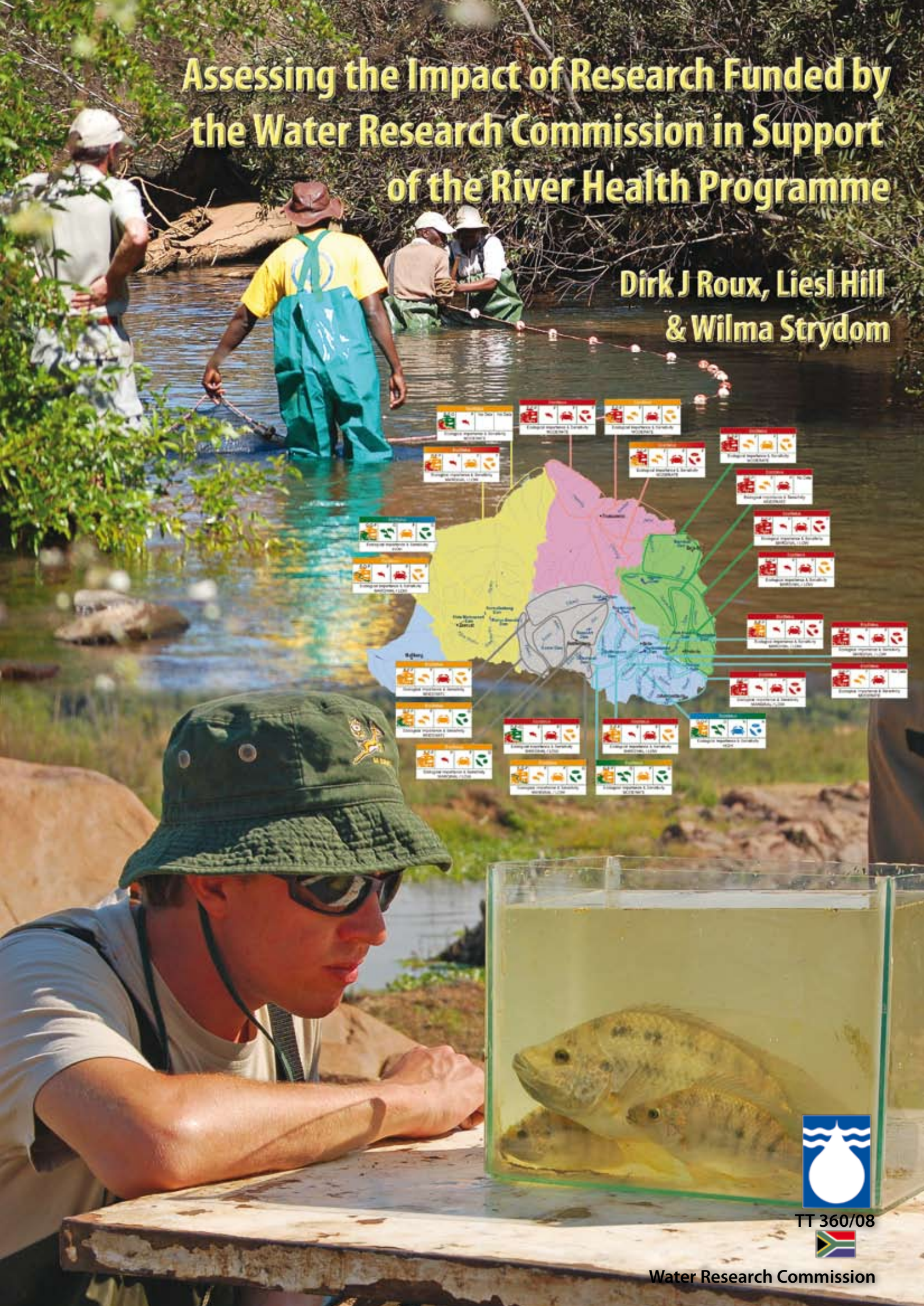
Assessing the Impact of Research Funded by the Water Research Commission in Support of the River Health Programme

Dirk J Roux, Liesl Hill & Wilma Strydom



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Water Research Commission

ASSESSING THE IMPACT OF RESEARCH FUNDED BY THE WATER RESEARCH COMMISSION IN SUPPORT OF THE RIVER HEALTH PROGRAMME

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

Background

The Water Research Commission (WRC) is committed to ensuring that the publicly funded research under its management provides both research excellence and public benefit. With this in mind, the WRC has commissioned a project to assess the impact of its research investment made in support of the national River Health Programme (RHP) and the role played by the WRC in the management of the RHP. This report presents the findings of that assessment.

Firstly, an overview is presented of the developments that led to the design of the RHP and the subsequent phases of implementation. Secondly, the notion of assessing the impact of research investment is explored and the specific approach that was used to assess impact in this study is described. Following the described method, the results of the assessment are presented and discussed. Finally, several recommendations are made stemming from the results of this study.

Assessment method

It was virtually impossible to isolate the research investment of the WRC because of the several organisations that have co-invested in the RHP. Acknowledging this limitation, a novel assessment framework was developed using 14 different impact measures while distinguishing between measures for research excellence (three indicators) and measures for research relevance (11 indicators). The three indicators for research excellence are:

- *Engagement in peer-review process* – the general quality of engagement in the scientific peer-review process
- *Validation of critical components* – the degree to which technical components have been subjected to a rigorous peer review associated with a respectable journal
- *Uptake within science* – degree to which RHP-related research has been taken up in the wider body of science

The 11 indicators for research relevance are:

- *Flexible management* – degree to which research teams have freedom to explore and be creative within appropriate bounds of accountability
- *Diversity of participation* – degree to which different individuals, organisations and functional domains (research, policy, management) co-create new knowledge
- *International collaboration* – degree of participation in international research initiatives
- *Continuity over time* – degree to which key individuals and organisations demonstrate long-term commitment
- *Knowledge capturing and sharing* – degree to which new knowledge is shared with others and captured in explicit form
- *Improved river health* – degree to which the health of rivers has improved
- *Increased capacity and awareness* – degree of improved understanding and capacity for informed action amongst a broad audience
- *Improved policy* – degree to which policy has been influenced
- *Adoption of RHP by implementers* – degree to which new knowledge has been adopted by implementation agencies

- *Broader societal influence* – degree to which the RHP has had a positive influence on other programmes and initiatives
- *Advancement of RHP- and WRC-specific objectives* – degree to which the objectives of the WRC and the RHP have been served.

Each of these indicators were rated using a five-point rating scale, where a rating of one indicates performance that is outright disappointing; two reflects a performance below the standard, expectation or benchmark rating; three is breaking even with the performance benchmark; four is better than the benchmark; and five reflects outstanding performance.

Assessment summary

The assessment has revealed varying performance associated with research investment in support of the RHP programme. Most disappointing is the poor performance in the research excellence category where all three indicators received a rating of one. Further disappointing results relate to the degree of international research collaboration (1), the ultimate goal of improved river health (1), and the influence on the water policy environment (1). Our assessment returned acceptable ratings for diversity of participation (3), continuity over time (3), increase of capacity and awareness (3), and adoption by implementers (3). The highest ratings were for flexible management (5), capturing and sharing of knowledge (5), the broader influence of the RHP (4) and achievement of RHP- and WRC-specific objectives (4).

An overall outcome is a sense that the WRC and its co-custodians have done extremely well in facilitating the transition from developing technical methods to establishing operational routines. The WRC has played an overwhelmingly positive role in enabling the kind and continuity of research that led to remarkable adoption by implementation agencies, capacity and awareness creation amongst diverse audiences, and an impact on water and research activities in a much broader sphere than that directly related to the RHP. Particularly noteworthy is the high level of knowledge capturing and social sharing that took place. We believe that this success is to a large degree the result of the community-of-practice style of participation that prevailed amongst RHP practitioners. The WRC's flexible management style has played a significant role in enabling this community formation and maintenance.

However, the assessment also reveals a number of areas where performance could and perhaps should have been better. First amongst these is the overall impact within the body of science. This aspect has clearly been neglected. Related to this is the low degree of international collaboration that has been achieved, while the impact on policy and actual improvement of river health are further disappointing features. The poor performance for research excellence is probably a result of the strong emphasis that was placed on understanding and catering for stakeholder needs and to facilitate practical implementation of the RHP. While such a focus is admirable, it should be matched with resources for and efforts to ensure scientific credibility.

Interestingly, the assessment indicated that RHP-related research in general advanced the specified impact areas of the WRC, notwithstanding the poor performance in the areas of research excellence and international collaboration. Although the WRC's main activity is to fund research projects and the organisation is explicit about its desire to build international knowledge networks, research excellence and international research collaboration does not seem to be actively encouraged, or portrayed as serious objectives, in the management of research projects. An improvement in these areas could benefit South Africa's research profile significantly and guard against the production, acceptance and incorporation of

"pseudo facts" (knowledge that has not been properly validated through a rigorous scientific process).

A further interesting phenomenon is that the RHP's objectives have largely been advanced, yet there is no evidence that the health of rivers has improved nor has the substantial body of river health information had much influence on water policy. The likely explanation is that the RHP has largely remained true to its main purpose of being a monitoring programme that generates and disseminates accurate and objective information. This is a sound position for a monitoring programme, but without effective extension into the management and policy domains, there is no guarantee that the information stemming from the programme will be used to the benefit of society.

Recommendations

The value of an impact assessment approach such as presented in this report is to facilitate periodic reflection and to reveal areas in need of more focussed research attention. This provides guidance for the strategic allocation of available research funding. Ideally, an impact assessment of this nature should be undertaken in close collaboration with all key role players to maximise the potential for social learning and the likelihood of an appropriate response to the findings. While an inclusive assessment process was beyond the scope of this study, we recommend that the findings of this assessment be presented to and deliberated within at least the RHP's custodian organisations.

Recommendations related to the WRC and its research management process:

- In a world of ever-increasing bureaucracy, accountability and administrative loads associated with the management of research funding, the WRC seems to be a shining exception to the rule. Leaders of research projects are highly complimentary of the WRC's professional, streamlined and flexible management process. Such a process relies on having competent and experienced research managers within the organisation and is worth protecting as a high priority.

- WRC (and indeed all participating organisations) need to consider the concerns expressed in this report regarding research excellence and international research collaboration as a central issue in the selection and management of research projects. The long time lag that commonly exists between conducting research and getting the results in peer-reviewed literature pose a practical problem. Furthermore, international research collaboration has cost implications. However, creative solutions are very important for both of these issues.

- The WRC acknowledges the value of investing in R&D *programmes* as opposed to investing in R&D *projects* only. This is an area that justifies some research in own right. The varying levels of success in RHP-related research provide valuable insights into the design and maintenance requirements of R&D programmes. We recommend using these insights, as well as those obtained through R&D programmes such as the KNP Rivers Research Programme, as a departure point to do further research into the enabling conditions for R&D programmes. If the findings of such work are truly incorporated into models for research funding and management, it could have

significant implications for future knowledge creation and application in the water sector.

Recommendations related to future research in support of the RHP:

- *International benchmarking*: During the early years of the RHP, much value was derived from international benchmarking. As an example, the considerable body of work that existed at the time and that was freely available from the United States Environmental Protection Agency was used to great benefit within the RHP. Developed countries often have much more resources to dedicate to research and South Africa can benefit from careful identification, adaptation and integration of externally produced scientific information. Much has happened in the field of environmental monitoring and reporting, also specifically related to river health, since the early years of the RHP. It is recommended that a comprehensive benchmarking exercise be undertaken to see where the RHP stands against related international practices. Such an exercise could also help identify international partner organisations for strategic research collaboration.

- *Embrace the scientific publication process*: Those who worked as part of the larger RHP community have achieved much to be proud of. This sense of achievement is only dampened by the belief that the RHP community has not had the international influence and acknowledgement that perhaps their collective achievement justified. The rich learning that is gained through a rigorous review process is a special type of capacity building and is a further by-product of scientific publication. It is recommended that peer-reviewed publication and presentation of at international conferences of key topics be encouraged and supported.

- *Extension into management and policy domains*: The influence of the RHP on river health and river management policy should have been much greater and this requires further exploration and investigation. We recommend that a project (or projects) be supported to explore ways of linking RHP-derived information with policy or governance frameworks and management frameworks. This is the area where the RHP can most directly influence the management and improvement of aquatic ecosystems.

- *Long-term research, development and implementation initiatives*: Related to the preceding point, the operational influence and effectiveness of the RHP could significantly improve following careful design of and support for a number of long-term research, development and implementation projects. Such projects should have as an ultimate goal the improvement of river health; team a research partner with implementation agencies; focus on a specific catchment or Water Management Areas; include both developmental and implementation objectives; and run for a period of seven years or longer. Such projects will fulfill the requirements for reporting on temporal trends by facilitating follow-on assessments. These projects will also facilitate significant capacity building of a conceptual and operational nature because of the stability that they will offer; and stand a better chance of influencing management decisions, general awareness and policy processes; and facilitate the development of trust, increased diversity and effective collaboration within diverse teams. Such projects would depend on the right mixture of inspirational leadership and core funding, both of which are thinly spread in South Africa. Core funding could potentially be sourced from various

partners, for example DWAF (under Chapter 14 of the National Water Act, DWAF has to report on the health of aquatic ecosystems), industry and WRC.

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1. INTRODUCTION

1.1. Scientific research and sustainable development

Scientific research, which is the organised and systematic process of gathering, testing and condensing (into laws and principles) knowledge about the world, has been immensely beneficial to society and "has yielded the most effective way of learning about the real world ever conceived" (Wilson, 1998). The chasm between scientific and pre-scientific cultures is the most significant divide within humanity, more so than race, religion or language. Societies that embrace scientific knowledge creation enjoy proportionately greater production and service benefits than those that do not (Sagasti, 2004).

However, humanity has not only used science to get to know our world but also as a source of knowledge enabling us to change the world (Russel, 1951). Notwithstanding its benefits, through enabling modern technologies, science has been indirectly responsible for the current human domination of our planet and extensive deterioration of ecological systems. This deterioration has widespread consequences because human health, economies, social justice and national security are inter-linked with and depend on the structure, function, and resilience of ecological systems. As a result, society is calling on science to respond to one of the most pressing issues of our time, namely to understand the interdependent relationship between human well-being and diverse, functioning ecological systems and to guide us towards a more sustainable existence within our biosphere (Lubchenco, 1998).

1.2. The WRC mandate

The Water Research Commission (WRC) is a statutory organisation established in 1971 by the Water Research Act (Act 34 of 1971). Its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa. The WRC engages stakeholders and partners in solving water related problems that impede South Africa's sustainable development and economic growth, and is committed to promoting a better quality of life for all. As its main activity, the WRC funds research projects in the whole of the water field, utilizing funding from levies on national water sales.

The WRC faces many challenges in its endeavour to execute its mandate responsibly. These challenges include facilitating the creation of appropriate new water-centred knowledge, ensuring effective dissemination and application of such knowledge, building international knowledge networks and fostering local capacity for sustainable water resource management. In order to retain and strengthen its standing with relevant stakeholders, the WRC has to demonstrate that it is a "value-for-money" institution, providing research products that will contribute to the socio-cultural, economic, political, technical and environmental aspects and well-being of South Africa and all of its people. To this end, the WRC has embarked upon a number of selected studies to determine and portray the impact that its research products have had – and will have in future – to the benefit of the whole of the country.

1.3. The River Health Programme as a case study

The South African River Health Programme (RHP) has a relatively long history (more than ten years) of receiving research investment and providing benefits to public and private organisations in the context of improving river monitoring and management practices. The RHP has developed into a flagship for the water resources monitoring programmes operated by the Department of Water Affairs and Forestry (DWAF). However, its success is to a large degree a result of the active involvement of, and strong ownership by, a diverse suite of national and sub-national organisations. The RHP also drew funding and contributions in kind from several organisations during its different developmental phases while retaining critical cohesion between programme components and a distinct overall identity. As such, the RHP is an example of a research programme, as opposed to a research project.

An effective research and development (R&D) programme is more than a mere collection of independent research projects and facilitate learning interdependence among multiple programme components. An important dimension of learning interdependence is between those doing research and those that make decisions based on the outcomes of research.

Properly functioning R&D programmes have the potential for building significant capacity through the adaptive development and implementation of new knowledge. While most research funders have mechanisms in place to measure the performance of individual projects, the measurement of returns from investing into a broader R&D programme is not as straightforward. To this end, a reflective assessment of the returns resulting from investment in RHP-related research could present valuable lessons regarding research investment in general.

1.4. Objectives and outline of this report

The WRC is committed to ensuring that the publicly funded research under its management provides both research excellence and public benefit. With this in mind, the WRC has commissioned a project to assess the impact of its research investment made in support of the RHP and the role played by the WRC in the management of the RHP. This report presents the findings of that assessment.

Firstly, a brief history of the RHP is provided in Section 2 of this report. In a further contextual section (Section 3), the notion of assessing the impact of research investment is explored. The specific approach that was used to assess impact in this study is described in Section 4 and the results of the assessment are presented in Section 5. Finally, concluding comments and recommendations stemming from the assessment can be found in Section 6.

2. THE HISTORY OF THE RIVER HEALTH PROGRAMME

This section presents a brief chronology of the RHP.

2.1. Stressor and response monitoring

Until the late 1980s, water quality managers relied almost solely on information gained from the monitoring of chemical and physical water quality variables. Such "stressor monitoring" focuses on the stressors that are likely to cause pollution or ecological change. However, a predictive ability is only possible where a known cause-effect relationship exists between a specific stressor and a receiving ecosystem. Whereas the effects of a single substance on a single species under controlled conditions can be determined with reasonable confidence, extrapolation of such effects to complex ecosystems is fraught with problems (Preston et al., 2000).

Acknowledging the limitations of a stressor only approach, water resource managers started looking at response monitoring as a complementary approach. Response monitoring entails the use of biological or ecological indicators to characterise the response of the environment to a stressor or disturbance. The response-oriented approach is diagnostic, in that it indicates how well an ecosystem is functioning given the degree to which it is subjected to multiple stressors.

Today, comprehensive water resource assessment and management strategies integrate the relative precision of stressor monitoring with the broader coverage of response monitoring.

2.2. Response monitoring in practice

While response monitoring made sense conceptually, water resource managers still had to be convinced of the practicality and value of this new monitoring approach. Work such as in the United States on fish communities (Karr et al., 1986) and in Great Britain on macro-invertebrate species (Wright et al., 1984) served to demonstrate that response monitoring can indeed provide valuable and useful information. In South Africa, the development of a rigorous invertebrate-based index of water quality (Chutter, 1972) was somewhat before its time and largely escaped the notice of local water resource managers. The index required specialised, time-consuming species-level invertebrate identification, which did not help its cause.

In the USA, the development of simpler and quicker field techniques – known as rapid bioassessment protocols – for the routine use of biological indicators (Barbour et al., 1999) greatly increased the attractiveness of response monitoring. South Africa followed suit with the development of a simple and rapid bioassessment protocol based on the identification of families of aquatic invertebrates in the field. The resulting index is the South African Scoring System or SASS (Chutter, 1998; Dickens and Graham, 2002). Testing of various developmental versions of SASS and its application in many types of water quality assessments popularised response monitoring amongst water resource managers. Response monitoring methods later expanded to embrace techniques that considered different parts of the aquatic ecosystem, including fish, riparian vegetation and habitat integrity.

2.3. Responding to a new information need

The abovementioned international and local developments helped to confirm that, to execute their mandate effectively, water resource managers needed a new type of information. To collect this information systematically would require the design and implementation of a new monitoring programme. The first steps towards designing a new monitoring programme were taken at the then Hydrological Research Institute (now called Resource Quality Services) in the early 1990s (Roux, 1992).

A survey of perceived information needs (conducted among local water resource managers and scientists) and international benchmarking were two important factors that shaped the objectives of the new monitoring programme. The main information need that emerged was to quantify the effect of human activities on the state or health of rivers. Regarding international benchmarking, a joint South African-Australian workshop that took place in Cape Town during 1994 (Uys, 1994) was influential and lessons were also drawn from a number of response monitoring programmes that were in various stages of development worldwide. Most notable of these developments were:

- River InVertebrate Prediction And Classification System (RIVPACS) in the United Kingdom (Wright et al., 1993);
- Environmental Monitoring and Assessment Program (EMAP) for Surface Waters in the United States (Lazorchak et al., 2000); and
- AUStralian RIVer Assessment Scheme (AUSRIVAS) in Australia (Davies, 2000).

The new South African monitoring programme was initially called the National Aquatic Ecosystem Biomonitoring Programme (NAEBP). An early focus on river ecosystems led to the establishment of the River Health Programme (RHP) as a sub-programme of the NAEBP. The first objectives for the NAEBP still apply, namely to:

- Measure, assess and report on the ecological state of aquatic ecosystems;
- Detect and report on spatial and temporal trends in the ecological state of aquatic ecosystems;
- Identify and report on emerging problems regarding the ecological state of aquatic ecosystems in South Africa; and
- Ensure that all reports provide scientifically sound and managerially relevant information for national aquatic ecosystem management (Roux, 1997; Murray, 1999).

A description of the design criteria and design process of the RHP is presented in Roux (1999). Key elements include that the RHP is a screening-level monitoring programme and therefore makes use of a low sampling frequency and a low resolution of sampling sites that are distributed across river networks, with a bias towards main stems. The assessment philosophy of the RHP is founded on the concept of ecological integrity, which is the undiminished ability of an ecosystem to continue its natural path of evolution, its normal transition over time, and its successional recovery from disturbances (Westra et al., 2000). There are no significant degrees of integrity. Ecological integrity serves as a benchmark of what is natural. In the RHP, the health of a river is ranked by the extent of its deviation from its integrity benchmark at an agreed location and point in time. Scientists use biological indices based on fish, invertebrates and riparian vegetation, as well as indices for assessing in-stream and riparian habitats, to calibrate the integrity of rivers and measure their health (deviation from integrity).

2.4. Growing from an idea into a national operation

After the initial formulation of the scope and objectives of the RHP, attention shifted to developing the technical protocols for applying measurement indices, selecting monitoring sites and deciding on monitoring frequency, processing data and reporting information. The various components of the RHP were tested and the programme was implemented at a pilot scale in Mpumalanga (Roux, 2001b). Coordination of the development of concepts, methods and processes would take place at national level, while loose networks of agencies operating at provincial level carried out and resourced implementation activities. Each implementation network was to be coordinated and directed by an implementation champion. This model of programme governance was launched during a "consultation planning meeting" during 1996 (Department of Water Affairs and Forestry 1996).

During the late 1990s and early 2000s, a key priority was to promote adoption of the RHP by provincial agencies and implementation teams. As more and more provincial government agencies experimented with implementing the programme, valuable lessons regarding successes and mistakes had to be shared with other provinces. At the same time, new developments funded by the national custodians had to be communicated to provincial implementation agencies. Mechanisms to facilitate communication horizontally between provinces and vertically between provincial and national agencies included annual meetings of all role players, technical reports, a newsletter and a dedicated website (www.csir.co.za/rhp).

Towards the end of 2003, a review of the design of the RHP began. The main purpose of the review process was to align the design of the programme with the National Water Act (Act 36 of 1998) and DWAF's Strategic Framework for National Water Resource Quality Monitoring Programmes (Department of Water Affairs and Forestry 2004). This process further aimed at formalising the various roles and responsibilities regarding programme governance at both national and provincial levels; developing a systematic national monitoring plan; revising procedures for quality control, quality assurance and data management; and revitalising a short course on biomonitoring.

By this time, the RHP had grown from a mere idea into a national network of research and implementation activities. This is especially significant when considering that adoption and implementation of the RHP are largely voluntary. To add to the achievement, implementation is taking place in an environment characterized by limited financial resources, a multitude of competing social and economic priorities, and a scarcity of appropriately skilled people.

3. ASSESSING THE IMPACT OF RESEARCH INVESTMENT

3.1. Introduction

Economic and social development is scarcely feasible without research-based knowledge creation. In this sense, scientific research is a key ingredient in developing human capital and making nations and organisations competitive. The Human Development Index for 177 countries shows a strong correlation with the research capacity of nations, subject to first achieving a critical mass of approximately 1 000 researchers per million people (UNDP 2006). However, it remains very difficult to quantify the direct social and economic returns from research investment (Colquhoun, 2007).

With an ever-increasing drive for higher social accountability, governments and funding agencies place greater emphasis on demonstrating the returns on research investment. To this end, researchers have to participate in objective-driven research programmes and compete for research funding streams aligned with national economic, social, technological and environmental priorities. An increasing awareness of the close links between social and ecological systems has elevated sustainable development as one such research priority. Furthermore, South Africa's water-constrained economy adds special significance to the sustainable development of water resources as a research priority. This rationale makes it intuitively "right" to invest in the development and implementation of a programme such as the RHP. But how can we assess the return from a particular investment in more quantitative terms? This section presents some of the approaches for assessing the impact of investment in research.

3.2. Assessing research impact

Assessing the impact of research is not a precise science and could follow a number of approaches. In general, there is no aggregate measure of the "return" to those who have invested in research. Among the characteristics that make such exercises inherently difficult are:

- the expense of doing a proper study, with a team of experts in the field evaluating the complete scientific output;
- the long time periods that may elapse between completion of a body of research and achievement of its full impact;
- the difficulty of identifying the contribution of a particular body of research to broader outcomes that may be influenced by diffuse research initiatives; and
- the difficulty, in the case of co-investment and collaborative research, of linking specific funding contributions to specific research products and impacts.

Most frameworks for assessing research performance distinguish between the quality of research and the beneficial application of research to achieve social, economic, environmental and cultural outcomes. This broad classification relates to the distinction between research for producing "reliable" knowledge and research for producing "socially robust" knowledge (Gibbons, 1999). Reliable knowledge is based on the replicability of research statements and sanctioning by a relevant peer group (Ziman, 1991), and socially robust knowledge embraces the process of contextualisation whereby it is also valid outside the laboratory; its validity is

achieved through involving an extended group of experts and stakeholders (lay experts). Gibbons (1999) argues that the processes that underpin the production of reliable knowledge need not be compromised by a shift to socially robust knowledge and that reliable knowledge has always been reliable only within boundaries or specific contexts. The reality is that reliable knowledge can only become socially robust if society sees the process of knowledge production as transparent and participative. When society has participated in the production of socially robust knowledge, it is more likely to accept than contest it (Nowotny et al., 2001).

The two types of knowledge are clearly complementary. RHP practitioners have recognised the need for a dual focus, namely on ensuring scientific rigour as perceived by peers (research excellence) and on adding value as perceived by the beneficiaries of research (research relevance). Based on these driving variables, four scenarios are possible (Figure 1; Roux, 2001b; Roux, 2004):

- *Scenario 1*: Low scientific credibility and value to stakeholders lead to the disappearance of the programme and both river managers and researchers will pursue options that are more relevant.

- *Scenario 2*: Resources are primarily directed towards technical design and ongoing improvement through research and development. The RHP is recognized for its scientific and technical excellence but stakeholders are not experiencing benefits from the programme. Too little attention is given to understanding and satisfying the needs of the nontechnical stakeholder community. These end-users of river health information lose their enthusiasm for the RHP and redirect their support to other initiatives. The RHP largely remains of academic interest and does not become an operational programme.

- *Scenario 3*: All attempts are made to understand and satisfy stakeholder needs but insufficient resources are allocated to scientific development, testing, verification, and ongoing improvement. Initial support by stakeholders is replaced by scepticism as the gaps in the programme's science-base become evident. The end result is a programme that will have ever-decreasing support but that will not be able to contribute to ecologically sound management of rivers.

- *Scenario 4*: Only when sufficient resources are available to add real value for stakeholders and to ensure scientifically rigorous products will the RHP endure as an integral component of decision-making and policy development. Under this scenario, scientists, river managers, and environmental policy makers interact frequently, which results in reconciliation of perspectives, development of a deep understanding of each other's needs and limitations, and adaptive improvement of the programme over time to ensure continued scientific and managerial relevance. The programme positively influences decision-making and the health of rivers.

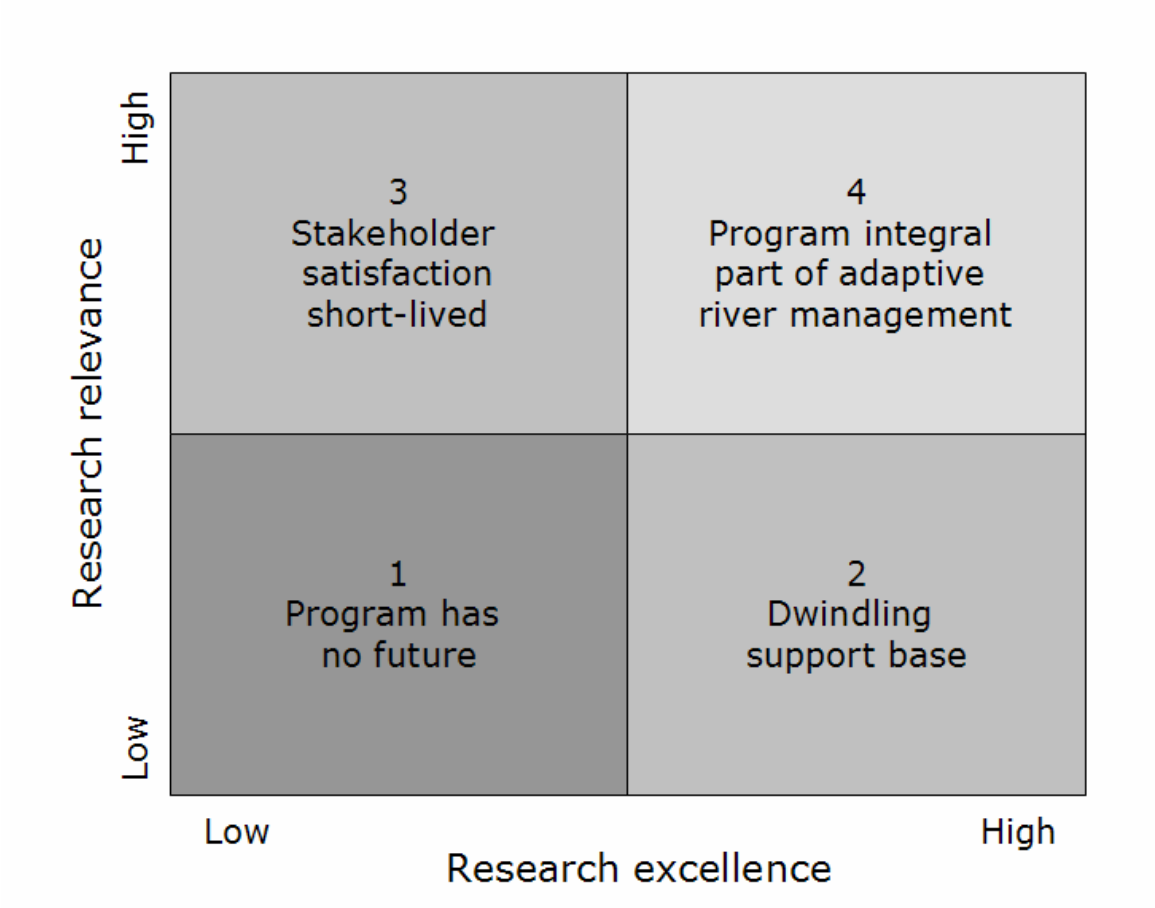

Figure 1
Two key factors influencing the continued relevance and impact of a monitoring programme (modified after Roux, 2004).

For the purpose of this report, we will assume that research impact encompasses two broad arenas:

- The impact through research excellence, which is the impact of a piece of research or a research product within its own discipline or field or within science in general; and
- The impact through research relevance, which is the impact of research beyond the discipline and science, including broader societal, economic and environmental impacts.

3.2.1. Measuring impact through research excellence

The impact of research within science can be quantified using bibliometrics such as the impact factor of the journal in which a particular paper appeared and the number of times that it has been cited in the scientific literature. The widely used Impact Factor (IF) of the Institute for Scientific Information (ISI) is the ratio between original, peer-reviewed papers published in a journal in the prior two years and the number of citations to these papers in the broad scientific or scholarly, indexed literature (including forms of publication other than original articles, such as reviews, commentaries, editorials, etc.) in the succeeding year (Dong et al., 2005).

The ready accessibility of the IF and the lack of other simple indicators contribute to the popularity of IF as an indicator of journal quality. The benefits to publishing in high impact journals include the prestige and visibility that such journals bring to scholars and their departments and universities, and the recognition by peers for producing high quality research. However, some biases and shortcomings inherent to the calculation of the IF have been documented (Dong et al., 2005), for example the lack of distinction between fame and notoriety. Much of the criticism against the use of impact factors as an indicator of research excellence relates to the fact that the citation rate for individual papers shows little or no correlation to the impact factor of the journal in which it was published (Seglen, 1997). Lawrence (2003) warns that the IF of a journal should never be regarded as more important than the quality of the paper, and that the scientific peer community can be the only true judge of quality. In fact, an emphasis on impact factors as an assessment measure could drive undesirable behaviour from researchers (Lawrence, 2007). However, journals with a high IF may have an advantage in that they are the most likely to consult top referees successfully, run rigorous and professional review processes, and provide authors with meaningful feedback. Participation in such a peer-review process could potentially be a rich learning and international benchmarking exercise for any author.

The counting of citations to a particular paper or group of papers is a further method in evaluating the impact of research within science. The rationale behind citation counts is essentially that a citation indicates a paper has influenced someone and therefore, the more often a paper is cited, the greater its influence on the scientific community. The assumption is that papers containing important scientific contributions will be cited more frequently. Citation counts provide a quantifiable indicator for assessing and comparing the relative impact and quality of research produced by authors, programs, institutions, and countries. However, citations to a paper may sometimes be determined more by visibility and convenience than by the content or quality of the published work (Lawrence, 2007).

Research excellence can also be assessed as a function of peer esteem, i.e. to what extent has the research led to awards, honours, invitations to speak at conferences or contribute to books or special issues of journals. These measures are essentially indicators of the quality of research as perceived by the researcher's own peers.

As an example of a national quality assessment system, the British Research Assessment Exercise (RAE) is undertaken approximately every five years on behalf of the four higher education funding councils in the United Kingdom to evaluate the quality of research undertaken by British higher education institutions. Assessments are largely based on the quality of research outputs (which usually means papers published in academic journals and conference proceedings) as evaluated against five quality levels (listed in increasing level of quality):

1. Quality that falls below the standard of nationally recognised work, or work which does not meet the published definition of research for the purposes of this assessment;
2. Quality that is recognised nationally in terms of originality, significance and rigour;
3. Quality that is recognised internationally in terms of originality, significance and rigour;
4. Quality that is internationally excellent in terms of originality, significance and rigour but which nonetheless falls short of the highest standards of excellence; and
5. Quality that is world-leading in terms of originality, significance and rigour (http://www.rae.ac.uk/).

3.2.2. Measuring impact through research relevance

Measuring the broader impact of research is even more difficult. Ideally, relevant stakeholders should take part in a qualitative assessment of the beneficial effects of the research programme. However, an exercise involving stakeholders was beyond the scope of this project. Partial assessments could focus on:

- The achievement of particular research objectives (such as the development of a new capability, dissemination of information or transfer of know-how);
- The impact on particular groups (such as water resource managers or conservation agencies); and
- Particular outcomes (such as altered behaviour or improved environmental conditions).

In essence, one needs to assess the direct benefits of research to the country, and the indirect benefits of knowledge and methods produced through that research. Some measures of the impact of these are:

- *Improved environmental conditions*: The ultimate purpose of a monitoring programme is to generate information in support of informed action to achieve a desirable outcome. In the case of the RHP, information should support decision making and management actions that will ultimately lead to the maintenance and improvement of river health.

- *Increased capacity and awareness*: Increased capacity refers to improvements in the ability of mandated organisations to perform appropriate tasks related to river management, either on their own or in cooperation with other organisations. This capacity is largely a function of the breadth and depth of related knowledge that reside in the members of the organisation. Increased awareness refers to a higher degree of understanding within society regarding the importance of healthy rivers.

- *Improved policy*: Ideally, policy should be set on the basis of good science and the best available information as derived from sound monitoring programmes. Did the RHP influence South African water policy?

- *Degree of adoption by intended user agencies*: The generation of new and appropriate knowledge and tools (including monitoring programmes) is a necessary response to new and evolving environmental challenges. However, such knowledge is of little use without its acceptance, legitimacy, and subsequent adoption (including absorptive capacity, emotional ownership, and financial commitment to allowed sustained use) by user agencies.

- *Breadth of influence*: Of relevance here is whether the impact of a research initiative is wider than just its main area of focus, in this case the monitoring of river health.

- *Advancement of programme-specific and organisation-specific objectives*: Research is commonly directed by a set of objectives that could be formulated at a national, organisation or programme level of interest. For this study, the objectives of the WRC and those set for the RHP are of particular relevance. To what degree did RHP-related research advance these objectives?

The above consequential impacts of research are unlikely to be realised without the creation and maintenance of an appropriate research process and enabling research environment. To this end, indicators of the enablement of research relevance could include:

- *Flexibility*: The impact of research has a strong temporal dimension that often manifests in a tension between immediate or short-term needs versus long-term or inter-generational benefits. Fostering an environment conducive to research is about finding the right balance between allowing freedom and providing strategic direction. Scientific procedures are not easy to conceptualise or master. The work requires absolute dedication and may be frustrating for long periods. Most new ideas lead nowhere (Wilson, 1998). Research teams need sufficient space to change course when necessary and the time to follow new leads through to impact.

- *Diversity of participation*: Diversity and inclusiveness of participation adds resilience, examination of more options and wider acceptance of outcomes to a research initiative. Diversity has many dimensions, including disciplinary, cultural, organisational and functional (e.g. science, policy, management). Different knowledge forms (scientific, practical, traditional and local) also contribute to diversity. Participation in informal communities of practice often enable diverse domains, disciplines, organisations and knowledge forms to co-learn and co-create new knowledge in a field of common interest.

- *International collaboration*: Because scientific knowledge is validated in a particular way and through a particular process, there is only one universal body of scientific knowledge. In theory that body of knowledge can be accessed by anyone from anywhere in the world and all research initiatives or nations can benefit from it. In practice, however, at least two factors constrain the ability of a learning system (country, organisation or R&D initiative) to access and benefit from the pool of available scientific knowledge. Firstly, the ability of a social or organisational system to recognize the value of new, external information or knowledge and exploit it for benefit is largely a function of the level of prior related knowledge in the system. This limit to the rate or quantity of external information that can be absorbed is the *absorptive capacity* of a system (Cohen and Levinthal, 1990). Secondly, human interactions and relationships permit effective flow of knowledge across boundaries. No individual or even organisation can claim exclusive ownership or full mastery of the vast and rapidly evolving pool of knowledge in any field, though effective participation in relevant research or learning networks significantly improves access to these knowledge pools. Appreciating the bounds of one's own knowledge is essential to being able to participate effectively. Effective participation in complex learning systems also requires a critical level of related prior knowledge as well as skill to engage. "You know your part, but because your partial knowledge is engaged, in practice you know more than you know" (Wenger, 2005).

- *Continuity*: Long-term commitment of funding and key individuals is essential to managing any research programme. Building more effective knowledge systems that span disciplinary, research, policy, and operational domains takes time (much more than is usually planned or budgeted for) and requires patient persistence. Funding strategies and mechanisms to promote such systems require a sufficiently long-term perspective that takes into account the generally slow impact of ideas (and new scientific information) on practice (Cash et al., 2003). Over-reliance on a few key individuals could lead to regression of efforts when those individuals leave the process.

- *Knowledge capturing and sharing*: The capturing of knowledge in explicit form enables the maintenance of memory and information sharing. However, we should not only focus on explicit knowledge/information and tangible products, without due consideration to the contribution of tacit knowledge, experiential learning and the value systems of individuals (Leavy, 1998; Ison et al., 2004). To this end, cooperation during a field survey could facilitate valuable experiential learning and knowledge sharing.

4. ASSESSMENT METHOD

Two significant limitations of this assessment are related to demarcating the body of work to be assessed. Firstly, many products are not linked solely to the RHP. Although many early developments were closely aligned with the objectives of the RHP, others serve multiple purposes or are only marginally related to the RHP. Secondly, it is equally difficult to link individual products to an individual source of funding, because many developments related to the RHP benefited from co-investment by two or more parties. Ironically, although they complicate the assessment process, both of these limitations or conditions are desirable for the development of an R&D programme such as the RHP.

Working within these limitations, we have assessed the overall performance of the RHP in more quantitative terms and the contribution of the WRC to this performance more qualitatively. Appendix A is a compilation of RHP-related products comprising: Reports (by RHP, DWAF, WRC, DEAT, CSIR); State-of-River reports and posters; peer-reviewed journal papers and book chapters; popular articles; educational activity books, information brochures, flyers and fact sheets; newsletters; training courses; symposia, workshops and conference proceedings and presentations. The list of products is comprehensive, though it is almost inevitable that some may have been overlooked. We have included some products that were possibly not part of the RHP initiative but have contributed substantially to the objectives of the RHP.

Using the list of products (Appendix A) as primary data, our impact assessment is divided between research excellence (the impact of research within a scientific context) and research relevance (the impact of research in a broader social and national context).

4.1. Research excellence

Research excellence was assessed as a function of two main factors, namely the quality and pattern of engagement in the scientific peer-review process and the degree to which relevant research was taken up in the wider body of science.

Rigorous peer-review should form the foundation of any scientific initiative. Therefore, our first measure of research excellence is the degree to which the peer-review process has been engaged. For this measure, we look at the pattern of relevant peer-reviewed publications over time and across journals. Secondly, we identify key technical components within the RHP and assess the degree to which these components have been validated through scientific peer-review.

While noting the limitations of using impact factors as indicators of quality, we assume that journals with higher impact factors in general provide authors with more rigorous reviews and better quality feedback.

Impact Factors were accessed through *ISI Web of Knowledge* from the 2006 Journal Citation Report published by Thomson Scientific. We searched for Impact Factors of all the journals that published RHP-related papers between 1993 and March 2008.

Citation of RHP-related papers was used as a proxy of general uptake within science. Two citation databases were consulted to obtain citation counts, namely

Google Scholar and ISI Web of Knowledge (provided by Thompson Scientific). Only citations in peer-reviewed journal papers were considered. Self-citations were retained and apparent duplications were excluded for the sum of citations per article per given year.

4.2. Research relevance

We used all the evidence at our disposal to qualitatively assess the degree to which the WRC has, through its funding, created an enabling environment for research. For this assessment, the main factors supporting quality research are a flexible management approach, diversity in participation, international collaboration, continuity in key role players and support, and active capturing of explicit knowledge and sharing of tacit knowledge contribute to enabling quality research.

Did the enabling research environment have a positive impact on society? This question was addressed by assessing the degree to which RHP-related research has resulted in: improved river health; increased capacity and awareness regarding river management and health; improved water resource management policy; adoption of river health assessment methods; knowledge applicable to other programmes and areas of application; and satisfaction of specific objectives of the RHP and the WRC.

5. RESULTS AND DISCUSSION

5.1. Research excellence

5.1.1. Engagement in peer-review process

From 1993 to March 2008, 20 papers directly related to the development and implementation of the RHP appeared in peer-reviewed journals (Appendix A8). Of the 11 different journals, six were not rated by Thomson Scientific in 2006. Three of the five rated journals had impact factors (IF) of higher than one with the highest impact factor being 2.502 (Table 1). Thirteen of the 20 papers have appeared in four local journals (*Water SA; African Journal of Aquatic Science; South African Geographical Journal; Southern African Journal of Aquatic Sciences*) of which only one (*Water SA*) was rated.

Table 1
Journals in which RHP-related papers have been published and their impact factors.

Journal	**2006 Impact Factor**	**Number of papers**
Freshwater Biology	2.502	1
Environmental Management	1.097	1
Hydrobiologia	1.049	1
Environmental Monitoring and Assessment	0.793	1
Water SA	0.494	5
African Journal of Aquatic Science	Not rated	6
Aquatic Ecosystem Health and Management	Not rated	1
Journal of Aquatic Ecosystem Health	Not rated	1
South African Geographical Journal	Not rated	1
Southern African Journal of Aquatic Sciences	Not rated	1
Water Science and Technology	Not rated	1
Total number of papers		20

The publication pattern of papers on the RHP shows a strong bias for journals that are either unrated or have a low IF (Figure 2). Some may argue that local journals were targeted because of the local interest of the RHP and to disseminate developments locally. However, we feel that the primary objective of publication should not be one-directional dissemination of new information, but rather participation in the systematic knowledge production process of science. With this in mind, it is important to seek the best possible peer review and to target a journal that is most likely to advance the discourse in the discipline or field of relevance. There is also the fact that most RHP-related research has been of an applied nature. In general, journals with lower IF would be interested in publishing the findings of such applied research, where most of the high impact journals favour novel and cutting-edge findings.

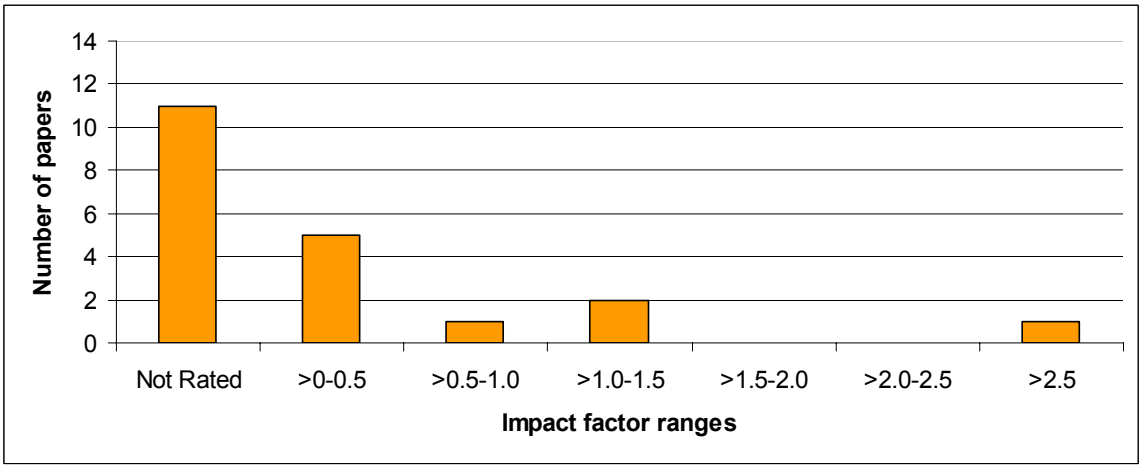

Figure 2
Number of papers published in peer-reviewed journals per 2006 journal impact factors (ISI Web of Knowledge).

Notwithstanding the abovementioned factors, we believe that a R&D programme such as the RHP should have featured more prominently in the peer-reviewed literature. What is a realistic benchmark for publication performance within an R&D programme such as the RHP? Given the various research and academic organisations that were involved in developing the different methods and processes related to the RHP, we would venture a benchmark of three papers per year (from at least 1995 to 2007) published in journals that reflect an equal distribution between IF of lower and higher than one. The RHP's 20 papers fall well below a benchmark of 39 papers and the distribution of these papers across journals of high and low impact factors is significantly skewed to low impact journals.

5.1.2. Validation of critical components

Twenty-one components of the RHP were identified as critical building blocks of the programme (Table 2). Material related to 19 of these components has appeared in reports and nine of the components have been exposed to the formal peer-reviewed literature. In terms of ensuring scientifically sound building blocks, each of the critical programme components should ideally have been subjected to a rigorous review associated with a respectable scientific journal. Table 2 indicates that 12 of the 21 critical components of the RHP have not been exposed to such a review. All of the components have at least had some form of review and each component is available in at least an official report of a supporting organisation. Still, the legitimisation of these components through the formal peer-review process falls far short of the benchmark suggested above.

Table 2

Critical methods of the RHP and how these were exposed to an organisational or internal peer review process versus an external or formal scientific peer-review process.

NO.	RHP component	Peer review	
		Official reports and book chapters	**Journal papers**
	Macroinvertebrates		
1	South African Scoring System	Moore and McMillan ,1993; Roux, 1992; Dallas *et al*., 1995; Chutter, 1998; Dallas *et al*., 1998	Dickens and Graham, 2002; Vos et al., 2002; Dallas, 2004b; Ollis et al., 2006b; Dallas, 2007c
2	Macroinvertebrate Response Assessment Index	Thirion, 2007	
	Fish		
3	Fish Assemblage Integrity Index		Kleynhans, 1999
4	Fish Response Assessment Index	Kleynhans, 2007	
	Riparian vegetation		
5	Riparian Vegetation Index	Kemper, 2001	
6	Vegetation Response Assessment Index	Kleynhans et al., 2007c	
	Habitat		
7	Index of Habitat Integrity	Kleynhans et al., 2007a	Kleynhans, 1996
8	Integrated Habitat Assessment System	McMillan, 1998	Ollis et al., 2006a
	Geomorphology		
9	Index of Stream Geomorphology	Rowntree and Ziervogel, 1999; Rowntree and Wadeson, 2000	
10	Geomorphological classification		Rowntree et al., 2000
	Hydrology		
11	Hydrological Index	Hughes, 2000	
	Reference conditions		
12	Reference conditions for macroinvertebrates	Eekhout et al., 1996; Dallas, 2000a; 2000b; Dallas and Fowler, 2000	Dallas, 1997; 2004a; 2007b; Dallas and Day, 2007
13	Reference frequency of occurrence of fish species	Kleynhans et al., 2007b	
	Other components		
14	EcoStatus and Ecoclassification	Kleynhans and Louw, 2007	
15	Aquatic Ecoregions for South Africa	Kleynhans et al., 2005; Kleynhans et al., 2007d	
16	Ecological Importance and Sensitivity Rating	DWAF 1999	
17	Quality assurance and control	Dickens et al., 2008	
18	Data interpretation and management	Fowler et al., 2000; Dallas, 2007a; Dallas et al., 2007; Strydom, 2003	Dallas et al., 1999
19	Information dissemination (including state-of-rivers reporting)	Strydom, 2003; Strydom et al., 2006; Murray and Hill, 2008	
20	Monitoring design and implementation process	Brown et al., 1996; Hohls, 1996; Uys et al., 1996; Roux, 1997; Murray, 1999; Roux, 1999; Mangold, 2001; Hill and Grobler, 2004; Roux, 2004; Murray and Hill, 2008	Roux, 2001a
21	Contextualising biomonitoring within the assessment and management of rivers	Roux, 1992	Roux et al., 1993; Roux et al., 1999b; Roux et al., 1999a; Roux et al., 1999c

5.1.3. Uptake within science

The first of the identified RHP papers was published in 1993. Between 1993 and 1998, there were only one and two citations to RHP papers according to Google Scholar and ISI respectively. Citations increased significantly during 1999 together with new papers published, suggesting at least a number of self citations. There was a generally increasing trend in the number of citations between 2000 and 2007 (Figure 3). Again, there is no benchmark to work with. It would have been most interesting and insightful to benchmark, for example, against the Australian river health programme, but such an assessment was beyond the scope of this project. Given the prominence and longevity of the RHP, and if the programme had delivered the suggested quota of high-quality peer-reviewed papers, a significantly better citation performance was possible. Especially uptake in the international literature has been poor.

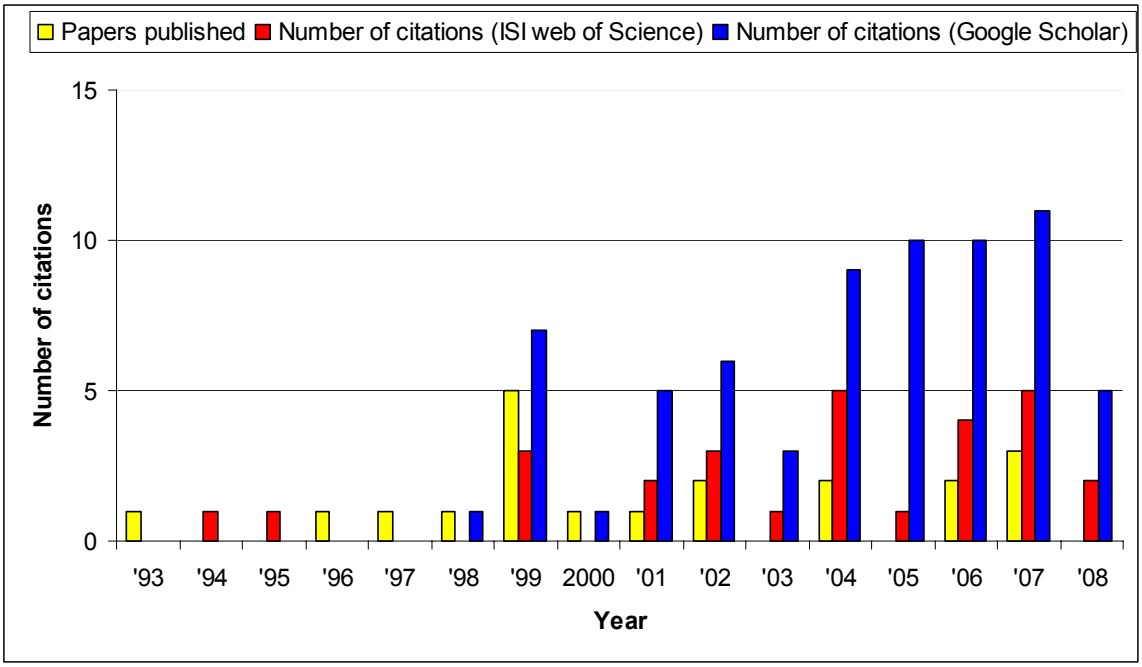

Figure 3
Time series of the number of papers published in peer-reviewed journals and the citations to these papers in the peer-reviewed literature according to ISI web of science and Google Scholar. For Google Scholar results, citations in literature other than peer-reviewed journals were filtered out. Self-citations (where an author cites his/her own work in another paper) were included.

5.2. Research relevance

5.2.1. Flexible management

The RHP was launched at a time when biological monitoring was a very new concept in water quality management circles. In a predominantly engineering environment at the time in South Africa, investment in a new programme that represented a radical departure from the established thinking and methods was a relatively high-risk

venture. The leading individuals from the three custodian organisations (DWAF, WRC and DEAT) showed remarkable vision and commitment to dedicate time, funding and staff to the new venture. DWAF in particular has articulated the vision of the RHP clearly during the initial years and the WRC has responded by supporting research that explored various trajectories towards this vision. The WRC's approach to the management of research has been commendable in that it has not compromised on accountability regarding delivery but at the same time has not been rigid or overly prescriptive around how projects were executed and deliverables were structured. Given reasonable motivation, mid-course alterations to project designs were freely accommodated. As a further demonstration of flexibility, the WRC has entertained many requests for funding outside their normal funding cycles. Although it was not possible to collate information on all the special projects, examples from anecdotal evidence include funding for technical workshops, training courses and conference attendance. We believe that the flexibility afforded by the WRC has been a significant enabling factor to the research and development performance of the RHP.

5.2.2. Diversity of participation

Technical contributions to RHP reports (Appendix A1) were made mainly by the University of Cape Town, Rhodes University, CSIR and DWAF, with some input also from Insight Modelling Services and the University of KwaZulu-Natal. Little diversity in main contributing organisations is added by the listed DWAF reports (Appendix A2), WRC reports (Appendix A3) and other reports (Appendix A4). Active provincial participation (Appendix A5), especially through the compilation of state-of-river reports and posters (Appendix A6), has added substantially to the organisational, cultural and disciplinary diversity within the broad RHP community. The 20 identified peer-reviewed papers and two book chapters (Appendix A7) have eight different first authors. The same names dominate in the listed conference presentations and proceedings (Appendix A12). A conscious effort was made to complement scientific information with local knowledge during the compilation of state-of-river products (Roux, 2004).

In summary, fewer than 10 scientists appear to have played critical roles regarding technical developments within the RHP. The continuity in contribution of some of these individuals over time is commendable but the lack of new role players entering the scene is a cause for concern. The active participation of several provincial teams boosted diversity of participation to an acceptable level.

5.2.3. International collaboration

Apart from an early and highly significant joint workshop between South Africa and Australia on the health indicators and classification of rivers (Uys, 1994), research collaboration with related initiatives in other regions of the world was virtually absent. The 1990s was a particularly dynamic era for the development of biomonitoring programmes around the world. We believe that a major learning opportunity has been forfeited by not actively pursuing international research collaboration.

5.2.4. Continuity over time

Continuity in leadership from the three national custodian organisations has been remarkable. Of the three, DWAF has had the highest turnover in people at the strategic leadership level, especially during the second half of the RHP's life. Given the importance of DWAF as the lead implementation agency of the RHP, this degree of discontinuity in leadership has led to at least some discontinuity in support and funding of ongoing development of the RHP. However, the core of DWAF's technical staff involved with RHP developments remained stable throughout the period and played an outstanding role in the development, testing and diffusion of various methods. The WRC has shown a very high level of stability in leadership related to the RHP. The organisation has consistently supported the RHP and funded various RHP-related research projects ever since the inception of the programme. The high level of continuity at a strategic and leadership level has been most important in enabling the RHP to grow into a national research, development and implementation programme.

As already mentioned under "diversity of participation", a very high level of continuity prevailed amongst the relatively few researchers that actively contributed to technical developments related to the RHP. Continuity of key individuals in active provincial teams was relatively high. It is worth noting that, especially during the early and middle phases of the RHP, these individuals participated largely on a voluntary basis. Rather than having organisational mandates, they simply care for rivers and believe that the RHP provides a mechanism to improve river health. Continuity in the interaction between national R&D teams and provincial implementation teams could and should have been higher. Whereas these respective teams mostly worked together very well in, for example, conducting river health surveys and compiling state-of-river products, follow-through to the next round of surveys or reporting did not exist. As a result, some regression in efforts was common and river health information that was produced did not become an integral part of adaptive monitoring and management systems in the participating organisations. Our view is that this particular lack of continuity is largely a symptom of insufficient funding and the usual restrictive nature of research projects that focus on one output or outcome at a time.

The "licence" for participation in the development and implementation of the RHP has changed over time from one characterised by trusting relationships and a shared philosophical vision (Roux, 2004) to one characterised by contractual or formal agreements. The former arrangement, although associated with a high degree of voluntary participation and flexibility in the styles and models of RHP implementation (Roux, 2001a), has resulted in a high sense of ownership by participating individuals and organisations. It is unclear how the latter "contractual environment", whereby DWAF would for example formalise the responsibilities of implementation agencies, will influence the continuity experienced to date in the programme.

5.2.5. Knowledge capturing and sharing

The many products (newsletters, technical reports, state-of-river reports and posters, peer-reviewed papers, book chapters, popular articles, conference proceedings, and a website) listed in Appendix A are testimony of the fact that the RHP was highly successful in terms of capturing and sharing new methods and information in explicit form. All three custodian organisations contributed significantly towards this end. An often more challenging but equally important feat is to facilitate sharing of tacit knowledge such as the subtleties of know-how to do a certain assessment. In this

regard, the WRC excelled as a most enabling research partner. It provided funding support for many social learning events: field trips where teams from various provinces would work together and exchange knowledge; road shows especially during the anchoring phase; champions symposia during which progress regarding the latest developments as well as difficulties with implementation were shared and discussed; and various technical workshops on methods such as the fish- and vegetation-based health indices. One point of criticism is that most of the knowledge sharing was restricted to South African audiences with limited effort applied to two-way sharing at international forums.

5.2.6. Improved river health

One of the primary objectives of the State-of-River (SoR) reporting initiative is to provide information on the ecological state of South Africa's rivers to enable resource managers to make informed decisions and take appropriate action. This information must furthermore show whether previous decisions were successful or failed to improve river health. For this to happen, monitoring and reporting must be repetitive to reveal trends and to establish whether appropriate management actions have taken place and have been successful. SoR reports are available for several catchments across the country and the WRC has funded the production and printing of the first three of these reports. Although a frequency of reporting every three years is recommended, none of the catchments has been revisited for full follow-on surveys and reporting. It is therefore not possible to say with certainty whether the health of these rivers have improved or declined. However, anecdotal accounts from provincial river health champions agree that the health of rivers are in general declining rather than improving. It seems that the RHP has facilitated a progression from a mindset of monitoring for the sake of monitoring (Roux, 2004) to a mindset of monitoring for the sake of reporting. A further step, of monitoring for the sake of influencing management decisions and environmental outcomes, is still largely lacking.

5.2.7. Increased capacity and awareness

The RHP has helped popularise river health to a level where it is understood and applied by a wide variety of people, ranging from consultants to politicians and learners. The WRC has played an active role in promoting and funding a number of river health awareness-creation events, the development of related educational material and tools such as colouring-in books, activity books and the development of mini-SASS, a simple method for measuring river health aimed at learners (Appendix A10). In addition, a number of short courses and technical courses have been developed and presented and river health related seminars held. Several people have obtained higher degrees based on research that is directly related to the RHP (a few examples are listed in Appendix A15). Substantial effort has gone into the development of material and products to address the information needs of the programme's wide stakeholder base (e.g. Strydom et al., 2002). However, there is limited understanding of the effectiveness of these products on influencing decision-making or the impact that the respective products has had on river health (Van Wyk et al., 2008). Notwithstanding the widespread capacity development and enthusiastic support of the active few, the thin spread of key individuals and the general lack of substitutes for these individuals have always left the programme vulnerable to staff changes in participating organisations.

5.2.8. Improved policy

The RHP has been progressive in the sense that the programme's aim and objectives are fully aligned with the monitoring requirements of the National Water Act (Act No 36 of 1998). As such the results generated by the RHP can potentially complement and influence water resource assessment, management and planning as well as associated policies and strategies. Yet, there are no formal feedback loops between the RHP's monitoring results and the processes that shape national water resource management strategy and policy. We could find no evidence that the results of the RHP have had any direct influence on national or sub-national water policies, beyond some support for monitoring programmes.

5.2.9. Adoption of the RHP by implementers

During 1996, the RHP was first adopted by a number of sub-national government agencies with a mandate to manage and conserve river ecosystems. Provincial implementation teams self-organised around these early adopters, largely based on key individuals and existing professional or personal networks. Since then, some new adopters have come on board and a few of the early adopters have become less active as RHP practitioners. Adoption of the programme was never complete across all provinces of South Africa. However, given resource limitations and the multitude of other priorities and responsibilities that characterise these sub-national agencies, the level of adoption of an essentially new technical product that was achieved is quite remarkable. The fact that not all intended users have adopted the programme to date reflects the reality of a relatively small pool of skilled human resources that is available, a lack of dynamic leadership that could foster cooperative implementation at sub-national level, lack of stability and high staff turnover in the target organisations, and insufficient funding to secure long-term commitment and to meet all the programme's implementation and maintenance requirements.

5.2.10. Broader societal influence

The RHP is widely viewed as a model R&D programme and has served as a source of inspiration for many other programmes, for example a wetland monitoring programme and an estuarine monitoring programme. The assessment techniques and monitoring results of the RHP are also widely used outside the programme, for example in determining the ecological reserve for rivers, identifying spatial options for freshwater conservation, assessing environmental impacts, monitoring environmental compliance associated with commercial forestry, and even in specifying in-stream quality objectives for water use licences. The SoR reporting initiative has made a significant contribution to state-of-the-environment reporting in South Africa and the development and use of river health categories has strongly influenced the ecological classification of rivers in the country. A combination of careful design and relatively widespread application of the RHP has resulted in significant value addition also outside the immediate sphere of the programme.

5.2.11. Advancement of RHP- and WRC-specific objectives

The four objectives of the RHP are related to state, trends, problems and sound management (see the section on the history of the RHP). In retrospect, RHP-related research has done exceedingly well in advancing some of these objectives, notably

to measure, assess and report on spatial trends in the ecological state of aquatic ecosystems; and to identify and report on emerging problems regarding the state of aquatic ecosystem in South Africa. A third objective of the RHP was not achieved, namely to detect and report on temporal trends in the ecological state of aquatic ecosystems. The fourth objective, to ensure that all reports provide scientifically sound and managerially relevant information for management, was advanced through research funded by the WRC but with some ambivalence as to the degree to which this was achieved.
The WRC sets as objectives for its research projects to contribute value to South Africa and its people in each of four impact areas: knowledge contribution, society, economy, human health and environment. RHP-related research has significantly advanced knowledge in the field of monitoring, assessing and reporting on the health of aquatic ecosystems. It has also contributed significantly to the overall understanding of rivers and their biophysical structure and ecological functioning. The links between healthy rivers and healthy people as well as healthy rivers and societal well-being in general have been explored, albeit to a lesser degree. The relationship between river health and economic costs and benefits has remained largely untouched in the RHP context.

In summary, advancement of RHP- and WRC specific objectives through RHP-related research has been good.

5.3. Assessment summary

Our assessment has revealed varying performance associated with research investment in support of the RHP programme (Figure 4). Most disappointing is the poor performance in the research excellence category where all three indicators received a rating of one. Further disappointing results relate to the degree of international research collaboration, the ultimate goal of improved river health, and the influence on the water policy environment. Our assessment returned acceptable ratings for diversity of participation, continuity over time, increase of capacity and awareness, and adoption by implementers. The highest ratings were for flexible management, capturing and sharing of knowledge, the broader influence of the RHP and achievement of RHP- and WRC-specific objectives.

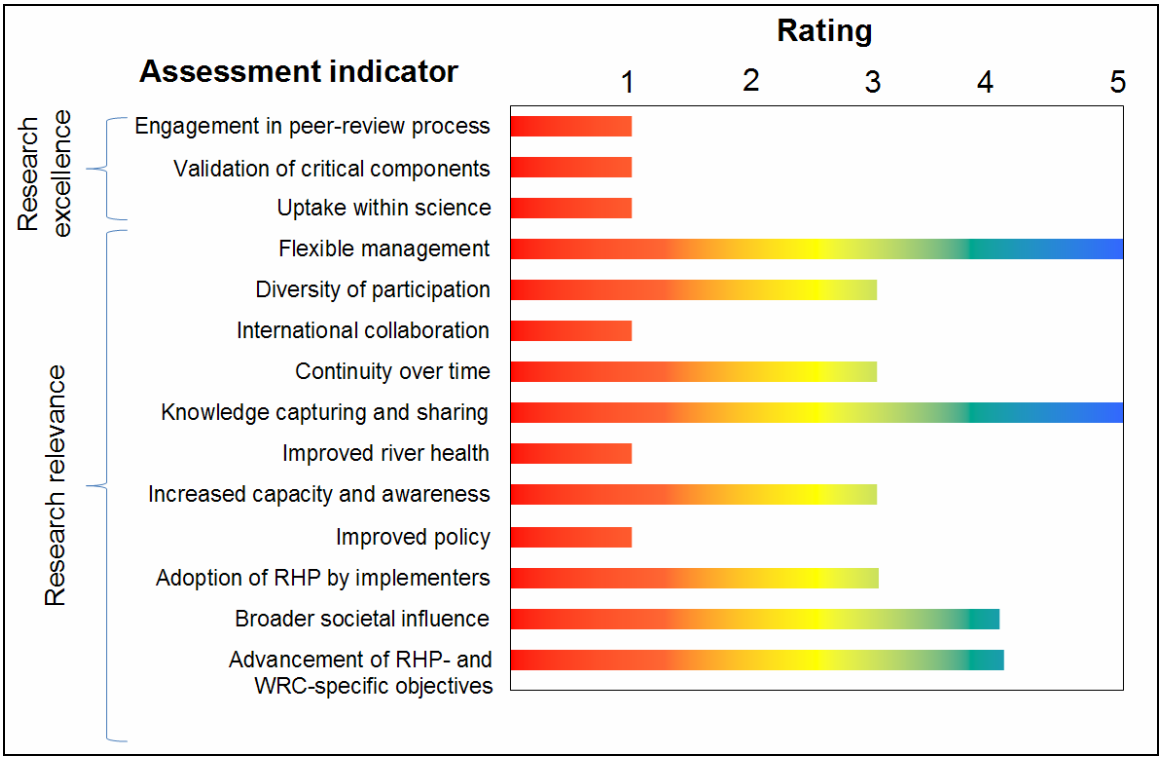

Figure 4
Summary of the impact assessment using a five-point rating scale for each of the measures developed in this study. A rating of one indicates performance that is outright disappointing; two reflects a performance below the standard, expectation or benchmark rating; three is breaking even with the performance benchmark; four is better than the benchmark; and five reflects outstanding performance.

6. CONCLUSION

We assessed the impact that research investment in the development and implementation of the RHP has had in a broad social-environmental context. It was virtually impossible to isolate the research investment of the WRC because of the several organisations that have co-invested in the RHP. Acknowledging this limitation, we have developed an assessment framework using 14 different impact measures while distinguishing between measures for research excellence (three indicators) and measures for research relevance (11 indicators).

We would like to stress that an over-emphasis on quantitative measures of research impact can be misleading. As an example, uninformed acceptance of the results of impact factors and citation indices can stifle creativity and impair diversity of styles that contribute to overall innovation (Sparkes, 2007). The use of quantitative data on the basis of their availability is no substitute for a careful examination of the tangible products and also intangible outcomes of a research programme. In our assessment we have attempted to balance the use of quantitative measures and qualitative assessments, and between looking at tangible products and intangible outcomes.

6.1. Overall finding

The results of this assessment reflect a balance between poor, satisfactory (average) and good areas of performance related to research impact. An overall outcome is a sense that the WRC and its co-custodians has done extremely well in facilitating the transition from developing technical methods to establishing operational routines. The WRC has played an overwhelmingly positive role in enabling the kind and continuity of research that led to remarkable adoption by implementation agencies, capacity and awareness creation amongst diverse audiences, and an impact on water and research activities in a much broader sphere than that directly related to the RHP. Particularly noteworthy is the high level of knowledge capturing and social sharing that took place. We believe that this success is to a large degree the result of the community-of-practice style of participation that prevailed amongst RHP practitioners. The WRC's flexible management style has played a significant role in enabling this community formation and maintenance.

However, our list of impact measures and benchmarks also reveals a number of areas where performance could and perhaps should have been better. First amongst these is the overall impact within the body of science. This aspect has clearly been neglected. Related to this is the low degree of international collaboration that has been achieved, with the impact on policy and actual improvement of river health further disappointing features. The poor performance for research excellence is probably a result of the strong emphasis that was placed on understanding and catering for stakeholder needs and to facilitate practical implementation of the RHP. While such a focus is admirable, it should be matched with resources for and efforts to ensure scientific credibility.

Interestingly, the assessment indicated that RHP-related research in general advanced the specified impact areas of the WRC, notwithstanding the poor performance in the areas of research excellence and international collaboration. Although the WRC's main activity is to fund research projects and the organisation is explicit about its desire to build international knowledge networks, research excellence and international research collaboration does not seem to be actively encouraged, or portrayed as serious objectives, in the management of research

projects. An improvement in these areas could benefit South Africa's research profile significantly and guard against the production, acceptance and incorporation of "pseudo facts" (knowledge that has not been properly validated through a rigorous scientific process).

A further interesting phenomenon is that the RHP's objectives have largely been advanced, yet there is no evidence that the health of rivers has improved nor has the substantial body of river health information had much influence on water policy. The likely explanation is that the RHP has largely remained true to its main purpose of being a monitoring programme that generates and disseminates accurate and objective information. This is a sound position for a monitoring programme, but without effective extension into the management and policy domains, there is no guarantee that the information stemming from the programme will be used to the benefit of society.

6.2. Recommendations

The value of an impact assessment approach such as this is to facilitate periodic reflection and to reveal areas in need of more focussed research attention. This provides guidance for the strategic allocation of available research funding. Ideally, an impact assessment of this nature should be undertaken in close collaboration with all key role players to maximise the potential for social learning and the likelihood of an appropriate response to the findings. While an inclusive assessment process was beyond the scope of this study, we recommend that the findings of this assessment be presented to and deliberated within at least the RHP's custodian organisations.

Based on our findings, two sets of further recommendations can be made. The first relates to the WRC and its research management process and the second to future support for RHP-related research.

Recommendations related to the WRC and its research management process:

- In a world of ever-increasing bureaucracy, accountability and administrative loads associated with the management of research funding, the WRC seems to be a shining exception to the rule. Leaders of research projects are highly complimentary of the WRC's professional, streamlined and flexible management process. Such a process relies on having competent and experienced research managers within the organisation and is worth protecting as a high priority.

- WRC (and indeed all participating organisations) need to consider the concerns expressed in this report regarding research excellence and international research collaboration as a central issue in the selection and management of research projects. The long time lag that commonly exists between conducting research and getting the results in peer-reviewed literature poses a practical problem. Furthermore, international research collaboration has cost implications. However, creative solutions are very important for both of these issues.

- The WRC acknowledges the value of investing in R&D *programmes* as opposed to investing in R&D *projects* only. This is an area that justifies some research in own right. The varying levels of success in RHP-related research provide valuable insights into the design and maintenance requirements of

R&D programmes. We recommend using these insights, as well as those obtained through R&D programmes such as the KNP Rivers Research Programme, as a departure point to do further research into the enabling conditions for R&D programmes. If the findings of such work are truly incorporated into models for research funding and management, it could have significant implications for future knowledge creation and application in the water sector.

Recommendations related to future research in support of the RHP:

- *International benchmarking*: During the early years of the RHP, much value was derived from international benchmarking. As an example, the considerable body of work that existed at the time and that was freely available from the United States Environmental Protection Agency was used to great benefit within the RHP. Developed countries often have much more resources to dedicate to research and South Africa can benefit from careful identification, adaptation and integration of externally produced scientific information. Much has happened in the field of environmental monitoring and reporting, also specifically related to river health, since the early years of the RHP. It is recommended that a comprehensive benchmarking exercise be undertaken to see where the RHP stands against related international practices. Such an exercise could also help identify international partner organisations for strategic research collaboration.

- *Embrace the scientific publication process*: Those who worked as part of the larger RHP community have achieved much to be proud of. This sense of achievement is only dampened by the belief that the RHP community has not had the international influence and acknowledgement that perhaps their collective achievement justified. The rich learning that is gained through a rigorous review process is a special type of capacity building and is a further by-product of scientific publication. It is recommended that peer-reviewed publication and presentation of at international conferences of key topics be encouraged and supported.

- *Extension into management and policy domains*: The influence of the RHP on river health and river management policy should have been much greater and this requires further exploration and investigation. We recommend that a project (or projects) be supported to explore ways of linking RHP-derived information with policy or governance frameworks and management frameworks. This is the area where the RHP can most directly influence the management and improvement of aquatic ecosystems.

- *Long-term research, development and implementation initiatives*: Related to the preceding point, the operational influence and effectiveness of the RHP could significantly improve following careful design of and support for a number of long-term research, development and implementation projects. Such projects should have as an ultimate goal the improvement of river health; team a research partner with implementation agencies; focus on a specific catchment or Water Management Areas; include both developmental and implementation objectives; and run for a period of seven years or longer. Such projects will fulfil the requirements for reporting on temporal trends by facilitating follow-on assessments. These projects will also facilitate significant capacity building of a conceptual and operational nature because of the stability that they will offer; and stand a better chance of influencing management decisions, general awareness and policy processes; and

facilitate the development of trust, increased diversity and effective collaboration within diverse teams. Such projects would depend on the right mixture of inspirational leadership and core funding, both of which are thinly spread in South Africa. Core funding could potentially be sourced from various partners, for example DWAF (under Chapter 14 of the National Water Act, DWAF has to report on the health of aquatic ecosystems), industry and WRC.

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APPENDIX A

Products of the River Health Programme (1992 to April 2008)

A1. RHP REPORTS

Report Series

Report Series No.	Title (National Biomonitoring Programme for Riverine Ecosystems: …)	Author(s)	Year of publication
1	Framework Document for the Programme	Hohls, D.R.	1996
2	Proceedings of spatial framework workshop.	Brown, C.A., Eekhout, S. and King, J.M	1996
3	Technical considerations and protocols for the selection of reference and monitoring sites	Eekhout, S., Brown, C.A. and King, J.M.	1996
4	Ecological indicators, a review and recommendations	Uys, M.C., Goetsch, P-A. and O'Keeffe, J.H.	1996
5	Proceedings of a Consultation Planning Meeting	DWAF	1996
6	Overview of the design process and guidelines for implementation	Roux, D.J.	1997
7	Development of an index of stream geomorphology for the assessment of river health	Rowntree, K.M. and Ziervogel, G.	1999
8	National Implementation Assessment	Murray, K.	1999
9	Delineation of river types of Mpumalanga, South Africa: Establishing a spatial framework for selection of reference sites	Dallas, H.F. and Fowler, J.	2000
10	Ecological Reference condition project: Field-manual. General information, catchment condition, invertebrates and water chemistry.	Dallas, H.F.	2000
11	Rivers database: A user manual (revised edition)	Fowler, J., Dallas, H.F. and Janssens, P.	2000
12	The derivation of ecological reference conditions for riverine macroinvertebrates	Dallas, H.F.	2000
13	An Index of Stream Geomorphology for the Assessment of River Health. Field manual for channel classification and condition assessment	Rowntree, K. and Wadeson, R.	2000
14	Aquatic Biomonitoring - Hydrology	Hughes, D.A.	2000
15	An Implementation Manual for the River Health Programme - A hitchhiker's guide to putting the RHP into action	Mangold, S.	2001
16	Report on a National Workshop on the use of Fish in Aquatic Health Assessment	Kleynhans, C.J.	2003
17	Compiling State-of-Rivers Reports and Posters: A Manual.	Strydom, W.F.	2003
18	River Health Programme: Site characterisation field-manual and field-data sheets	Dallas, H.F.	2005

NAEHMP: RHP: National Coverage Phase Reports

Dallas, H.F. 2005. *Inventory of National River Health Programme Monitoring Sites, Volume 1*. Internal Report. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria. Available online: http://www.csir.co.za/rhp/

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A2. DWAF REPORTS

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Department of Water Affairs and Forestry. 1999. *Resource Directed Measures for the Protection of Water Resources: River Ecosystems.* Appendix 7: Assessment of the Ecological Importance and Sensitivity. Department of Water Affairs and Forestry, Pretoria.

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Everett, M.J. and Quibell, G. 1995. *The Feasibility of Using a Physiographic Approach in Water Quality Management. Phase II – Protocols towards Physiographic Boundary Verification, Using the Eastern Transvaal Regions as an Example*. IWQS Report No.: N/0000/00/REQ/0794. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

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A3. WRC REPORTS

Chutter, F.M. 1998. *Research on the rapid biological assessment of water quality impacts in streams and rivers*. WRC Report No 422/1/98. Water Research Commission, Pretoria.

Dallas, H.F., Day, J.A. and Reynolds, E.R. 1995. *The effects of water quality variables on riverine biotas*. WRC Report No 351/1/94. Water Research Commission, Pretoria.

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Kemper, N.P. 2001. *RVI - Riparian Vegetation Index.* WRC Report No. 850/3/01. Water Research Commission, Pretoria.

Kleynhans, C.J. 2007. *Module D: Fish Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2).* WRC Report No. TT 330/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria.

Kleynhans, C.J. and M.D. Louw. 2007. *Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2)*. WRC Report No. TT 329/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria.

Kleynhans, C.J., Louw, M.D. and Moolman, J. 2007a. *Reference frequency of occurrence of fish species in South Africa.* WRC Report No. TT 331/08. Joint Water Research Commission and Department of Water Affairs and Forestry report., Pretoria.

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Uys, M.C. (Ed.). 1994. *Classification of Rivers and Environmental Health Indicators. Proceedings of a joint South African / Australian workshop. February 7-14 1994, Cape Town, South Africa*. WRC Report No. TT 63/94. Water Research Commission, Pretoria.

Wolhuter, L.E. and Impson, N.D. 2007. *The state of yellowfish report in South Africa*. WRC Report Number: TT 302/07. Water Research Commission, Pretoria.

A4. OTHER REPORTS

Eekhout, S., King, J.M. and Wackernagel, A. 1997. *Classification of South African Rivers, Volume 1.* Department of Environmental Affairs and Tourism, Pretoria.

McMillan, P.M. 1998. *An integrated Habitat Assessment System (IHAS v2), for Rapid Biological Assessment of Rivers and Streams.* CSIR research project, number ENV-P-1 98132 for the Water Resources Management Programme.

A5. PROVINCIAL RHP REPORTS

A large number of provincial RHP reports have been produced. These reports can be obtained from the RHP Provincial Champions:

PROVINCIAL CHAMPIONS				
Name	**Capacity**	**Affiliation**	**Address**	**Email Address**
Mr Mick Angliss	Provincial Champions: Limpopo	Limpopo Department of Economic Development, Environment and Tourism (LEDET)	Limpopo Department of Economic Development, Environment and Tourism (LEDET), P.O.Box 217, Polokwane, 0700	anglissmk@ledet.gov.za
Mr Paul Fouché		University of Venda	Department of Biological Sciences University of Venda Pbag X5050, THOHOYANDOU, 0950	pso@univen.ac.za
Ms Tovho Nyamande	Provincial Champion: Western Cape	Department of Water Affairs and Forestry: Western Cape (DWAF)	DWAF: Western Cape, Private Bag X16, Sanlamhof, 7532	NdiitwT@dwaf.gov.za
Ms Hermien Roux	Provincial Champion: North West	North West Department of Agriculture, Conservation and Environment (DACE)	North West Department of Agriculture, Conservation and Environment	hroux@nwpg.gov.za
Ms Gerda Venter	Provincial Champion: Free State	Department of Water Affairs and Forestry: Free State (DWAF)	DWAF: Free State, P O Box 528, Bloemfontein, 9300	venter.gerda@dwaf.gov.za
VACANT	Provincial Champion: KwaZulu- Natal			
Dr Johan Engelbrecht	Provincial Champion: Mpumalanga	Mpumalanga Tourism and Parks Agency (MTPA)	Mpumalanga Parks Board, Private Bag X1088, Lydenburg, 1120	jseng@intekom.co.za
Dr Andrew Deacon	Provincial Champion: Kruger National Park	South African National Parks (SANParks)	SANParks, Private Bag X402, SKUKUZA, 1350	andrewd@sanparks.org

Ms Pumza Gasa-Lubelwana	Provincial Champion: Eastern Cape	Department of Water Affairs and Forestry: Eastern Cape (DWAF)	Department of Water Affairs and Forestry, P.O. Box 7019, East London, 5200	lubelwp@dwaf.gov.za
Mr Piet Muller	Provincial Champion: Gauteng	Gauteng Department of Agriculture, Conservation and Environment (GDACE)	Gauteng Department of Agriculture, Conservation and Environment (GDACE), P O Box 8769, Johannesburg, 2000	piet.muller@gauteng.gov.za
VACANT	Provincial Champion: Northern Cape			

A6. STATE-OF-RIVERS REPORTS AND POSTERS

State-of-Rivers Reports

Available online: http://csir.co.za/rhp/

No	Title	Year of publication
1	State of the Crocodile River (Mpumalanga)	1998
2	*Crocodile, Sabie-Sand & Olifants River Systems*.	2001
3	*Letaba and Luvuvhu River Systems*.	2001
4	*uMngeni River and neighbouring rivers and streams*	2002
5	*Diep, Hout Bay, Lourens and Palmiet River Systems*	2003
6	*Free State Region Rivers*	2003
7	*The Hartenbos and Klein Brak River Systems*	2003
8	*Berg River System*	2004
9	*Buffalo River System*	2004
10	*Greater Cape Town's Rivers*	2005
11	*Monitoring and Managing the Ecological State of Rivers in the Crocodile (West) and Marico WMA*	2005
12	*Mokolo River*	2006
13	*Olifants/Doorn and Sandveld Rivers*	2006
14	*Rivers of the Gouritz Water Management Area*	2007

State-of-Rivers and related posters

Available online: http://csir.co.za/rhp/

No	Title	Year of publication
1	*The Ecological State of the Crocodile River (Mpumalanga)*	2000
2	The Ecological State of the Modder River poster (Free State)	2002
3	The Ecological State of the Southern Gauteng Rivers	2003
4	The Ecological State of the rivers of the Free State Region	2004
5	Free State Region Fun Poster	2004
6	The Ecological State of the Crocodile (West) Marico (English and Afrikaans & English and seTswana)	2005

7	The Ecological State of Cape Town's Rivers (English and isiXhosa)	2005
8	The Ecological State of the Berg River (English and Afrikaans)	2005
9	The Ecological State of the Rivers of the Overberg Region.	2006
10	The Ecological State of the Goukou and Duiwenhoks Rivers	2006
11	Habitat Integrity of Selected Rivers of the North West Province	2007
12	Habitat Integrity of Selected Rivers of the North West Province Major Impacts and Management Actions	2007

A7. PEER REVIEWED JOURNAL PAPERS AND BOOK CHAPTERS

Peer reviewed journal papers

Dallas, H. 1997. A preliminary evaluation of aspects of SASS (South African Scoring System) for the rapid bioassessment of water quality in rivers, with particular reference to the incorporation of SASS in a national biomonitoring programme. *Southern African Journal of Aquatic Sciences* 23(1): 79-94.

Dallas, H.F. 2004(a). Spatial variability in macroinvertebrate assemblages: comparing regional and multivariate approaches for classifying reference sites in South Africa. *African Journal of Aquatic Science* 29 (2): 161 – 171.

Dallas, H.F. 2004(b). Seasonal variability of macroinvertebrate assemblages in two regions of South Africa: implications for aquatic bioassessment. *African Journal of Aquatic Science* 29 (2): 173-184.

Dallas, H.F. 2007(a). The effect of biotope-specific sampling for aquatic macroinvertebrates on reference site classification and the identification of environmental predictors in Mpumalanga, South Africa. *African Journal of Aquatic Science* 32 (2): 165-173.

Dallas, H.F. 2007(b). The influence of biotope availability on macroinvertebrate assemblages in South African rivers: implications for aquatic bioassessment. *Freshwater Biology* 52: 370-380.

Dallas, H.F., Janssens, M.P. and Day, J.A. 1999. An aquatic macroinvertebrate and chemical database for riverine ecosystems. *Water SA* 25(1): 1-8.

Dallas, H.F and Day, J.A. 2007. Natural variation in macroinvertebrate assemblages and the development of a biological banding system for interpreting bioassessment data – a preliminary evaluation using data from upland sites in the south-western Cape, South Africa. *Hydrobiologia* 575 (1): 231-244.

Dickens, C.W.S. 1998. Implementing a River Health Programme in South Africa. *Verhandlungen Internationale Vereinigung Limnologie* 27: 2323-2325.

Dickens, C.W.S. and Graham, P.M. 1998. Biomonitoring for effective management of wastewater discharges and the health of the river environment. *Aquatic Ecosystem Health and Management* 1: 199-217.

Dickens, C.W.S. and Graham, P.M. 2002. The South African Scoring System (SASS) Version 5: Rapid Bioassessment Method for Rivers. *African Journal of Aquatic Science* 27: 1-10.

Kleynhans, C.J. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo system, South Africa). *Journal of Aquatic Ecosystem Health* 5: 41-54.

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Ollis, D.J., Boucher, C., Dallas, H.F. and Esler, K.J. 2006(a). Preliminary testing of the Integrated Habitat Assessment System (IHAS) for aquatic macroinvertebrates. *African Journal of Aquatic Science* 31(1):1-14.

Ollis, D.J., Dallas, H.F., Esler, K.J. and Boucher C. 2006(b). Bioassessment of the ecological integrity of river ecosystems using aquatic macroinvertebrates: An overview with a focus on South Africa. *African Journal of Aquatic Science* 31 (2): 205-227.

Roux, D.J. 2001. Strategies used to guide the design and implementation of a national river monitoring programme in South Africa. *Environmental Monitoring and Assessment* 69: 131-1581.

Roux, D.J., Van Vliet, H.R. and Van Veelen, M. 1993. Towards integrated water quality monitoring: assessment of ecosystem health. *Water SA* 19(4): 275-280.

Roux, D.J., Kempster, P.L., Kleynhans, C.J., Van Vliet, H.R. and Du Preez, H.H. 1999a. Integrating stressor and response monitoring into a resource-based water-quality assessment framework. *Environmental Management* 23 (1): 15-30.

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Roux, D.J., Kleynhans, C.J. Thirion, C., Hill, L., Engelbrecht, J.S., Deacon, A.R. and Kemper, N.P. 1999c. Adaptive assessment and management of riverine ecosystems: the Crocodile/Elands river case study. *Water SA* 25: 501–511.

Rowntree, K.M., Wadeson, R.A. & O'Keeffe, J., 2000: The Development of a Geomorphological Classification System for the Longitudinal Zonation of South African Rivers, *South African Geographical Journal*, 82(3), p.163-172.

Vos, P., Wepener, V. and Cyrus, D.P. 2002. Efficiency of the SASS4 rapid bioassessment protocol in determining river health: A case study on the Mhlathuze River, KwaZulu-Natal, South Africa. *Water SA* 29(1).

Peer-reviewed book chapters

Roux, D.J. 1999. Design of a national programme for monitoring and assessing the health of aquatic ecosystems, with specific reference to the South African River Health Programme Reports. In: Gerhardt, A. (Ed). 1999. *Biomonitoring of Polluted Water*. Environmental Research Forum Vol. 9, pp. 13-32. Trans Tech Publications, Switzerland.

Roux, D.J. 2004. From Monitoring Design to Operational Program: Facilitating the Transition under Resource-Limited Conditions. In: Wiersma, G. B. (Editor). *Environmental Monitoring,* pp 631-648. CRC Press, Boca Raton.

Strydom, W.F., Hill, L. and Eloff, E. 2006. The Role of Communication in Governance: The River Health Programme as a Case Study. In: Turton, A.R., Hattingh, J., Maree, G.A., Roux, D.J., Claassen, M. and Strydom, W.F. (Eds). *Governance as a Trialogue: Government-Society-Science in Transition.* Water Resources Development and Management Series, pp 254-290. Springer-Verlag, Berlin.

A8. POPULAR ARTICLES

Author unknown. 2000. National RHP - provincial plan for Mpumalanga. 2000. *SA Waterbulletin* 26(4).

Author unknown. 2000. River Health Programme workshop: November 2000, Pretoria. *SA Waterbulletin* 27 (1).

Author unknown. 2001. Fish experts gather for a gaggle. *SA Waterbulletin* 27(5).

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Roux, D.J. 2001. The first of a series of State-of-Rivers reports for South Africa was released by Minister Ronnie Kasrils on 20 March 2001 in Pietermaritzburg, as part of the National Water Week Campaign (19 to 25 March 2001). *Technobrief* 10(2).

Author unknown. 2005. Report highlights Impacts on River Health (Buffalo River State-of-Rivers Report). 2005. *The Water Wheel*, March/April 2005.

Author unknown. 2007. More bulk infrastructure planned for South Africa. 2007. *The Water Wheel*, January/February 2007.

Author unknown. 2008. Water Resource Management. *The Water Wheel*, September/October 2008.

Hill, L. and Leaner, J. 2006. Case Study: Plankenbrug River, Western Cape, South Africa. *Water Resources and Pollution of Water*, Operation Day's Work, 2006, Denmark.

Hill, L. and van Vuuren, L. 2007. Tenth Anniversary of River Health Programme. *The Water Wheel,* March/April 2007.

Roux, H. 2005. The unique dolomitic eyes of the Crocodile (West) and Marico Water Management Area. Southern African Wildlife Management Association Newsletter, January 2005: 45-47.

Strydom, W. 2001. State of the Rivers reports – a first for South Africa. *SA Waterbulletin* 27 (4), July/August 2001.

Strydom, W. 2006. Award for Rivers Programme. *The Water Wheel,* January/February 2006.

Van Vuuren, L. 2002. Preventing the damnation of SA's rivers. *Water Sewage and Effluent*, May 2002.

Van Vuuren, L. 2006. Award for Rivers Programme. *The Water Wheel*, January/February 2006.

Van Vuuren, L. 2007. Freshwater Conservation. Helping Rivers fight for their lives. *The Water Wheel*. January/February 2007.

Van Vuuren, L. 2007. Diatoms – a new dimension to water monitoring. *The Water Wheel*, May/June 2007.

Van Vuuren, L. 2007. Poor decisions of the past may cost the cape its 'living gold'. *The Water Wheel*, September/October 2007.

A.9. ENVIRONMENTAL TRAINING EDUCATION AND AWARENESS CREATION

Activity books

River Health Programme. 2000. My home: a healthy river! Colouring-in Book (Finny Fish) in English, isiZulu and Sesotho. Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 2001. My home: a healthy river! Colouring-in Book (Finny Fish) in English, Afrikaans and isiXhosa. Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 2003. My home: a healthy river! Colouring-in Book (Finny Fish) in English, Afrikaans and Sesotho. Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 2005. My home: a healthy river! Activity Book for the Eastern Cape Grade 1-3 Foundation Phase Learners. Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 2005. Water-wise with our rivers. Activity Book for the Free State Grade R-3 Foundation Learners in English and Afrikaans. Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 2006. Rivierpret! Aktiwiteitsgids vir die Wes-Kaapse Grondslagfase Leerders (Graad 1-3). Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 2006. Rivers are fun! Activity Book for the Western Cape Foundation Phase Learners (grade 1-3). Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 2007. Yonwabele imilambo yetho! Incwadana yemisebenzi yabaFundi besiga esisisiseko baseNtshona Koloni (ibanga loku-1 ukuya kwelesi – 3). CSIR, Pretoria.

Information brochures and guideline documents

Gerber, A. and Gabriel, M.J.M. 2002. *Aquatic Invertebrates of South African Rivers, Field Guide*. First Edition. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

Gerber, A. and Gabriel, M.J.M. 2002. Aquatic Invertebrates of South Africa (Illustrations). Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 199(?). A National Biomonitoring Programme (information brochure). Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

River Health Programme. 2003. Hartenbos and Klein Brak Flyer. Department of Water Affairs and Forestry, Pretoria.

Strydom, W. 2003. Rural Communication and River Health. CSIR, Pretoria.

RHP Newsletters

River Health – Newsletters of the River Health Programme. (1996 – 2002). Available online: http://www.csir.co.za/rhp/

Training

1) Biomonitoring Short Courses

Courses presented:

24 to 28 February 1997, Roodeplaat Training Centre, Pretoria.

27 to 31 October 1997, Roodeplaat Training Centre, Pretoria.

23 to 27 February 1998, Roodeplaat Training Centre, Pretoria.

10 to 14 February 2003, Rhodes University, Grahamstown (the biomonitoring short course was presented by Rhodes University for several years; detailed information could not be obtained)

For more details, contact Mr Ramogale Sekwele, Resource Quality Services, Department of Water Affairs and Forestry, Tel: 012 808 9500, Email: SekweleR@dwaf.gov.za

2) EcoStatus training courses

20 to 21 April 2005, Stellenbosch.

3 to 4 May 2005, Bloemfontein.

5 to 5 May 2005, Pretoria.

10 to 11 May 2005, Durban.

17 to 19 August, Kruger National Park (Letaba).

11 to 13 July 2006, Pretoria.

18 to 20 July 2006, Stellenbosch.

22 to 24 July 2006, East London

1 to 3 August 2006, Pietermaritzburg

For more details, contact Dr Neels Kleynhans, Resource Quality Services, Department of Water Affairs and Forestry, Tel: 012 808 9500, Email: KleynhansN@dwaf.gov.za

3) SASS workshops and training courses

SASS5 workshops

SASS5 workshops. Several workshops were held in the late 1990s and early 2000s where the input of a number of experts was gathered as a contribution to the refinement of the SASS method. Most of these were held under the direction of the WRC.

SASS5 training courses

A number of SASS training courses have been presented over the past few years. The following is a list of some of the courses presented more recently.

2000, Cape Town (Southern Waters)

17 to 18 September 2001, Sabie (presented by AfriDev consultants).

6 to 8 May 2002, Sabie (presented by AfriDev consultants).

23 September 2002, Sabie (refresher course presented by AfriDev consultants).

10 to 2 May 2004, Sabie (presented by AfriDev consultants and Environmental Biomonitoring Services).

19 to 21 September 2005, Sabie (presented by Nepid Consulting).

15 to 17 April 2008, Sabie (presented by Nepid Consulting).

For more details, contact Dr Rob Palmer, Nepid Consulting, Tel: 013 751 1533, Email: rob@nepid.co.za or Dr Helen Dallas, Freshwater Research Unit / The Freshwater Consulting Group, Tel: 021 650 3631, Email: Helen.Dallas@uct.ac.za.

A.10 RHP WEBSITE

http://csir.co.za/rhp/

A.11 CONFERENCE PRESENTATIONS AND PROCEEDINGS

(Incomplete list)

Conference presentations

Dallas, H.F. 2003. *Spatial variability in macroinvertebrate assemblages: implications for bioassessment and defining reference conditions.* Oral presentation at the North America Benthological Society Annual Conference, Athens, Georgia, United States.

Dickens, C.W.S. and Graham, P.M. 1996. *Biomonitoring for effective management of wastewater discharges and the health of the river environment*. Vic Falls Conference on Aquatic Systems and International Symposium of Great Lakes of the World, Victoria Falls, Zimbabwe, 1996.

Dickens, C.W.S. 1998. Implementing *a River Health Programme in South Africa.* SIL, International Society for Theoretical and Applied Limnology, Dublin, Ireland, 1998.

Roux, D.J. 1992. *Development of a Surveillance Programme as Part of the National Water Quality Information Programme of South Africa.* Conference on Aquatic Ecosystems. Cape Town, South Africa, 7-10 July 1992.

Roux, D.J. 1993. *Towards an Environmental Assessment Program for South Africa: Current Developments and Future Challenges.* The 3rd International Conference on Aquatic Ecosystem Health and the Ecological Significance of Bioassay Techniques. Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA, 23-27 May 1993.

Roux, D.J. 1996. *Design considerations for a National Biomonitoring Programme.* Biennial Conference and Exhibition of the Water Institute of Southern Africa. Feather Market Centre, Port Elizabeth, 20-23 May 1996.

Roux, D.J. 1996. *Conceptual design for a biomonitoring programme to assess the state of South African riverine ecosystems*. Vic Falls Conference on Aquatic Systems and International Symposium on Exploring the Great Lakes of the World (GLOW) food-web dynamics, health and integrity. Elephant Hills Hotel, Victoria Falls, Zimbabwe, 15-19 July 1996.

Roux, D.J. 1996. *Links between chemical, toxicological and biological assessment of water quality.* 2nd African Water Conference. Gallagher Estate, Midrand, South Africa, 2-5 September 1996.

Roux, D.J. 2001. *To proceed beyond flirting when implementing a national river-health programme.* 36th Annual Conference of the Southern African Society of Aquatic Scientists. Aventura Eiland Resort, South Africa, 1-6 July 2001.

Conference proceedings

Dallas, H.F. 2000. Ecological reference conditions for riverine macroinvertebrates and the River Health Programme, South Africa. *Proceedings of 1st WARFSA/WaterNet Symposium: Sustainable use of water resources: advances in education and research.* Volume 1. Maputo, Mozambique, November 2000.

Dallas, H.F. 2002. Spatial and temporal heterogeneity in lotic systems: implications for defining reference conditions for riverine macroinvertebrates. *Proceedings of 3rd WARFSA/WaterNet Symposium: Integrating water supply and water demand management for sustainable use of water resources.* Dar Es salaam, Tanzania, October 2002.

Dickens, C.W.S. 1994. The use of rapid biological assessments for monitoring water quality and the "health" of the river environment: The experience in KwaZulu/Natal, South Africa. *Proceedings of the Southern African International Conference on Environmental Management (SAICEM 2)*. Victoria Falls.

Dickens, C.W.S. and de Moor, FC. 1997. Using macroinvertebrates to determine the flow requirements of the Mooi River, kwaZulu/Natal. A SASS (rapid bioassessment) perspective. *Proceedings of the congress of the South African Society of Aquatic Scientist.,* Mtunzini.

De Moor, F.C., Barber-James, H.M. Dickens, C.W.S. 1997. Using macroinvertebrates to determine the flow requirements of the Mooi River, kwaZulu/Natal. A detailed taxonomic perspective. *Proceedings of the congress of the South African Society of Aquatic Scientists, Mtunzini*.

Roux, D.J. 1998. The National River Health Programme as a tool in effective water resource management. *In: Proceedings of the annual conference of the South African Affiliate of the International Association of Impact Assessment - Innovative Tools and Methods for Meeting the Challenge of IEM in South Africa.* 30 September - 2 October 1998, Cathedral Peak Hotel, Drakensberg, South Africa, pp 231-237.

Roux, D.J and Everett, M.J. 1994. The ecosystem approach for river health assessment: A South African perspective. In: Uys MC (compiler), Classification of rivers and environmental health indicators. *Proceedings of a joint SA-Australian workshop. 7-14 February 1994, Cape Town, South Africa*. Water Research Commission Report No. TT 63/94, pp 343-361.

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A.12. DISSERTATIONS

(Incomplete list; examples only)

Dallas, H.F. 1995. *An evaluation of SASS (South African Scoring System) as a tool for the rapid bioassessment of water quality.* Master of Science Thesis, Department of Zoology, University of Cape Town.

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Roux, D.J. 1993. *The Role of Biological Monitoring in Water Quality Assessment and a Case Study on the Crocodile River, Eastern Transvaal*. Master of Science Thesis, Department of Zoology, University of Johannesburg.

Roux, D.J. 1993. *Incorporating Technologies for the Monitoring and Assessment of Biological Indicators into a Holistic Resource-Based Water Quality Management Approach – Conceptual Models and Some Case Studies.* Doctor of Philosophy, Department of Zoology, University of Johannesburg.

APPENDIX B
WRC funded projects relating to the RHP

Start date	Responsible organisation	Project title
1991	Freshwater Research Unit, University of Cape Town	The effects of water quality variables on riverine biotas
1992	Nasionale Krugerwildtuin	Monitering van die gevolge van die droogte op die biota van die histories standhoudende Sabierivier
1994	Freshwater Research Unit, University of Cape Town	Water quality requirements for riverine biotas
1994	Rhodes University	A geomorphological classification system for South African river systems
1995	Rhodes University	Invertebrate fauna of temporary rivers in the Eastern Cape
1995	Albany Museum	Curational services for aquatic invertebrates: Phase II
1997	CSIR Environmentek	Development of procedures for regional implementation and maintenance of the national River Health Programme
1997	Afridev Consulting	Analysis of invertebrate samples from the Orange River
1997	Southern Waters Ecological Research and Consulting cc	The derivation of ecological reference conditions for aquatic invertebrates and factors affecting the utility of such reference conditions within a National Biomonitoring Programme
1999	CSIR Environmentek	The compilation of a state of the environment report on the rivers of Mpumalanga
1999	JLB Smith Institute of Ichthylogy	The production of a fish atlas
2002	University of Cape Town / Southern Waters	Spatial and temporal heterogeneity in lotic systems: implications for defining reference conditions for macroinvertebrates
2002	Southern Waters	To assess, collate and store data relating to unprocessed, uncollated information on diatoms in Southern African surface waters with a view to determining ecosystems and water quality reference conditions, and for the augmentation of extant aquatic ecosystem assessment methodologies
2005		Development of a Diatom Assessment Protocol (DAP) for river health assessment
2005	The Freshwater Consulting Group (University of Cape Town)	National Wetland Inventory: Development of a Wetland Classification System for South Africa. Phase 1
2006		National wetland research programme: Phase 2: Wetland health and integrity

2007	Ground Truth cc	Reassessment of the mini-SASS biomonitoring tool as a resource for environmental education in the River Health Programme and cross-linking with the National Curriculum Statement
2007	DH Environmental Consultants and North West University	Development of a diatom index for wetland health
2007		Development of a diatom-based biomonitoring protocol for South African rivers and streams Phase 3: Regional testing, method refinement and calibration, index formulation and river health program accreditation
	The Freshwater Consulting Group (University of Cape Town)	National Wetland Inventory: Development of a Wetland Classification System for South Africa. Phase 2
?	The Albany Museum	The invertebrates of South Africa - identification keys: Expert input into a training workshop on the use of the identification keys training
?	University of Natal, Pietermaritzburg	The invertebrates of South Africa - identification keys: Expert input into a training workshop on the use of the identification keys training
?	University of Durban-Westville	The invertebrates of South Africa - identification keys: Expert input into a training workshop on the use of the identification keys training
?	University of Cape Town	Invertebrates of South Africa - identification keys: Expert input into a training workshop on the use of the identification keys training
		Evaluation of the suitability of the Fish Assemblage Integrity Index (FAII) to assess river health, and its refinement to ensure high levels of accuracy
		A system related scale study to determine the functioning of the riparian vegetation of the Olifants River, Transvaal
		The tolerances of selected macro-invertebrates from the Buffalo River
		The identification of diatoms and their use in the assessment of water quality
		Assessment of the geomorphological reference condition: Application to resource directed measures and the river health programme
		Development of criteria for the design of fish ladders for SA rivers and estuaries
		The rapid biological assessment of water quality impacts in streams and rivers