) river reaches for research, monitoring and extrapolation of water quality conditions, can be done with the currently available experience, techniques and criteria.

*Water quality criteria*

Table 4.4 summarises the mean scores of the aspects on the category of water quality criteria of the KNPRRP in general and of the different catchments.

Table 4.2. Mean scores of the aspects on the *Desired state of rivers* of the KNPRRP in general and of the different catchments

| Categories | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Procedures / protocols to define the desired future state of a river in terms of water quality | COMP | COMP | COMM /COMP | COMP / SUBST | MOD / ABUN | MOD | MOD | MOD | URG | URG | URG | URG |
| Other: | | | | | | | | | | | | |
| Comments: | | | | | | | | | | | | |

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Table 4.3. Mean scores of the aspects on the *Zoning of river reaches* of the KNPRRP in general and of the different catchments

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Identification of representative (benchmark) reaches for research, monitoring and extrapolation of water quality conditions | COMP | COMP | COMP | COMP | MOD | MOD | MOD | MOD | URG | URG | URG | URG |
| Other: | | | | | | | | | | | | |
| Comments: | | | | | | | | | | | | |

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Table 4.4. Mean scores of the aspects on *Water quality criteria* of the KNPRRP in general and of the different catchments

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Desired in-stream water quality criteria | COMM /COMP | COMP | COMM /COMP | COMP | MOD | MOD | MOD | MOD | IMP/ URG | IMP/ URG | IMP/ URG | IMP/ URG |
| 2. Region-specific water quality criteria | COMM | COMM | COMM | COMM | SOME/ MOD | MOD | *MOD* | *MOD* | IMP/ URG | IMP/ URG | IMP/ URG | IMP/ URG |
| 3. Water quality tolerance and threshold values for selected biota | COMM /COMP | COMM /COMP | *COMM* | *COMM* | MOD | MOD | *SOME/ MOD* | *MOD* | IMP/ URG | URG | URG | URG |
| 4. Thresholds of potential concern | COMM /COMP | COMM /COMP | COMM /COMP | COMP | SOME/ MOD | *NONE/ SOME* | *NONE/ SOME* | *NONE/ SOME* | IMP/ URG | URG | URG | URG |
| 5. Applicability of water quality criteria from elsewhere to local conditions | COMM | COMM | *COMM* | *COMM* | SOME/ MOD | *SOME/ MOD* | *SOME* | *SOME* | IMP | IMP | IMP | IMP |
| 6. Water quality index (number and the period of variables higher than criteria) | COMM | *COMM* | *COMP* | *COMP* | SOME | *SOME* | *MOD* | *MOD* | IMP | IMP | IMP | IMP |
| Other: | | | | | | | | | | | | |
| Comments: 1. Good tools, but need for local species<br>2. Need vulnerability criteria for high biodiversity areas<br>3. Make limited use of inorganic toxics<br>4. Sediment yield must get special attention | | | | | | | | | | | | |

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Although the respondents felt that there was a moderate amount of good procedures and techniques available to determine desired in-stream and regional specific criteria for water quality (e.g. tolerance and threshold values for selected biota), few of these criteria have been determined. Thresholds of potential concern (TPCs), that were deemed to be urgently needed, have not yet been determined because few procedures were judged to be in place to determine this. The applicability of water quality criteria from other regions to conditions of the rivers flowing through the KNP has not yet been evaluated. However, the need to do this evaluation is perceived to be important, but not urgent.

The respondents felt that research was urgently needed to develop and refine procedures for the determination of thresholds of potential concern and water quality criteria for specific river reaches. The determination of criteria for sediment yield / turbudity for selected biota and vulnerability criteria for high biodiversity areas must get special attention, according to the perception scores.

*Prediction technology*

Table 4.5 summarises the mean scores of the aspects of the *Prediction technology* category for the KNPRRP in general, and for the different catchments.

Although an abundant amount of technologies, like models and methods, were judged to be available (also internationally) to predict water quality, only a few of these technologies were perceived to be in use for the Sabie / Sand, Olifants and Crocodile catchments. According to the respondents, few models and methods have been validated, adapted for specific KNP catchments.

Table 4.5. Mean scores of the aspects on *Prediction technology* of the KNPRRP in general and for the different catchments

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Responses of instream biota to changing water quality | COMM | NOWO/ COMM | *NOWO* | *NOWO* | SOME/ MOD | SOME | *NONE/ SOME* | *NONE/ SOME* | IMP/ URG | URG | *URG* | *URG* |
| 2. Effect of water quality on wetlands | COMM | *NOWO/ COMM* | *NOWO/ COMM* | *NOWO/ COMM* | NONE/ SOME | NONE/ SOME | *NONE/ SOME* | *NONE/ SOME* | IMP | IMP/ URG | *IMP/ URG* | *IMP/ URG* |
| 3. Likely impacts of catchment activities on water quality | COMM | NOWO/ COMM | COMM | COMM | SOME | NONE/ SOME | NONE/ SOME | NONE/ SOME | IMP/ URG | URG | URG | URG |
| 4. Effect of flow modification on water quality | COMM | *NOWO* | COMM | *NOWO/ COMM* | SOME | *NONE* | *SOME* | *NONE/ SOME* | URG | URG | URG | URG |
| 5. Effect of wetlands on water quality | COMM | *NOWO* | *NOWO* | *NOWO* | SOME | *NONE* | *NONE* | *NONE* | *IMP* | *IMP/ URG* | *IMP/ URG* | *IMP/ URG* |
| 6. Linking of terrestrial and aquatic systems | NOWO | NOWO | *NOWO* | *NOWO* | NONE | NONE | *NONE* | *NONE* | *IMP* | *IMP/ URG* | *IMP/ URG* | *IMP/ URG* |

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Table 4.5. (Continued)

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 7. Factor based / empirical models for use in information- and decision support systems | *COMM* | *NOWO* | *NOWO* | *NOWO* | *SOME* | *NONE* | *NONE* | *NONE* | URG | *IMP/ URG* | *IMP/ URG* | *IMP/ URG* |
| 8. Conceptual models for water quality processes in the river and catchment | *COMP* | *NOWO* | *NOWO* | *NOWO* | *MOD* | *NONE* | *NONE* | *NONE* | URG | *IMP/ URG* | *IMP/ URG* | *IMP/ URG* |
| 9. Simulation models to describe present water quality conditions and to predict future conditions | *COMP* | *NOWO* | *NOWO/ COMM* | *NOWO* | *MOD* | *NONE* | *NONE* | *NONE* | URG | *IMP/ URG* | *IMP/ URG* | *IMP/ URG* |
| Other: | | | | | | | | | | | | |

Comments: 1. Models must be practical, applicable and users friendly

2. Abundant technology not used

3. Linking of terrestrial and aquatic systems important

| | | | | | |
|---|---|---|---|---|---|
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| COMM | = SOME WORK COMMENCED | SOME | = SOME TECHNOLOGY IS AVAILABLE | LIM | = LIMITED IMPORTANCE |
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The results (Table 4.5) also showed that research was needed to determine the applicability and the shortcomings of models and methods to predict the impact of water quality on river and wetland ecosystems, as well as the impacts of in-stream and catchment activities on water quality. Attention must also be given to models that link terrestrial and aquatic systems, because catchment activities can have a big impact on the water quality of rivers (this relationship was stressed by a number of respondents).

*Monitoring of water quality*

Table 4.6 summarises the mean scores of the aspects of the *Monitoring of water quality* category of the KNPRRP in general and for the different catchments.

The systems and technology to monitor the various biological, chemical and physical characteristics of water were in general sufficient, according to the respondents. However, the monitoring of heavy metals, microbiological and toxic compounds regarding human health, sediment yield, turbudity and temperature needed further attention. Existing data on monitored biological and chemical characteristics of water can be easily extracted via a data extraction user-interface integrated with a computerised databank, but is not currently available to most users. Some work was needed to include toxic compounds and physical characteristics such as sediment yield and turbudity to this databank. The respondents also identified an urgent need to extract the monitored data through the Internet.

*Impacts on water quality*

Table 4.7 summarises the mean scores of the aspects on the *Impacts on water quality* category of the KNPRRP in general and for the different catchments.

Table 4.6. Mean scores of the aspects on *Monitoring of water quality* of the KNPRRP in general and for the different catchments

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Biological characteristics of water (including river health)<br>▪ Monitoring system | COMM/ COMP | COMP | COMM/ COMP | COMP/ SUBST | ABUN | MOD/ ABUN | MOD/ ABUN | MOD/ ABUN | IMP | IMP/ URG | IMP/ URG | IMP/ URG |
| ▪ Monitoring database | COMP | COMP | COMP | COMP | MOD/ ABUN | MOD/ ABUN | MOD | MOD/ ABUN | URG | IMP/ URG | URG | IMP/ URG |
| ▪ Identification of trends | COMM/ COMP | COMM/ COMP | COMM/ COMP | COMM/ COMP | MOD | MOD | MOD | MOD | IMP/ URG | IMP/ URG | URG | IMP/ URG |
| 2. Chemical characteristics of water<br>▪ Monitoring system | COMP/ SUBST | COMP/ SUBST | COMP/ SUBST | COMP/ SUBST | MOD/ ABUN | MOD/ ABUN | ABUN | ABUN | URG | IMP/ URG | URG | IMP/ URG |
| ▪ Monitoring database | COMP | COMP | COMP/ SUBST | COMP/ SUBST | MOD/ ABUN | MOD | ABUN | ABUN | URG | IMP/ URG | URG | IMP/ URG |
| ▪ Identification of trends | COMM/ COMP | COMM/ COMP | COMM/ COMP | COMM/ COMP | MOD/ ABUN | MOD/ ABUN | *ABUN* | *ABUN* | URG | URG | URG | IMP/ URG |

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Table 4.6. (Continued)

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 3. Physical characteristics of water ▪ Monitoring system | COMM/ COMP | COMM | COMM/ COMP | COMM/ COMP | MOD | SOME/ MOD | MOD | SOME/ MOD | URG | URG | URG | IMP/ URG |
| ▪ Monitoring database | COMM/ COMP | COMM | COMM | COMM | MOD | SOME/ MOD | MOD | MOD | URG | URG | URG | URG |
| ▪ Identification of trends | COMM | COMM | COMM | COMM | MOD | SOME/ MOD | MOD | MOD | URG | URG | URG | URG |
| Other: Microbiological aspects regarding human health | *COMM* | *NOWO* | *NOWO* | *NOWO* | *MOD* | *MOD* | *MOD* | *MOD* | *URG* | *URG* | *URG* | *URG* |
| Other: Toxic element aspects regarding human health | *COMP* | *COMM* | *COMP* | *COMP* | *MOD* | *MOD* | *MOD* | *MOD* | *IMP* | *IMP* | *IMP* | *IMP* |
| Other: | | | | | | | | | | | | |
| Comments: 1. Monitoring of heavy metals needed<br>2. Monitor sediment yield and turbudity, but not temperature<br>3. Need monitored data on Internet e.g. website | | | | | | | | | | | | |

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Table 4.7. Mean ratings of the issues on impacts on water quality of the KNPRRP in general and of the different catchments

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Point source pollution<br>• Mining | COMP | | COMP | COMM | MOD | | MOD ABUN | MOD | URG | | URG | URG |
| • Power generation | COMP | | COMP | | MOD/ ABUN | | SOME/ MOD | | IMP/ URG | | IMP/ URG | |
| • Wood / paper milling | COMP | COMM/ COMP | | NOWO/ COMM | MOD | SOME | | SOME | IMP/ URG | IMP/ URG | | IMP/ URG |
| • Agriculture | NOWO/ COMM | NOWO | NOWO | NOWO | MOD | SOME | SOME | SOME | IMP/ URG | IMP/ URG | IMP/ URG | IMP/ URG |
| • Aquaculture | COMM | COMM | NOWO/ COMM | COMM | SOME/ MOD | SOME/ MOD | SOME/ MOD | MOD | IMP/ URG | IMP/ URG | IMP/ URG | URG |
| • Construction activities | COMM | COMM | COMM | COMM | SOME/ MOD | SOME/ MOD | SOME/ MOD | SOME/ MOD | IMP/ URG | URG | URG | URG |
| • Domestic (formal) | COMP | NOWO/ COMM | COMM | COMM | SOME/ MOD | MOD | SOME/ MOD | SOME/ MOD | IMP/ URG | IMP/ URG | IMP/ URG | IMP/ URG |
| • Domestic (informal) | NOWO | NOWO | NOWO | NOWO | MOD | SOME/ MOD | SOME | SOME | URG | URG | URG | URG |
| • Other: Kruger National Park rest camps | NOWO | NOWO | NOWO | NOWO | NONE | NONE | NOWO | NOWO | URG | URG | URG | URG |
| • Other: | | | | | | | | | | | | |

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Table 4.7. (Continued)

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 2. Non-point source pollution through *inter alia* erosion<br>▪ Agriculture | COMM | COMM | *NOWO/ COMM* | *COMM* | SOME/ MOD | SOME/ MOD | *SOME/ MOD* | SOME/ MOD | URG | URG | *URG* | URG |
| ▪ Forestry | COMM/ COMP | COMP | *COMM/ COMP* | *COMM/ COMP* | SOME/ MOD | SOME/ MOD | *SOME/ MOD* | SOME/ MOD | URG | IMP/ URG | *URG* | IMP/ URG |
| ▪ Air pollution | COMM/ COMP | *COMM* | *COMP* | *COMM/ COMP* | SOME | SOME | MOD | SOME/ MOD | IMP/ URG | IMP | URG | IMP |
| ▪ Other: Kruger National Park (1 stakeholder) | *COMP* | *COMP* | *COMP* | *COMP* | *SOME* | *SOME* | *SOME* | *SOME* | *URG* | *URG* | *URG* | *URG* |
| ▪ Other: | | | | | | | | | | | | |

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Table 4.7. (Continued)

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 3. Aquatic weeds / Alien invaders / seed pollution | *COMM/ COMP* | *NOWO/ COMM* | *NOWO* | *NOWO/ COMM* | MOD | SOME/ MOD | *SOME/ MOD* | SOME/ MOD | IMP | *IMP* | *IMP* | *IMP/ URG* |
| 4. Land use type and pressure | COMM | NOWO/ COMM | *NOWO/ COMM* | NOWO/ COMM | SOME/ MOD | SOME | *SOME* | *SOME* | IMP/ URG | URG | *IMP/ URG* | IMP/ URG |
| 5. Alteration in land use and management practices | COMM | COMM | NOWO/ COMM | NOWO/ COMM | SOME | SOME/ MOD | SOME | SOME | URG | URG | URG | URG |
| 6. Contaminated sites | COMM | NOWO | *COMM* | *NOWO/ COMM* | SOME | SOME | SOME/ MOD | SOME | IMP/ URG | URG | URG | URG |
| Other: Malaria control | *COMM* | | | | *MOD* | | | | *URG* | | | |
| Other: | | | | | | | | | | | | |

Comments:
1. Impact of Aquaculture in Crocodile is a very important
2. Impact of Agriculture on sediment yield in Olifants important
3. Impact of RDP houses next to Sabie-Sabie needs urgent attention
4. Impacts of breakage of dams on water quality

| | | | | | |
|---|---|---|---|---|---|
| NOWO | = NO WORK DONE | NONE | = NO TECHNOLOGY IS AVAILABLE | NOT | = NOT IMPORTANT |
| COMM | = SOME WORK COMMENCED | SOME | = SOME TECHNOLOGY IS AVAILABLE | LIM | = LIMITED IMPORTANCE |
| COMP | = SOME WORK COMPLETED | MOD | = MODERATE AMOUNT TECHNOLOGY | IMP | = IMPORTANT, NOT URGENT |
| SUBST | = SUBSTANTIAL WORK COMPLETED | ABUN | = ABUNDANT TECHNOLOGY IS AVAILABLE | URG | = IMPORTANT AND URGENT |

Few studies were deemed to have been conducted to determine quantitatively the impact of water and land uses on poor water quality for (problem) river reaches. More was known on the impact of point source pollution than on non-point source (diffuse) pollution. Some research was known to have been done on the impacts of point source pollution of the mining, power generation, paper and wood milling, aquaculture and formal domestic sectors. However, according to the respondents, little was known on the impacts of point source pollution of agriculture, rest camps of parks and the informal domestic sector. Although some research was done on the impact of non-point source pollution on water quality, the respondents expressed the need for a great deal more knowledge and information. They also perceived that very little research has been done on the impact of aquatic weeds / alien invaders / seed pollution. The impacts of contaminated sites on water quality have also not yet been quantified

The results showed that the respondents felt that a great deal more research was needed to quantify and predict trends of the impacts of water and land uses on water quality. They identified urgent work to be done to determine the impacts of point source pollution of the informal domestic sector, aquaculture and rest camps of parks, as well as for non-point source pollution of the agricultural sector. This was especially also the case for sediment yield in the Olifants catchment and the impact of breakage of dams on water quality. Of the three catchments, there was unanimous agreement that the Olifants required the most urgent attention regarding impacts of water and land uses on water quality.

*Managing water quality*

Table 4.8 summarises the mean scores of the aspects on the *Managing water quality* of the KNPRRP in general and for the different catchments.

Table 4.8. Mean scores of the aspects on *Managing water quality* of the KNPRRP in general and for the different catchments

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Water quality situation assessment | COMP | COMM/ COMP | *COMP* | *COMP* | MOD/ ABUN | MOD/ ABUN | *MOD/ ABUN* | *MOD/ ABUN* | IMP/ URG | URG | IMP/ URG | IMP/ URG |
| 2. Risk assessment | COMM | *NOWO* | *COMM* | *COMM* | SOME | *NONE/ SOME* | *NONE/ SOME* | *NONE/ SOME* | IMP/ URG | IMP/ URG | *URG* | *URG* |
| 3. Water quality management plans | COMM | COMM | *COMP* | *COMP* | SOME/ MOD | MOD | *MOD* | *MOD* | IMP/ URG | IMP/ URG | IMP | IMP |
| 4. Managing the water reserve with regard to water quality | COMM | COMM/ COMP | *COMP* | COMM/ COMP | SOME/ MOD | MOD | MOD | MOD | IMP/ URG | IMP/ URG | IMP/ URG | IMP/ URG |
| 5. Use of whole catchment-scale approach in managing water quality | COMM/ COMP | COMM/ COMP | *COMP* | COMM/ COMP | SOME/ MOD | MOD | *MOD* | MOD | IMP/ URG | IMP/ URG | IMP/ URG | IMP/ URG |
| 6. Use of indigenous / traditional practices | *NOWO* | *NOWO/ COMM* | | | *NOWO/ COMM* | *NOWO/ COMM* | | | *IMP/ URG* | *URG* | *URG* | *URG* |
| Other: | | | | | | | | | | | | |
| Comments: 1. Good management is important, especially on whole catchment scale | | | | | | | | | | | | |

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|---|---|---|---|---|---|
| NOWO | = NO WORK DONE | NONE | = NO TECHNOLOGY IS AVAILABLE | NOT | = NOT IMPORTANT |
| COMM | = SOME WORK COMMENCED | SOME | = SOME TECHNOLOGY IS AVAILABLE | LIM | = LIMITED IMPORTANCE |
| COMP | = SOME WORK COMPLETED | MOD | = MODERATE AMOUNT TECHNOLOGY | IMP | = IMPORTANT, NOT URGENT |
| SUBST | = SUBSTANTIAL WORK COMPLETED | ABUN | = ABUNDANT TECHNOLOGY IS AVAILABLE | URG | = IMPORTANT AND URGENT |

According to respondents, no work was known to integrate indigenous / traditional practices with conventional practices and methods to manage water quality. There is a moderate amount of technology available to assess the water quality situation, to manage the water reserve with regard to water quality, and to draw up water quality management plans. Few river-specific methods and criteria were known to be available for risk assessments.

Research was felt to be needed to integrate indigenous / traditional practices and local knowledge with conventional practices and methods to manage water quality. The refinement of water quality risk assessment methodologies and criteria for specific river reaches is urgently needed for the Olifants and Crocodile catchments.

*Policies regarding water quality*

Table 4.9 summarises the mean perception scores of the aspects on *Policies regarding water quality* category of the KNPRRP in general and for the different catchments.

The respondents felt that adequate work was done on policy formulation regarding protection of aquatic ecosystems in relation to water quality. They did however, identify an urgent need for a policing policy to enforce the existing policies. Comments were made that most water quality management activities will only result in restricted improvement in an environment where adherence to policies and regulations was not monitored.

*Technology transfer / training / communication of water quality issues*

Table 4.10 Summarises the mean scores of the aspects on the *Technology transfer / training / communication of water quality* category of the KNPRRP in general and for the different catchments.

Table 4.9. Mean scores of the aspects on *Policies regarding water quality* of the KNPRRP in general and for the different catchments

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Policy regarding protection and rehabilitation of aquatic ecosystems in relation to water quality | COMP | COMP | COMP | COMM | MOD | *MOD* | *MOD/ ABUN* | *MOD/ ABUN* | URG | URG | *URG* | *URG* |
| Other: | | | | | | | | | | | | |
| Comments: 1. Policing is a problem<br>2. Need policing policy<br>3. Current Water Act better than previous one | | | | | | | | | | | | |

NOWO = NO WORK DONE
COMM = SOME WORK COMMENCED
COMP = SOME WORK COMPLETED
SUBST = SUBSTANTIAL WORK COMPLETED

NONE = NO TECHNOLOGY IS AVAILABLE
SOME = SOME TECHNOLOGY IS AVAILABLE
MOD = MODERATE AMOUNT TECHNOLOGY
ABUN = ABUNDANT TECHNOLOGY IS AVAILABLE

NOI = NOT IMPORTANT
LIM = LIMITED IMPORTANCE
IMP = IMPORTANT, NOT URGENT
URG = IMPORTANT AND URGENT

Table 4.10. Mean scores of the aspects on *Technology transfer / training / communication of water quality* of the KNPRRP in general and for the different catchments

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 1. Dissemination of knowledge and skills to all stakeholders (empowerment) | COMM | COMM/ COMP | COMP | COMM/ COMP | MOD | MOD | MOD | MOD | URG | URG | URG | URG |
| 2. Information systems – catchment / applied / geographic | COMM/ COMP | COMP | COMM | COMM/ COMP | SOME | SOME/ MOD | SOME | SOME/ MOD | IMP/ URG | IMP/ URG | IMP/ URG | IMP/ URG |
| 3. Decision support systems | COMM | COMP | *COMM* | *COMM/ COMP* | MOD | MOD | *MOD* | *MOD* | URG | *URG* | *URG* | *URG* |
| 4. Workshops | COMM/ COMP | COMM/ COMP | COMM/ COMP | COMM/ COMP | MOD | MOD | *MOD* | MOD | IMP | IMP | IMP | IMP |
| 5. Conferences | COMM | COMM | *COMM* | *COMM* | MOD | MOD | *MOD* | *MOD* | IMP | IMP | IMP | IMP |
| 6. Effective functioning of catchment forums | COMP | COMP | COMP/ ABUN | COMP | *SOME/ MOD* | SOME/ MOD | *SOME* | *SOME/ MOD* | URG | URG | URG | URG |
| 7. A multi-level stakeholder framework (bottom-up and top-down) | COMM/ COMP | COMP | COMP | COMM/ COMP | SOME | SOME/ MOD | SOME/ MOD | SOME/ MOD | URG | URG | URG | URG |

NOWO = NO WORK DONE
COMM = SOME WORK COMMENCED
COMP = SOME WORK COMPLETED
SUBST = SUBSTANTIAL WORK COMPLETED

NONE = NO TECHNOLOGY IS AVAILABLE
SOME = SOME TECHNOLOGY IS AVAILABLE
MOD = MODERATE AMOUNT TECHNOLOGY
ABUN = ABUNDANT TECHNOLOGY IS AVAILABLE

NOT = NOT IMPORTANT
LIM = LIMITED IMPORTANCE
IMP = IMPORTANT, NOT URGENT
URG = IMPORTANT AND URGENT

Table 2.10. (Continued)

| Aspects | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil | General | Sabie / Sand | Olifants | Crocodil |
| 8. Use of community based programmes (e.g. Landcare, Streamwatch, Riverwatch) | *NOWO/ COMM* | *COMM* | *COMM* | *COMP* | SOME | SOME/ MOD | SOME/ MOD | SOME/ MOD | URG | URG | URG | URG |
| 9. Use of participatory learning and/or technology transfer methods (e.g. "on-farm research" and PRA) and group extension methods (e.g. 'facilitation') | COMM | COMM | *NOWO/ COMM* | COMM | *SOME* | *MOD* | *MOD* | *MOD* | URG | IMP/ URG | IMP/ URG | IMP/ URG |
| Other: | | | | | | | | | | | | |
| Comments: | | | | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| NOWO | = NO WORK DONE | NONE | = NO TECHNOLOGY IS AVAILABLE | NOT | = NOT IMPORTANT |
| COMM | = SOME WORK COMMENCED | SOME | = SOME TECHNOLOGY IS AVAILABLE | LIM | = LIMITED IMPORTANCE |
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The respondents found that adequate information, methodologies and techniques were at hand, but not yet effectively used, on issues of dissemination of knowledge and skills to all stakeholders (empowerment), information- and decision support systems, and for effective functioning of catchment forums. The respondents felt that the KNPRRP should investigate ways to link-up with Landcare and to promote community streamwatch programmes. For rural communities, participatory research and group extension methods should be used for technology transfer / communication of water quality issnes.

## 4.4 SUMMARY OF PERCEIVED INFORMATION AND RESEARCH NEEDS

The above survey, although conducted with only a few respondents, has identified a number of areas of concern. The perceptions of the research needs, according to the respondents, are summarised from the tables in this section. Because the respondents were not required to motivate or further prioritise their answers, we cannot comment on the reasons and considerations behind their perceptions. The results do indicate that the differences between the level of knowledge and availability of technology on the one hand, and the urgency and importance of information needs as identified by the respondents on the other, show a strong research and implementation need for most of the categories, especially "Criteria" (3), "Prediction Technology" (4) and "Technology Transfer" (9).

Within the categories used in the survey, the greatest need was found by the respondents to be the implementation of validated and catchment-relevant prediction tools (e.g. models, methods and procedures). A great deal of research was also judged to be needed to refine water quality criteria for river reaches, to determine the impacts on water quality, to manage the quality of water, and to find effective ways to transfer and communicate water quality issues to all the different stakeholders.

Although the two categories of urgency (important and urgent; important, but not as urgent; see *Perception rating system* in 4.2.2) below were extracted from the questionnaire, no attempt was made to prioritise any of the issues identified relative to each other within these two categories. Therefore, the order in which they are presented below does not indicate any priority.

The **important and urgent** needs identified by the respondents for research on water quality were:

- Necessary knowledge / information to define the desired state for the rivers of the Olifants catchment.
- Procedures to determine thresholds of potential concern (TPCs).
- Refinement of water quality criteria specific for river reaches. The determination of criteria for sediment yield / turbudity for selected biota and vulnerability criteria for high biodiversity areas must get special attention.
- To include monitored data of heavy metals and physical characteristics to the databank of the data extraction user-interface system at the Water Quality Institute.
- Ways to extract the monitored data of biological, chemical and physical characteristics of water through the Internet.
- A policing policy to enforce the current policies on protecting the quality of aquatic systems.
- Effective ways to transfer / communicate water quality issues to all stakeholders.

The following issues were judged as **important, but not as urgent** by the respondents, for research on water quality:

- Selection and implementation of applicable models and methods to predict the impact of water quality on river and wetland ecosystems, and the impacts of in-stream and catchment activities on water quality for the catchments of the KNPRRP.
- Adaptation of models and methods to the conditions of the Sabie / Sand, Olifants and Crocodile catchments of the KNPRRP.
- Quantification of the impacts of water and land uses on water quality. The impacts of point source pollution of the informal domestic sector, aquaculture in the Crocodile catchment, rest camps of parks, as well as non-point source pollution by the

agricultural sector (especially sediment yield in the Olifants catchment) were mentioned.

- Quantification of the impacts of breakage of dams on water quality.
- Prediction of the trends of water and land uses on water quality.
- Integration of (applicable) indigenous / traditional practices and local knowledge with more formal water quality management.
- Ways to link-up with Landcare and other initiatives, and to promote community streamwatch programmes.

## 4.5 GENERAL SUMMARY OF SURVEY

Even though this survey was based on a limited number of respondents, the results do indicate that such a survey method, administered to more respondents from each of the different levels of stakeholders, will produce useful information to guide future research strategies for the KNPRRP, and also on a national scale. Such surveys will also provide guidelines on how water quality information can be communicated (within the proposed MLSF) to different levels, as well as the information needs (type of information) at those levels. Although the aim of the survey was not to compare the perceptions of the respondents with the existing technology and knowledge, there seemed to be a lack of adequate knowledge of such at the lower levels of the stakeholder framework. This in turn, indicates a need for improved communication of such aspects to those levels, which was also shown by their indicated information needs.

The questionnaire itself was considered by the team members (and many of the respondents) as too long. The interviews generally took at least three intensive hours to complete. We therefore do not recommend that this questionnaire be used in a general survey, but that it can serve as a base from which to design a more streamlined version. It is conceivable that different questionnaires need to be developed for stakeholders at different levels. Since this type of information gathering and interpretation is a specialised field of investigation, we propose that a sociologist be included in future needs assessments.

A section should also be added at the end of these questionnaires for the respondents to prioritise the identified needs. Such surveys can also serve to introduce the concepts of ICM and CMAs to many of the respondents, and establish the beginning of a communications network or 'soft system platform' as indicated in Chapter 2.

# CHAPTER 5

## CONCLUSION AND RECOMMENDATIONS

### 5.1 SUMMARY AND RECOMMENDATIONS

One of the significant contributions of the KNPRRP towards R&D, is the provision of a structure within which essential links could be established with different stakeholders, aimed at the development and transfer of appropriate technology. However, to build effective links, a combination of various mechanisms are needed at various levels of the institutional (formal and informal) hierarchy.

A number of initiatives were recently launched in South Africa, which provides an 'enabling environment' wherein these essential links could be established. These initiatives are Integrated Catchment Management (ICM) of the Department of Water Affairs and Forestry, the Landcare programme of the Department of Agriculture and Integrated Environmental Management (IEM) of the Department of Environmental Affairs and Tourism. The 'mechanisms' of integration, communication and participation which are shared by IEM, ICM and Landcare, appears to be of particular importance for the successful development and transfer of new technology.

**Recommendation 1.** We propose that a multi-level (hierarchical) stakeholder approach (MLSF) to sustainable natural resource management be considered (Figure 2.1) as the basis for further activity, as it shows promise for finding feasible, acceptable, viable and ecologically sound solutions at different scales.

The MLSF holds promise to serve as a platform from which to launch new research, decision support products, initiatives, as well as to serve as a framework for integration, communication and participation and consequently technology transfer.

A prominent and important part of the MLSF is the addition of, or a more widely employment of a bottom-up approach. The key to this is to place people at the centre of their own development by employing various 'soft system' methodologies, such as participatory approaches, mediation and methodologies for the facilitation of social learning. The MLSF approach, as proposed in this study, could consequently be viewed as a 'soft system platform' for water resource management and technology transfer in the KNPRRP.

Integrated catchment management planning plays an important role within the MLSF. The catchment (primary, secondary and tertiary catchments) is the level where the integration of top-down and bottom-up legs is the most prominent and forms an important link between the technology development (hard systems) and technology transfer (soft systems) activities.

Networks are a major key in the development and implementation phases in water and land management plans. The main reason for this is that they would usually be more advanced than the rest of the community in *inter alia* the dissemination and transfer of technology. Networks can grow in stature and importance through their planning strategies and can form a strong association with catchment management agencies (CMA's). This process puts pressure on catchment management agencies, as the community looks at issues in a broader context – thereby forcing specialists to work in a wider sphere with clients.

**Recommendation 2.** We propose a strategy by which water quality research, but also other water issues, can be addressed within the KNPRRP. This strategy is presented in Figure 3.1. and it features the MLSF as a focus for needs assessment and technology transfer.

The thrust by the KNPRRP to use a systems approach for better decision-making and research (e.g. to determine research priorities), will help scientists to give water and land managers useful answers for integrated water and land management planning in the

KNPRRP catchments. However, the shortage of new or improved technologies in general, which is further complicated by the fragmented nature of some of the research efforts, makes it difficult to relate the results of individual research projects to whole systems. Participatory and systems-based models of research can play a key role in 'the integration and transfer of knowledge and purposeful action' by creating an effective learning environment for those involved. Such an environment would need to be specifically created for each stakeholder group (e.g. catchment networks at a community level).

The idea that a system perceived as 'hard' (such as water resource modelling) requires a 'soft' platform to manage it sustainably have led to the formation of 'coupled systems'. Consistent with the notion of a coupled system, is the notion of adaptive management, which is viewed as crucial relevance for sustainable water and land management.

The introduction of a 'coupled system' approach means that computer-enhanced modelling, including such tools as GIS, simulation models, remote sensing and so forth, become tools for interactive learning, i.e., they are not only models for learning by scientists with some vague assumed impact on policy or public opinion, they are first and foremost tools for learning by water and land users themselves, and thus serve as a basis for technology transfer. Models (such as the installed modelling system for integrated water resources management on a catchment basis) are ideal catalysts and indeed vehicles to engage teams in deeper set of systems learning and allow them to experiment with the consequences of their thinking.

Based on the insights and approaches described above, it is clear that a series of changes in the practice of R&D within the KNPRRP is required if the adoption of new and appropriate technology by any stakeholder group is to become a reality. Starting at the workforce, advisors, scientists and administrators will require the motivation and skills required in inter-personal and group communication to become more effective 'salesmen' and facilitators than is presently the case. Generally, scientists know *what* to say to people, but they do not always know *how* to say it. The rural sociology and group dynamics approach to integrated catchment management and planning seems to be little used by the technology transfer advisors in these fields. Group learning in practical settings, coupled with the water resources modelling approach, is what is currently required on a greater scale.

**Recommendation 3.** We recommend that surveys via questionnaires be used to derive a needs assessment.

Within the proposed strategy and framework, surveys and questionnaires can be used for needs assessments for ICM and CMAs. The results of our limited survey indicate that the differences between the level of knowledge and availability of technology on the one hand, and the urgency and importance of information needs as identified by the respondents on the other, show a strong research and implementation need for most of the categories, especially *Criteria, Prediction Technology* and *Technology Transfer*.

The greatest need was found by the respondents to be the implementation of validated and catchment-relevant prediction tools (e.g. models, methods and procedures). A great deal of research was also judged to be needed to refine water quality criteria for river reaches, to determine the impacts on water quality, to manage the quality of water, and to find effective ways to transfer and communicate water quality issues to all the different stakeholders. Although this project concentrated on water quality issues, the proposed MLSF and research strategy can also be used to address many other water and land issues.

The questionnaire itself was considered by the team members (and many of the respondents) as too long. We therefore do not recommend that this questionnaire be used in a general survey, but that it can serve as a base from which to design a more streamlined version. It is conceivable that different questionnaires need to be developed for stakeholders at different levels. Since this type of information gathering and interpretation is a specialised field of investigation, we propose that a sociologist be included in future needs assessments. Such surveys can also serve to introduce the concepts of ICM and CMAs to many of the respondents, and establish the beginning of a communications network or 'soft system platform' as indicated in Chapter 2.

## 5.2 OBJECTIVES AND CUSTODIAN OF DATA OF THIS PROJECT

All the objectives of this project were met. The objective to compile an annotated list of the main interested and affected parties and their information and management needs was decided not to be exhaustive due to time and financial constraints. Due to the rapid ageing of the information, this section is not included in this report, but is available from the ARC-ISCW or the WRC.

Appendix 1 of this report shows the average ratings of the water quality issues in general and of the different catchments. The results for different stakeholder groups are not included in this report, but are available from the ARC-ISCW.

# CHAPTER 6

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# APPENDIX 1

## AVERAGE RATINGS OF THE WATER QUALITY ISSUES IN GENERAL AND OF THE DIFFERENT CATCHMENTS

| REFERENCE | CATCHMENT |
|---|---|
| G | Reflect the issues in general |
| S | Reflect the issues specific for Sabie / Sand |
| O | Reflect the issues specific for Olifant |
| C | Reflect the issues specific for Crocodile |

**RATING SYSTEM**

**Existing level of knowledge:**

*Knowledge and/or information which give insight into the specific issue.*

0 = not qualified to comment

1 = no work done

2 = some work commenced

3 = some work completed

4 = substantial work completed

**Availability of technology:**

*Implicates technology (e.g. models, instruments, methods, techniques, criteria) to investigate the specific issue.*

0 = not qualified to comment

1 = none

2 = some

3 = moderate

4 = abundant

**Information Need:**

0 = not qualified to comment

1 = not important, no need

2 = limited importance, nice to have

3 = important, not urgent

4 = important, urgent

Appendix 1. Average ratings of the water quality issues in general and of the different catchments

| Issues | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | S | O | C | G | S | O | C | G | S | O | S |
| 1. **Desired state of rivers** | | | | | | | | | | | | |
| 1.1 Procedures/protocols to define the desired future state of a river in terms of water quality | 3 | 3 | 2.5 | 3.5 | 3.5 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| 2. **Zoning** | | | | | | | | | | | | |
| 2.1 Identification of representative (benchmark) reaches for research, monitoring and extrapolation of water quality conditions | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |

Appendix 1. (Continued)

| Issues | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | S | O | C | G | S | O | C | G | S | O | C |
| **3. Criteria (guidelines / thresholds / tolerance values)** | | | | | | | | | | | | |
| 3.1 Desired instream water quality criteria | 2.5 | 3 | 2.5 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3.5 | 3.5 | 3.5 |
| 3.2 Region-specific water quality criteria | 2 | 2 | 2 | 2 | 2.5 | 3 | 3 | 3 | 3.5 | 3.5 | 3.5 | 3.5 |
| 3.3 Water quality tolerance and threshold values for selected biota | 2.5 | 2.5 | 2 | 2 | 3 | 3 | 2.5 | 3 | 3.5 | 4 | 4 | 4 |
| 3.4 Thresholds of potential concern | 2.5 | 2.5 | 2.5 | 3 | 2.5 | 1.5 | 1.5 | 1.5 | 3.5 | 4 | 4 | 4 |
| 3.5 Applicability of water quality criteria from elsewhere to local conditions | 2 | 2 | 2 | 2 | 2.5 | 2.5 | 2 | 2 | 3 | 3 | 3 | 3 |
| 3.6 Water quality index (number and the period of variables higher than criteria) | 2 | 2 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3.8 | | | | | | | | | | | | |

Comments:

3.3. Good tools, but need for local species

3.3. Need vulnerability criteria for high biodiversity areas

3.7. Make limited use of for inorganic toxics

Sediment yield must get special attention

Appendix **1**. (Continued)

| Issues | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | S | O | C | G | S | O | C | G | S | O | C |
| **4. Prediction technology**<br>*Please review the following issues with regard to the development, calibration and verification of prediction technology* | | | | | | | | | | | | |
| 4.1 Responses of instream biota to changing water quality | 2 | 1.5 | 1 | 1 | 2.5 | 2 | 1.5 | 1.5 | 3.5 | 4 | 4 | 4 |
| 4.2 Effect of water quality on wetlands | 2 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 3 | 3.5 | 3.5 | 3.5 |
| 4.3 Likely impacts of catchment activities on water quality | 2 | 1.5 | 2 | 2 | 2 | 1.5 | 1.5 | 1.5 | 3.5 | 4 | 4 | 4 |
| 4.4 Effect of flow modification on water quality | 2 | 1 | 2 | 1.5 | 2 | 1 | 2 | 1.5 | 4 | 4 | 4 | 4 |
| 4.5 Effect of wetlands on water quality | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 3.5 | 3.5 | 3.5 |
| 4.6 Linking of terrestrial and aquatic systems | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3.5 | 3.5 | 3.5 |
| 4.7 Factor based and/or empirical models for use in information- and decision support systems | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 4 | 3.5 | 3.5 | 3.5 |
| 4.8 Conceptual models for water quality processes in the river and catchment | 3 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 4 | 3.5 | 3.5 | 3.5 |
| 4.9 Simulation models to describe present water quality conditions and to predict future conditions, which inter alia simulate at daily time step, a range of spatial scales, based on physical processes, able to simulate a variety of land uses and the effect of subsurface flow on water quality | 3 | 1 | 1.5 | 1 | 3 | 1 | 1 | 1 | 4 | 3.5 | 3.5 | 3.5 |
| 4.10 | | | | | | | | | | | | |

Comments:

Models must be practical, applicable and users friendly

Abundant technology not used

**Appendix 1.** (Continued)

| Issues | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | S | O | C | G | S | O | C | G | S | O | C |
| **5. Monitoring** | | | | | | | | | | | | |
| 5.1 Biological characteristic of water (including river health) • Monitoring system | 3.5 | 3 | 2.5 | 3.5 | 4 | 3.5 | 3.5 | 3.5 | 3 | 3.5 | 3.5 | 3.5 |
| • Monitoring database | 3 | 3 | 3 | 3 | 3.5 | 3.5 | 3 | 3.5 | 4 | 3.5 | 4 | 3.5 |
| • Identification of trends | 2.5 | 2.5 | 2.5 | 2.5 | 3 | 3 | 3 | 3 | 3.5 | 3.5 | 4 | 3.5 |
| 5.2 Chemical characteristics of water • Monitoring system | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 4 | 4 | 4 | 3.5 | 4 | 3.5 |
| • Monitoring database | 3 | 3 | 3.5 | 3.5 | 3.5 | 3 | 4 | 4 | 4 | 3.5 | 4 | 3.5 |
| • Identification of trends | 2.5 | 2.5 | 2.5 | 2.5 | 3.5 | 3.5 | 4 | 4 | 4 | 4 | 4 | 3.5 |
| 5.3 Physical characteristics of water • Monitoring system | 2.5 | 2 | 2.5 | 2.5 | 3 | 2.5 | 3 | 2.5 | 4 | 4 | 4 | 3.5 |
| • Monitoring database | 2.5 | 2 | 2 | 2 | 3 | 2.5 | 3 | 3 | 4 | 4 | 4 | 4 |
| • Identification of trends | 2 | 2 | 2 | 2 | 3 | 2.5 | 3 | 3 | 4 | 4 | 4 | 4 |
| 5.4 Microbiological water quality aspects regarding human health (I stakeholder) | *2* | *1* | *1* | *1* | *3* | *3* | *3* | *3* | *4* | *4* | *4* | *4* |
| 5.5 Toxic element water quality aspects regarding human health (I stakeholder) | *3* | *2* | *3* | *3* | *3* | *3* | *3* | *3* | *3* | *3* | *3* | *3* |

Comments:

Monitoring of heavy metals needed

Monitor sediment yield and turbudity, but not temperature

Need monitored data on e.g. Website

**Appendix 1.** (Continued)

| Issues | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | S | O | C | G | S | O | C | G | S | O | C |
| **6. Impacts on river water quality** | 2 | 2 | 2 | 2 | 2.5 | 2.5 | 2.5 | 2.5 | 4 | 4 | 4 | 4 |
| 6.1 Point source pollution through *inter alia* effluent discharge<br>• Mining | 3 | | 3 | 2 | 3 | | 3.5 | 3 | 4 | | 4 | 4 |
| • Power generation | 3 | | 3 | | | | 2.5 | | 3.5 | | 3.5 | |
| • Forestry and wood / paper milling | 3 | 2.5 | | 1.5 | 3 | 2 | | 2 | 3.5 | 3.5 | | 3.5 |
| • Agriculture | 1.5 | 1 | 1 | 1 | 3 | 2 | 2 | 2 | 3.5 | 3.5 | 3.5 | 3.5 |
| • Aquaculture | 2 | 2 | 1.5 | 2 | 2.5 | 2.5 | 2.5 | 3 | 3.5 | 3.5 | 3.5 | 4 |
| • Construction activities | 2 | 2 | 2 | 2 | 2.5 | 2.5 | 2.5 | 2.5 | 3.5 | 4 | 4 | 4 |
| • Domestic (formal) | 3 | 2.5 | 2 | 2 | 2.5 | 3 | 2.5 | 2.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| • Domestic (informal) | 1 | 1 | 1 | 1 | 3 | 2.5 | 2 | 2 | 4 | 4 | 4 | 4 |
| (Other, specify) Kruger National Park rest camps (1 stakeholder) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 4 | 4 | 4 |
| 6.2 Non-point source pollution through *inter alia* erosion<br>• agriculture | 2 | 2 | 1.5 | 2 | 2.5 | 2.5 | 2.5 | 2.5 | 4 | 4 | 4 | 4 |
| • forestry | 2.5 | 3 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 4 | 3.5 | 4 | 3.5 |
| • air pollution | 2.5 | 2 | 3 | 2.5 | 2 | 2 | 3 | 2.5 | 3.5 | 3 | 4 | 3 |
| (Other, specify) Kruger National Park (1 stakeholder) | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 4 |

**Appendix 1.** (Continued)

| Issues | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | S | O | C | G | S | O | C | G | S | O | C |
| **Impacts on river water quality (continued)** | | | | | | | | | | | | |
| 6.3 Aquatic weeds / Alien invaders / seed **pollution** | 2.5 | 1.5 | 1 | 1.5 | 3 | 2.5 | 2.5 | 2.5 | 3 | 3 | 3 | 3.5 |
| 6.4 Land use type and land use pressure | 2 | 1.5 | 1.5 | 1.5 | 2.5 | 2 | 2 | 2 | 3.5 | 4 | 3.5 | 3.5 |
| 6.5 Alteration in land use and management | 2 | 2 | 1.5 | 1.5 | 2 | 2.5 | 2 | 2 | 4 | 4 | 4 | 4 |
| 6.6 Contaminated sites | 2 | 1 | 2 | 1.5 | 2 | 2 | 2.5 | 2 | 3.5 | 4 | 4 | 4 |
| 6.7 Malaria control (1 stakeholders) | 2 | | | | 3 | | | | 4 | | | |
| Comments: | | | | | | | | | | | | |
| 6.1 Impact of Aquaculture in Crocodile is very important issue | | | | | | | | | | | | |
| 6.1 Impact of RDP houses next to Sabie-Sabie needs urgent attention | | | | | | | | | | | | |
| 6.2 Impact of Agriculture on sediment yield in Olifants important issue | | | | | | | | | | | | |
| Impacts of breakage of dams on water quality | | | | | | | | | | | | |

**Appendix 1.** (Continued)

| Issues | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | S | O | C | G | S | O | C | G | S | O | C |
| **7. Management** | 2 | 2 | 2.5 | 2.5 | 2.5 | 2.5 | 3 | 3 | 3.5 | 4 | 4 | 4 |
| 7.1 Water quality situation assessment | 3 | 2.5 | *3* | *3* | 3.5 | 3.5 | *3.5* | *3.5* | 3.5 | 4 | 3.5 | 3.5 |
| 7.2 Risk assessment | 2 | *1* | *2* | *2* | 2 | *1.5* | *1.5* | *1.5* | 3.5 | 3.5 | *4* | *4* |
| 7.3 Water quality management plans | 2 | 2 | *3* | *3* | 2.5 | 3 | *3* | *3* | 3.5 | 3.5 | 3 | 3 |
| 7.4 Water reserve with regard to water quality condition | 2 | 2.5 | 3 | 2.5 | 2.5 | 3 | 3 | 3 | 3.5 | 3.5 | 3.5 | 3.5 |
| 7.5 Whole catchment-scale approach | 2.5 | 2.5 | *3* | 2.5 | 2.5 | 3 | *3* | 3 | 3.5 | 3.5 | 3.5 | 3.5 |
| 7.6 Indigenous / traditional practices | *1* | *1.5* | | | *1.5* | *1.5* | | | *3.5* | *4* | *4* | *4* |
| 7.7 | | | | | | | | | | | | |
| Comments:<br>Good management is important, especially on whole catchment scale | | | | | | | | | | | | |
| **8. Policy** | | | | | | | | | | | | |
| 8.1 Policy regarding protection and rehabilitation of aquatic ecosystems in relation to water quality | 3 | 3 | 3 | 2 | 3 | 3 | 3.5 | 3.5 | 4 | 4 | 4 | 4 |
| 8.2 | | | | | | | | | | | | |
| Comments:<br>Policing is a problem<br>Need policing policy<br>Current Water Act better than previous one | | | | | | | | | | | | |

Appendix 1. (Continue)

| Issues | | Level of Knowledge | | | | Availability of Technology | | | | Information Need | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | G | S | O | C | G | S | O | C | G | S | O | C |
| **9.** | **Technology transfer, training and communication** | | | | | | | | | | | | |
| 9.1 | Dissemination of knowledge and skills to all stakeholders (empowerment) | 2 | 2.5 | 3 | 2.5 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| 9.2 | Information systems – catchment / applied / geographic | 2.5 | 3 | 2 | 2.5 | 2 | 2.5 | 2 | 2.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| 9.3 | Decision support systems | 2 | 3 | 2 | 2.5 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 |
| 9.4 | Workshops | 2.5 | 2.5 | 2.5 | 2.5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 9.5 | Conferences | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 9.6 | Effective functioning of catchment forums | 3 | 3 | 3.5 | 3 | 2.5 | 2.5 | 2 | 2.5 | 4 | 4 | 4 | 4 |
| 9.7 | A multi-level stakeholder framework (bottom-up and top-down) | 2.5 | 3 | 3 | 2.5 | 2 | 2.5 | 2.5 | 2.5 | 4 | 4 | 4 | 4 |
| 9.8 | Community based programmes (e.g. Landcare, Streamwatch, Riverwatch) | 1.5 | 2 | 2 | 3 | 2 | 2.5 | 2.5 | 2.5 | 4 | 4 | 4 | 4 |
| 9.9 | Participatory learning and/or technology transfer methods (e.g. "on-farm research" and PRA) and group extension methods (e.g. 'facilitation') | 2 | 2 | 1.5 | 2 | 2 | 3 | 3 | 3 | 4 | 3.5 | 3.5 | 3.5 |
| 9.13 | | | | | | | | | | | | | |
| Comments: | | | | | | | | | | | | | |

# APPENDIX 2

## AVERAGE RATINGS OF THE WATER QUALITY ISSUES OF THE DIFFERENT STAKEHOLDER GROUPS

| REFERENCE | LEVEL | MAIN INTERESTED AND AFFECTED PARTIES |
|---|---|---|
| A | NATIONAL (± 1: 1 000 000) | National Departments of Water Affairs and Forestry, Environmental Affairs and Tourism and Agriculture and Land Affairs; national and international research organisations; National Parks Board |
| B | PROVINCIAL (± 1: 250 000) | Provincial Departments of Environmental Affairs and Tourism and Agriculture and Land Affairs; research institutions Provincial Park Boards |
| C | CATCHMENT (± 1: 50 000) | Catchment forums; research institutions, movements and programs; NGO's |
| D | NETWORKS (± 1: 25 000) | Communities; catchment networks; community associations; Working for Water; Landcare networks; NGO's; research groups and projects. |
| E | GROUPS (± 1: 10 000) | Land user (farmer) groups; water use groups; discussion groups; research and development groups; NGO's; Landcare groups; catchment groups; |
| F | INDIVIDUALS (± 1: 5 000) | Land users (commercial and small-scale farmers, private game farm and -park owners); water users and managers; private land owners; |

## RATING SYSTEM

### Existing level of knowledge:

*Knowledge and/or information which give insight into the specific issue.*

0 = not qualified to comment

1 = no work done

2 = some work commenced

3 = some work completed

4 = substantial work completed

### Availability of technology:

*Implicates technology (e.g. models, instruments, methods, techniques, criteria) to investigate the specific issue.*

0 = not qualified to comment

1 = none

2 = some

3 = moderate

4 = abundant

### Information Need:

0 = not qualified to comment

1 = not important, no need

2 = limited importance, nice to have

3 = important, not urgent

4 = important, urgent

Appendix 2. Average ratings of the **water quality issues of the different stakeholder groups**

| Issues | Level of Knowledge | | | | | | Availability of Technology | | | | | | Information Need | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | A | B | C | D | E | F | A | B | C | D | E | F |
| 1. **Desired state of rivers** | | | | | | | | | | | | | | | | | | |
| 1.1 Procedures/protocols to define the desired future state of a river in terms of water quality | 3.5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3.5 | 3.5 | 3.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| 2. **Zoning** | | | | | | | | | | | | | | | | | | |
| 2.1 Identification of representative (benchmark) reaches for research, monitoring and extrapolation of water quality conditions | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 3 | 3 | 3.5 | 3.5 | 3.5 | 3.5 | 4 | 4 | 4 | 4 | 4 | 4 |

Appendix 2. (Continued)

| Issues | Level of Knowledge | | | | | | Availability of Technology | | | | | | Information Need | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | A | B | C | D | E | F | A | B | C | D | E | F |
| **3. Criteria (guidelines / thresholds / tolerance values)** | | | | | | | | | | | | | | | | | | |
| 3.1 Desired instream water quality criteria | 3 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 3.5 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3.5 | 3.5 | 4 | 4 | 4 |
| 3.2 Region-specific water quality criteria | 2 | 2 | 2 | 2 | 1.5 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3.5 | 4 | 4 | 4 |
| 3.3 Water quality tolerance and threshold values for selected biota | 2.5 | 2.5 | 2.5 | 2 | 2.5 | 2 | 2.5 | 2.5 | 3 | 3 | 3 | 3 | 3.5 | 4 | 4 | 4 | 4 | 4 |
| 3.4 Thresholds of potential concern | 2 | 2 | 2.5 | 2.5 | 2.5 | 2.5 | 1.5 | 1.5 | 1.5 | 2 | 1.5 | 1 | 3.5 | 4 | 4 | 4 | 4 | 4 |
| 3.5 Applicability of water quality criteria from elsewhere to local conditions | 2.5 | 2 | 2 | 2 | 3 | 2.5 | 2 | 2 | 2.5 | 3.5 | 2 | 3.5 | 2.5 | 2 | 2.5 | 4 | 2.5 | 4 |
| 3.6 Water quality index (number and the period of variables higher than criteria) | 2.5 | 2.5 | 2 | 1.5 | 1 | 1 | 2 | 3 | 2 | 2 | 3 | 1 | 2.5 | 3.5 | 3.5 | 4 | 3.5 | 4 |

Appendix 2. (Continued)

| Issues | Level of Knowledge | | | | | | Availability of Technology | | | | | | Information Need | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | A | B | C | D | E | F | A | B | C | D | E | F |
| **4. Prediction technology** *Please review the following issues with regard to the development, calibration and verification of prediction technology* | | | | | | | | | | | | | | | | | | |
| 4.1 Responses of instream biota to changing water quality | 2 | 2 | 2 | 2 | 1.5 | 1.5 | 2 | 2 | 2.5 | 2.5 | 2 | 2 | 3.5 | 4 | 4 | 4 | 4 | 4 |
| 4.2 Effect of water quality on wetlands | 2 | 2 | 2 | 1 | 1.5 | 1 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 4 |
| 4.3 Likely impacts of catchment activities on water quality | 2 | 1.5 | 1.5 | 1 | 1 | 1 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1 | 3.5 | 4 | 4 | 4 | 4 | 4 |
| 4.4 Effect of flow modification on water quality | 2 | 2 | 2 | 1.5 | 1 | 1 | 2 | 1.5 | 1 | 1.5 | 1 | 1 | 4 | 4 | 4 | 4 | 4 | 4 |
| 4.5 Effect of wetlands on water quality | 2 | 2 | 1.5 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 3.5 | 3.5 | 3.5 | 3.5 | 4 | 4 |
| 4.6 Linking of terrestrial and aquatic systems | 1.5 | 1 | 1 | 1 | 1 | 1 | 1.5 | 1 | 1 | 1 | 1 | 1 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 4 |
| 4.7 Factor based and/or empirical models for use in information- and decision support systems | 1.5 | 1 | 1 | 1.5 | 1 | 1 | 1.5 | 1 | 1 | 1.5 | 1 | 1 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| 4.8 Conceptual models for water quality processes in the river and catchment | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 3.5 | 3.5 | 3.5 | 3 | 3.5 | 3.5 |
| 4.9 Simulation models to describe present water quality conditions and to predict future conditions | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |

Appendix 2. (Continued)

| Issues | Level of Knowledge | | | | | | Availability of Technology | | | | | | Information Need | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | A | B | C | D | E | F | A | B | C | D | E | F |
| **5. Monitoring** | | | | | | | | | | | | | | | | | | |
| 5.1 Biological characteristic of water (including river health)<br>• Monitoring system | 3.5 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 4 | 4 | 3.5 | 3.5 |
| • Monitoring database | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3 | 3.5 | 4 | 4 | 4 | 4 | 4 |
| • Identification of trends | 2 | 2.5 | 2.5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3.5 | 4 | 4 | 4 | 4 |
| 5.2 Chemical characteristics of water<br>• Monitoring system | 3.5 | 3.5 | 3.5 | 3 | 3 | 3 | 4 | 4 | 4 | 3 | 4 | 3 | 3.5 | 4 | 4 | 4 | 4 | 4 |
| • Monitoring database | 3.5 | 3.5 | 3.5 | 2.5 | 3 | 2.5 | 3.5 | 3.5 | 3.5 | 2.5 | 3 | 3 | 3.5 | 4 | 4 | 4 | 4 | 4 |
| • Identification of trends | 3.5 | 3 | 2.5 | 2 | 2.5 | 2 | 3.5 | 3.5 | 3.5 | 3 | 3 | 2.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| 5.3 Physical characteristics of water<br>• Monitoring system | 2.5 | 2 | 2 | 1.5 | 1.5 | 1.5 | 2.5 | 2.5 | 2.5 | 1.5 | 2.5 | 1.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| • Monitoring database | 3 | 2 | 2 | 1.5 | 1.5 | 1.5 | 3 | 3 | 3 | 2 | 2.5 | 2.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| • Identification of trends | 2 | 2 | 2 | 1.5 | 1.5 | 1.5 | 2.5 | 3 | 2.5 | 1.5 | 2.5 | 1.5 | 4 | 4 | 4 | 4 | 4 | 4 |

Appendix 2. (Continued)

| Issues | Level of Knowledge | | | | | | Availability of Technology | | | | | | Information Need | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | A | B | C | D | E | F | A | B | C | D | E | F |
| **6. Impacts on river water quality** | | | | | | | | | | | | | | | | | | |
| 6.1 Point source pollution through *inter alia* effluent discharge<br>• Mining | 3.5 | 3 | 3 | 3.5 | 3 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| • Power generation | 3.5 | 3 | 3 | 3.5 | 3.5 | 3.5 | 4 | 3.5 | 3.5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| • Wood / paper milling | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 3.5 | 4 | 4 | 4 | 4 | 3.5 |
| • Agriculture | 2 | 1.5 | 2 | 1.5 | 1 | 1.5 | 2.5 | 2.5 | 2 | 1.5 | 2 | 2 | 3.5 | 4 | 4 | 4 | 4 | 4 |
| • Aquaculture | 3 | 2.5 | 2.5 | 2 | 2 | 2 | 3 | 3 | 3 | 2.5 | 3 | 2.5 | 3.5 | 4 | 4 | 3.5 | 4 | 4 |
| • Construction activities | 2 | 2 | 2 | 3 | 2 | 2.5 | 3 | 3.5 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 |
| • Domestic (formal) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2.5 | 2.5 | 2 | 2.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| • Domestic (informal) | 2 | 2 | 1.5 | 1 | 1.5 | 1.5 | 2 | 2 | 2.5 | 2.5 | 2 | 2.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| 6.2 Non-point source pollution through *inter alia* erosion<br>• agriculture | 2.5 | 2 | 2 | 2 | 2 | 2 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| • forestry | 3 | 2.5 | 3 | 3.5 | 3 | 3 | 3 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 3.5 | 4 | 4 | 4 | 4 |
| • air pollution | 2.5 | 2.5 | 2.5 | 3 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 3 | 2.5 | 2.5 | 3.5 | 3.5 | 3.5 | 3 | 3.5 | 3.5 |

Appendix 2. (Continued)

| Issues | Level of Knowledge | | | | | | Availability of Technology | | | | | | Information Need | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | A | B | C | D | E | F | A | B | C | D | E | F |
| **Impacts on river water quality (continued)** | | | | | | | | | | | | | | | | | | |
| 6.3 Aquatic weeds / Alien invaders / seed **pollution** | 2.5 | 2 | 2 | 2.5 | 1.5 | 2 | 3 | 2.5 | 2.5 | 2 | 2.5 | 2.5 | 3.5 | 3 | 3 | 3.5 | 3.5 | 3.5 |
| 6.4 Land use type and land use pressure | 1.5 | 1 | 1 | 1.5 | 1 | 1.5 | 2 | 2 | 2.5 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 4 | 4 |
| 6.5 Alteration in land use and management | 2 | 1.5 | 2 | 2 | 1.5 | 2 | 2 | 2 | 2 | 2 | 2 | 2.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| 6.6 Contaminated sites | 2.5 | 2.5 | 2.5 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3.5 | 4 | 4 | 4 | 4 | 4 |

Appendix 2. (Continued)

| Issues | Level of Knowledge | | | | | | Availability of Technology | | | | | | Information Need | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | A | B | C | D | E | F | A | B | C | D | E | F |
| **7. Management** | | | | | | | | | | | | | | | | | | |
| 7.1 Water quality situation assessment | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3.5 | 3.5 | 4 | 4 | 4 |
| 7.2 Risk assessment | 2 | 2 | 1.5 | 1.5 | 2 | 1 | 2 | 2 | 1.5 | 1.5 | 1.5 | 1 | 3.5 | 4 | 4 | 4 | 4 | 4 |
| 7.3 Water quality management plans | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2.5 | 3 | 3 | 3 | 3.5 | 4 | 4 | 4 | 4 |
| 7.4 Water reserve with regard to water quality condition | 2 | 2 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 3.5 | 3 | 3.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| 7.5 Whole catchment-scale approach | | | | | | | | | | | | | | | | | | |
| 7.7 Indigenous / traditional practices | 2 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 2.5 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 4 | 4 |
| **8. Policy** | | | | | | | | | | | | | | | | | | |
| 8.1 Policy regarding protection and rehabilitation of aquatic ecosystems in relation to water quality | 3 | 3.5 | 3 | 3 | 3.5 | 3 | 3.5 | 3.5 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 |

Appendix 2. (Continued)

| Issues | Level of Knowledge | | | | | | Availability of Technology | | | | | | Information Need | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | A | B | C | D | E | F | A | B | C | D | E | F |
| **9. Technology transfer/ training / communication** | | | | | | | | | | | | | | | | | | |
| 9.1. Dissemination of knowledge and skills to all stakeholders (empowerment) | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 2.5 | 2.5 | 2 | 3 | 2.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| 9.2. Information systems – catchment / applied / geographic | 3 | 3 | 2.5 | 2.5 | 3 | 3 | 2.5 | 2.5 | 2.5 | 2 | 2.5 | 2.5 | 3.5 | 3.5 | 3.5 | 4 | 3.5 | 3.5 |
| 9.3. Decision support systems | 3 | 3 | 2.5 | 2.5 | 3 | 2.5 | 3 | 3 | 3 | 2.5 | 3 | 2.5 | 4 | 3.5 | 3.5 | 4 | 3.5 | 4 |
| 9.4. Workshops | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3.5 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3 | 3 | 3 |
| 9.5. Conferences | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3.5 | 4 | 4 | 3.5 | 4 |
| 9.6. Effective functioning of catchment forums | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 2.5 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 |
| 9.7. A multi-level stakeholder framework (bottom-up and top-down) | 2.5 | 2.5 | 2.5 | 2 | 2.5 | 2.5 | 2.5 | 3 | 2.5 | 2 | 3 | 2.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| 9.8. Community based programmes (e.g. Landcare, Streamwatch, Riverwatch) | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 3 | 2.5 | 2.5 | 3 | 2.5 | 4 | 4 | 4 | 4 | 4 | 4 |
| 9.9. Participatory learning and/or technology transfer methods (e.g. "on-farm research" and PRA) and group extension methods (e.g. 'facilitation') | 2 | 2 | 2 | 2.5 | 2 | 2.5 | 3.5 | 3.5 | 3.5 | 3 | 3.5 | 3.5 | 4 | 4 | 4 | 4 | 4 | 4 |

## APPENDIX 3

## MULTI-LEVEL STAKEHOLDER FRAMEWORK

| LEVELS | MAIN INTERESTED AND AFFECTED PARTIES |
|---|---|
| A: NATIONAL (± 1: 1 000 000) | National Departments of Water Affairs and Forestry, Environmental Affairs and Tourism, and Agriculture and Land Affairs; National Parks Board; national and international research organisations |
| B: PROVINCIAL (± 1: 250 000) | Provincial Departments of Environmental Affairs and Tourism, and Agriculture and Land Affairs; Provincial Park Boards; research institutions |
| C: CATCHMENT (± 1: 50 000) | Catchment forums; research institutions, movements and programs; NGO's |
| D: NETWORKS (± 1: 25 000) | Communities; catchment networks; community associations; working for water; Landcare networks; NGO's; research groups and projects. |
| E: GROUPS (± 1: 10 000) | Water user groups; Land (farmer) use groups; discussion groups; research and development groups; NGO's; catchment groups; Landcare groups; |
| F: INDIVIDUALS (± 1: 5 000) | Water users and managers, land users (commercial and small-scale farmers, private game farm and -park owners); private land owners; |

## APPENDIX 4

### LANDCARE MULTI-LEVEL STAKEHOLDER FRAMEWORK

**Data Provided** By "Government"

**NATIONAL**
(1:250 000 and smaller)

**TOP DOWN**
↓
Legislation
↓
DSS/Info.sys
↓
Research
↓
Moni/Aud.

↓ ↓ ↓

↑↓

**PROVINCIAL**
(1:100 000 – 1:250 000)

↑↓ ↓

*Integrated Catchment Plan* ← Catchment Management Agency ← **CATCHMENT** (±1:50 000)

**IMPLEMENTATION**

↑↓ ↑

**GROUP NETWORK**

Problems/Fears
↑
Needs/Wishes

↑↓

**STAKEHOLDER GROUPS**

↑
*(PARTICIPATION)*
↑

↑↓

*Land & Water Management Plan* ← **INDIVIDUAL STAKEHOLDERS** (1:5 000 – 1:10 000)

**BOTTOM-UP**

# APPENDIX 5

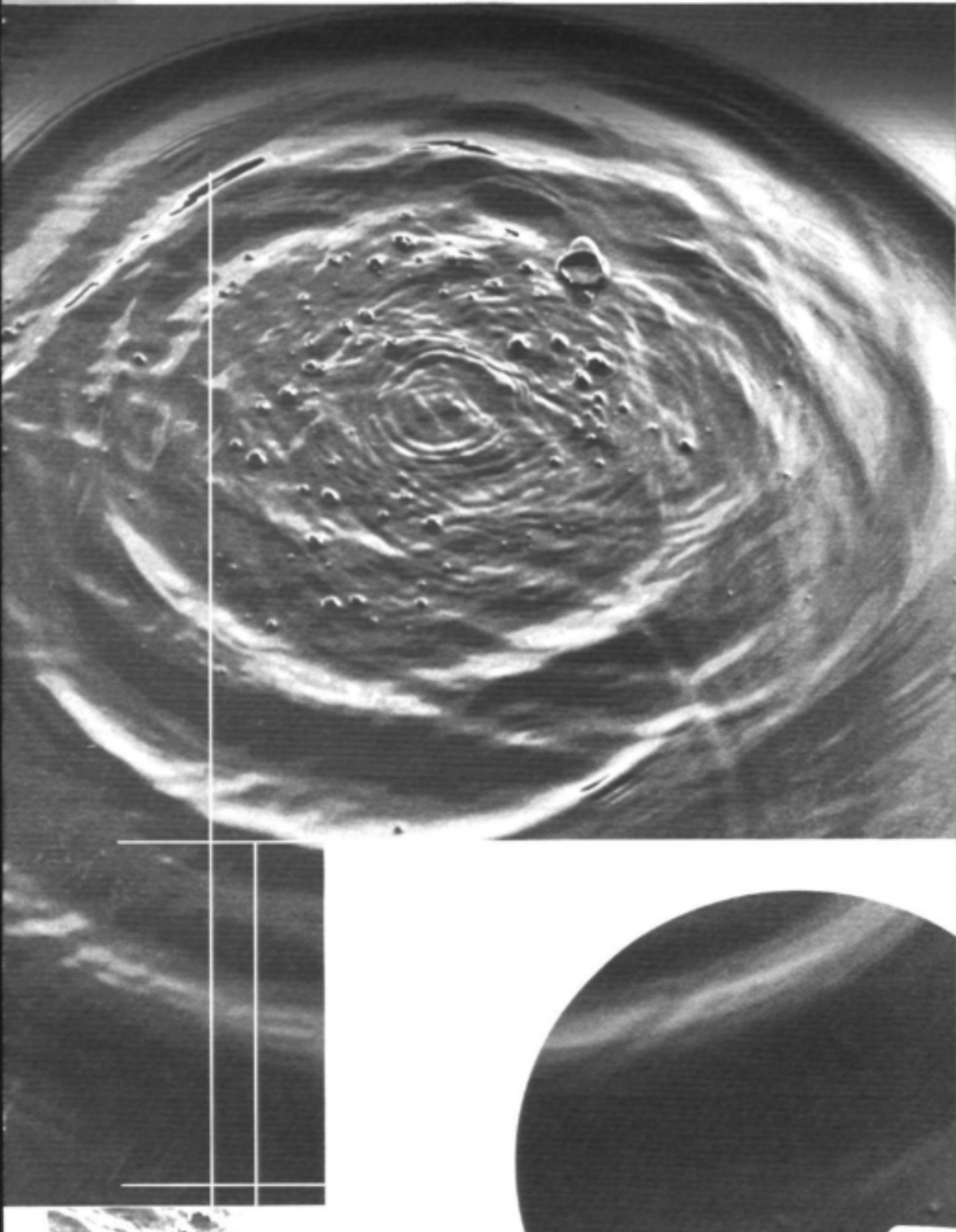
## EXAMPLES OF THE APPLICATION OF THE MULTI LEVEL STAKEHOLDER FRAMEWORK

| **LEVELS** | **APPLICABLE PREDICTION TECHNOLOGY (e.g. MODELS)** |
|---|---|
| < 1 : 250 000 (NATIONAL) | Qualitative: integrated geo-information and expert systems (including GIS & remote sensing); factor based models; Quantitative: summary mechanistic simulation models; |
| 1 : 100 000 – 1 : 250 000 (PROVINCIAL) | Qualitative: integrated geo-information and expert systems (including GIS & remote sensing); factor based models; Quantitative: summary mechanistic simulation models; |
| ± 1 : 50 000 (CATCHMENT) | Qualitative & semi-quantitative: integrated geo-information and expert systems (including GIS & remote sensing); factor based models; Quantitative: mechanistic simulation models and/or conceptual models simulating catchment processes; |
| 1 : 25 000 – 1 : 50 000 (NETWORKS) | Quantitative: mechanistic or process-based simulation models; Qualitative: applied geo-information systems and factor based models |
| 1 : 10 000 - 1 : 25 000 (GROUPS) | Quantitative: mechanistic or process-based models and factor based models; Qualitative: applied geo-information systems and factor based models |
| 1 : 5 000 – 1 : 10 000 (INDIVIDUALS) | Quantitative: mechanistic or process based models and factor based models; Qualitative: Applied geo-information systems and factor based models |

| LEVELS | APPROPRIATE TECHNOLOGY TRANSFER, INFORMATION, COMMUNICATION and MANAGEMENT SYSTEMS & TOOLS |
|---|---|
| **NATIONAL** | Integrated decision support systems; geo-information systems; Environmental Information Systems (EIS); Internet |
| **PROVINCIAL** | Integrated decision support systems; geo-information systems; EIS; Internet |
| **CATCHMENT** | Integrated Catchment Management Plans; geo-information systems; EIS; Internet; simple water quality test kits |
| **NETWORKS** | Integrated (sub-) catchment management plans; applied geo-information systems; simple water quality test kits |
| **GROUPS** | Integrated (micro-) catchment management plans; applied geo-information systems; simple water quality test kits |
| **INDIVIDUALS** | Integrated land management plan (farm plan); applied geo-information systems; simple water quality test kits |

| LEVELS | TECHNOLOGY TRANSFER and R&D STRUCTURES |
|---|---|
| **NATIONAL** | Extension services; national research & development (R&D) programs; |
| **PROVINCIAL** | Extension services; R&D programs |
| **CATCHMENT** | Catchment forums; catchment / district level R&D programs (KNPRRP); |
| **NETWORK** | Community forums; community networks and associations; community based / -level research programs and –networks; community 'waterwatch' initiatives |
| **GROUPS** | Community groups; 'on-farm' research projects and experiments; small R&D groups |
| **INDIVIDUALS** | Households; 'on-farm' research projects and experiments; |

| LEVELS | PARTICIPATORY METHODS & PROCESSES FOR TECHNOLOGY TRANSFER & NEEDS ASSESSMENT |
|---|---|
| **NATIONAL** | Conferences; workshops; facilitation |
| **PROVINCIAL** | Workshops; conferences; facilitation |
| **CATCHMENT** | Forums; workshops; facilitation |
| **NETWORKS** | Community forums and meetings; workshops; facilitation |
| **GROUPS** | Dynamic group communication and –extension (e.g. PRA); facilitation; participatory research; discovery learning |
| **INDIVIDUALS** | Interpersonal communication; participatory research; facilitation; discovery learning |



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