Application of ecological research to the development of a new South African water law

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In his 1997 North American Benthological Society presidential address, Jack Stanford painted a graphic picture of intense pressure on the water resources of the United States, particularly in the more arid western states. He commented: The road to recovery of damaged freshwater ecosystems and associated confidence in long-term availability of water quality and supply must be paved by a robust water policy (Stanford, 1997), and thus challenged ecologists and environmental scientists to become involved in policy development and law making. His address coincided with a fundamental review of water law in South Africa, where aquatic scientists were, and still are, involved in just such an interaction.

Water law reform in South Africa was initiated as part of the sweeping political reforms that accompanied the move to a democratic government in 1994. Although the Water Act 54 of 1956 was not explicitly discriminatory in nature, legal access to water was based on a system where land ownership conferred rights to ground- or surface-water use, and racially exclusive land ownership was a cornerstone of *apartheid* governance. This comprehensive water law reform aimed to meet the political and social goals of equitable water access, and provided the opportunity to develop an ecologically sound legal and policy basis for water resource management in an arid, developing country.

Scientific research was made accessible to the process as follows:

1994 The Southern African Society for Aquatic Scientists (SASAQS) held a series of regional workshops and submitted recommendations to the Department of Water Affairs and Forestry (DWAF).

1995 These recommendations led DWAF (1995) to publish the statement: “Recently the needs of the environment, particularly the riverine environment, have been increasingly taken into account, and the impact of development is beginning to be taken seriously. The law needs to view the environment as the resource base from which all development leads, the foundation on which all else depends”.

1995-1996 A SASAQS representative served on a panel tasked with development of fundamental principles on which to base the new law. Public workshops, where the principles were explained, were organized in each of 9 provinces. Rural, urban and industrial stakeholders debated the key issues of water rights, service provision, and ecological sustainability. Recommendations from the workshops were synthesized and presented, together with international perspective papers, at a National Water Law Conference. Finally, the principles were accepted by parliament. At each stage, it was necessary to present cogent scientific arguments for the inclusion of an ecologically sound basis to the law. The resultant key environmental principle was: The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromize the long-term sustainability of aquatic and associated ecosystems”.

1996-1997 A SASAQS representative served on a steering committee whose activities culminated in the publication and acceptance of a White Paper on a National

	Policy for South Africa (DWAF 1997). In this document, the principles were amplified into a policy, with the central environmental concept of resource protection to ensure sustainable resource use.
1998	The National Water Act (No. 36 of 1998) was passed by the South African Parliament.

Conceptual overview

Rights and the Reserve

Much argument has centered on the nature of water rights - the legal basis for water abstraction and use. This era of South Africa's history has brought a ready awareness of *rights*; and the White Paper provides for 2 rights: 1) the human right to safe accessible water (at least the United Nations-designated minimum of 25 L per person per day); and 2) the environmental right to the quantity, quality, and reliability of water required by aquatic ecosystems to ensure sustainable use. The water required to meet these rights has been termed the **Reserve**. The **ecological Reserve** will be defined principally in terms of water quantity and resource quality. The main purpose of this paper is to demonstrate the research basis on which the ecological Reserve will be determined.

In practical terms, the **human Reserve** is being met by providing a standpipe within 200m of all dwellings. What is historic, however, is the recognition that to support this and other water uses, aquatic ecosystem health must be maintained. The concept of an environmental right recognizes that water cannot be viewed simply as a commodity, because functionally it is part of the ecosystems in which it occurs. It was necessary to argue the scientific basis of this resource protection concept with specialists in the fields of law, policy, water resource management, industry, and agriculture. Finally, it was accepted that water supply and water quality depend on ecosystem health, and that aquatic ecosystems provide humans with a number of important, and free, services. These services include: 1) retention, supply, transport and storage of water (including flood water); 2) dilution, removal and purification of wastes; 3) commercial and subsistence supply products (e.g., fish and plants); and 4) recreation and tourism.

The finite capacity of these services was recognized. Ecosystems can accommodate finite quantities of waste, supply a finite quantity of any product, and recover from only so much structural damage. As they become overloaded, the quality of the service they provide deteriorates, the use of the system becomes unsustainable, and environmental degradation sets in (Dallas and Day, 1993; Ashton et al., 1995). The twin pillars of the new policy --- resource protection to ensure sustainable resource use --- were based on these concepts. Two questions then arose: What do we want to protect? How do we implement protection?

Resource protection and classification

The National Water Act is clear that resource protection includes the whole ecosystem - water, biota, sediments, and the riparian zone. Resource protection, therefore, is aimed at maintaining all the components of the full range of functioning aquatic ecosystems (rivers, lakes, dams, wetlands, estuaries, and the coastal marine environment).

However, resource protection and ecosystem health are difficult concepts to quantify and determine objectively. Ecosystems naturally are variable in time and space, and in the course of human use, we accept that some ecosystems suffer a certain amount of damage.

Ecosystems have an inherent capacity to recover from impacts, probably because impacts, or in ecological terms, disturbances, are a natural part of ecosystem function. We therefore also accept that ecosystems can function at 1 of a number of different levels of health. This acceptance is reflected in the classification system that categorizes acceptable levels of human use and impact, and the risk (sensu Suter 1993) of degradation that a particular use involves (Table 6.1.1). In another use of the term *classification*, South African river systems have been grouped, on the basis of their natural characteristics, at levels from habitat to biogeographic region, to recognize reference sites for biomonitoring (Hohls 1996, Uys et al. 1996, Eekhout et al. 1997).

In a developing country, it is important to include the reality of economic growth within plans for sustainable resource use, particularly because job creation and social upliftment are national priorities. Therefore, the classification system includes management categories that range from Class A systems, which are as near to pristine as possible, to Class D systems, which are judged to be sustainable despite use in terms of abstraction, effluent disposal, and structural change. The system also includes assessment categories (E and F), which are degraded and/or degrading. The policy requires these systems to be managed with the goal of achieving at least Class D status. An immediate challenge is to develop procedures for the consistent identification of each Class. There are a number of methods currently being developed, of which the Habitat Integrity Index (Kleynhans 1996) is the most advanced.

In the implementation of the protection policy, the classification procedure precedes the determination of the ecological Reserve, because the Reserve levels will differ for ecosystems with the different resource management goals associated with each management class. Decisions regarding classification will be public, involving stakeholder negotiations.

Determination of the Water Quantity Ecological Reserve

Instream flow requirements and the Building Block Methodology

Although South Africa intends to set an ecological Reserve for all aquatic ecosystems, quantification methods are best developed for rivers (Estes and Osborne, 1986; King and Tharme, 1994; Tharme, 1996; Richter et al., 1997). These water quantities are called instream flow requirements (IFR). After a comprehensive review and assessment of international methods (Tharme 1996), the Building Block Methodology (BBM) was developed specifically for the southern African situation (King, 1996; King and Louw, 1998). It was the existence of a relatively rapid, scientifically reliable method for determining IFRs that allowed the inclusion of the Reserve in the emerging legislation (Palmer et al., in press).

The BBM was developed in South Africa as a rapid 1st-estimate of the IFR for rivers targeted for development. The method was developed through its application in a series of workshops in South Africa (Louw, 1998) and Australia (Arthington et al., 1992). The method is based on 3 main assumptions (King and Louw, 1998): 1) riverine biota can cope with natural low-flow conditions that occur frequently, and may require specific, seasonal, higher flows, but atypical flow conditions constitute a disturbance and could cause fundamental changes; 2) identification of the most important components of the natural flow regime, and their incorporation into a

TABLE 6.1.1
AN OUTLINE OF THE PRELIMINARY BASIS FOR A SYSTEM TO CLASSIFY

AQUATIC ECOSYSTEM CONDITION IN SOUTH AFRICA	
Class A	
Water quality	Unmodified. Allow minimal risk to sensitive species. Remain within the target water quality range (TWQR, *sensu* DWAF, 1996a) for all constituents.
Water quantity	Natural variability and disturbance regime - allow minimal modification
Instream habitat	Allow minimal modification from natural conditions. Set resource quality objectives which include water quality, water quantity and habitat objectives.
Riparian habitat	Allow minimal modification from natural conditions. Control land-use in the riparian zone
Biota	Minimal modification from reference conditions as defined by the rapid bioassessment procedure SASS (Chutter, 1994).
Class B	
Water quality	Use Aquatic Ecosystems guideline values (DWAF, 1996a) such as chronic effects value (CEV) and TWQR to set objectives which pose slight rick to intolerant organisms
Water quantity	Use an Instream Flow Requirements (IFR) assessment method such as the Building Block Methodology (BBM) (King and Louw , in press) , to set flow requirements that allow only slight risk to intolerant organisms
Instream habitat	Allow slight modification from natural conditions. Set resource quality objectives which include water quality, water quantity and habitat objectives.
Riparian habitat	Allow slight modification from natural conditions
Biota	May be slightly modified from reference conditions. Especially tolerant biota may be reduced in numbers or extent of distribution
Class C	
Water quality	Use Aquatic Ecosystems guideline values such as Acute Effects Values (AEV), CEV and TWQR to set objectives which allow moderate risk only to intolerant biota.
Water quantity	Set IFR requirements which allow moderate risk only to intolerant biota
Instream habitat	Allow moderate modification from natural conditions. Set resource quality objectives which include water quality, water quantity, and habitat objectives.
Riparian habitat	Allow moderate modification from natural conditions
Biota	May be moderately modified from reference condition. Intolerant organisms may be absent from some locations
Class D	
Water quality	Use Aquatic Ecosystem guidelines values (AEV, CEV, TWQR) to set objective which may result in high risk to intolerant biota.
Water quantity	Set IFR requirements that may result in high risk of the loss of intolerant biota
Instream habitat	Allow a high degree of modification from natural conditions. Status dependent on quality, quantity and habitat objectives.
Riparian habitat	Allow a high degree of modification from natural conditions
Biota	May be highly modified from reference conditions. Intolerant biota unlikely to be present.

managed regime, will contribute to the maintenance of natural biota and ecosystem functions; and 3) flows that most strongly influence channel geomorphology should be included in the managed flow regime to aid in the maintenance of the natural channel structure and the diversity of physical biotopes.

Each IFR determination follows a sequence of activities in which specialists are involved. The study area is identified, assessed, and classified, and current and historical data are collected regarding geomorphology, water chemistry, and biota (especially fish, invertebrates, and riparian vegetation). Specialist knowledge is used in the workshop process. For example, at a particular IFR site, the cross section of the river is presented at variety of discharges, each shown as a particular water depth, which can be related to the inundation of particular habitat areas and to water velocities. Invertebrate specialists will consider the hydraulic habitat availability for the lotic invertebrate community, and will use experience and information from early river surveys (see references in O=Keeffe et al.,1989) and from basic research (King, 1981; King et al.,1987; Palmer et al.1991; 1993a; 1993b) to suggest the quality of habitat requirements in time and space, for key invertebrate taxa. Fish biologists will consider the requirements of a critical depth for up-stream movement in particular seasons, for the inundation of particular habitats, especially for breeding, and for habitat refuges in low-flow conditions. Riparian vegetation specialists will draw on information about the recruitment requirements of key riparian trees and the effects of geomorphological changes on the extent, for example, of reed beds (van Coller and Rogers, 1996).

This information is presented at the IFR workshop together with descriptions of the virgin and present daily flow regimes (simulated where necessary), including monthly flow duration curves and the statistics of the return periods of floods of various magnitudes. Habitat availability, together with the sediment-moving capacity of various flows, form the basis for a recommended modified flow regime *built* in monthly *blocks* of water to provide the base flow, on top of which higher flows are added for flood requirements. Each volume of water is characterized with a description of the biological, hydraulic, or geomorphological function it serves, and a requirement for the assurance of such a volume is given. The ecological quantity Reserve usually will be implemented through reservoir releases. Hydrological modelling research has provided techniques to translate IFR recommendations into reservoir release operating rules for both low flows and flood events (Hughes et al., 1997)

Hydraulic habitat requirements of biota and biotic-abiotic links have received the most innovative research attention. Weeks et al. (1996) identified a suite of fish species from the Sabie River (Mpumalanga, South Africa), including ecologically important and endangered species, and those characteristic of particular river zones; and recorded their preferred depths, velocities, substrates, and cover requirements. The selected fish species covered the range of life cycles and habitat requirements of the Sabie River ichthyofauna (Weeks et al., 1996), and these data were central to the application of the BBM. Van Coller et al. (1997) linked a series of vegetation types to fluvial geomorphological features characteristic of different flow regimes. These baseline studies were followed by a synthesis of biotic-abiotic links in the Sabie River (Jewitt et al., 1998) using a set of predictive models, including data on hydrology, hydraulics, geomorphology, fish, and riparian vegetation. These data contributed to the determination of the IFR of the Sabie River (Tharme, 1997).

Hydraulic habitat descriptors are only recently being investigated for invertebrates, and efforts are underway to develop a habitat-mapping method that combines invertebrate sampling with depth, velocity, substrate, and flow records. These efforts build on the work of Newson (1996) and Wadeson (1994), who characterized the hydraulic nature of habitats routinely described by ecologists, such as riffle and run. Like the IFR investigations, the South African research on the physical nature of biotic habitats was undertaken in the context of the international literature (Frissell et al., 1986; Statzner and Higler, 1986; Davis and Barmuta, 1989; Jowett et al., 1991; Kershner and Snider, 1992; Rowntree, 1996; Robertson et al., 1997).

Determination of the Water Quality Ecological Reserve

The Reserve concept was included in the new law mainly because of the BBM, an established method for dealing with water quantity requirements. No such method existed for establishing water quality requirements. However, the outline of an approach has been developed. For specified river reaches, historical data are used to describe the natural, or reference, condition. The Present Ecological Status (PES) then is described in 3 categories (habitat integrity, biological integrity, and water chemistry integrity), using the classification system (Table 6.1.1). Habitat integrity will be assessed as the deviation in habitat condition from the reference condition (Kleynhans, 1996). Biological integrity will be evaluated in terms of risk to maintaining reference conditions of the biotic community. Criteria for assessment will include biodiversity (Hughes and Noss, 1992), condition, and the maintenance of natural variability, and bioassessment methods will be used. Bioassessment is well established world wide (Karr, 1981; Fausch et al., 1984; Plafkin et al., 1989; Armitage and Petts, 1992; Reynoldson and Metcalfe-Smith, 1992; Cooper et al., 1994; Courtemanch, 1994; Hart, 1994; Gerritsen, 1995). South African approaches were among the pioneering methods (Chutter, 1972), and have been refined (Chutter, 1994; 1998; Roux et al., 1994; Hohls, 1996; Kleynhans, 1996). The work of Dallas et al. (1994; 1998) has contributed significantly to an understanding and use of reference sites, the relationship between bioregions and distribution, and biomonitoring.

Assessments of water chemistry integrity will be made for system variables, nutrients, toxics, and complex whole effluents. System variables will be evaluated relative to the target water quality ranges from the Guidelines for Aquatic Ecosystems (DWAF, 1996b). Nutrients will be assessed on the basis of percent orthophosphate content relative to total phosphate concentration, total inorganic nitrogen to total inorganic phosphorus ratio, and concentration of unionized ammonia. Toxic chemicals will be evaluated relative to the target water quality range and the chronic and acute effects values (DWAF, 1996b). Complex effluents will be assessed using whole-effluent toxicity testing (Slabbert et al., 1998a).

After the PES has been described, the class of the resource will be decided. This determination will delimit resource management objectives, and the ecological Reserve will be determined, with values given for amounts of water, and for habitat, biotic, and water chemistry integrity. Tools that will be used to fully develop this approach include guidelines (DWAF, 1996b), toxicology, and water quality modelling.

<u>Water quality guidelines</u>

The Water Act of 1956 specified general and special standards, set in terms of chemical concentrations of an acceptable end-of-pipe condition. However, in South Africa, as in other countries, water quality deteriorated despite these standards (van der Merwe and Grobler, 1990). Therefore, there was a move to manage the receiving environment and to set guidelines for users, aimed at maintaining water in a state that is fit for use by legitimate water users. Water quality guidelines were published (DWAF, 1993) for domestic, industrial, agricultural, and recreation users. These guidelines were followed by guidelines for aquatic ecosystems (DWAF, 1996b), which differed from other guidelines because aquatic ecosystems were not designated as water users, but were recognized as the resource base. The guidelines were therefore based on values that would ensure ecosystem protection.

<u>Toxicology</u>

Guideline values were based mainly on the results of international toxicology research (USEPA, 1986; CCREM, 1987; ANZECC, 1992; APHA, 1992; Dallinger and Rainbow, 1993) because of a paucity of data on the tolerances of local fauna. Acute and chronic toxicity values for a range of taxa synthesized in international databases were used to derive acute effects values (AEV) and chronic effects values (CEV) and, therefore, the target water quality range (TWQR) (Roux et al., 1996). Current South African research into the tolerances of fish (e.g., Grobler et al., 1989a; 1989b), invertebrates (e.g. Williams, 1996; Goetsch and Palmer, 1997; Dallas et al., in press) and standard test organisms (Slabbert et al., 1998a; 1998b) will contribute to the refinement and revision of the present guidelines for the protection of aquatic ecosystems. Local, site-specific testing may result in the setting of less conservative guidelines, because knowledge and information reduces risk in the application of results. The application of toxicology in water quality management is relatively new in South Africa, but its role will increase in importance in the future (Palmer et al., 1996), and work will inevitably include investigation of the effects of whole effluents as well as individual chemical variables (Slabbert et al., 1996a).

Modelling

Pegram et al. (1996) have reviewed the considerable research effort addressing the application of water quality modelling in the prediction of the effects of non-point-source pollution water quality conditions in rivers and reservoirs.

Conclusion

It is possible to identify key factors that contributed to a successful science/policy connection.

Water research funding

In South Africa, a water levy finances applied water research through a stator body, the Water Research Commission (WRC). The WRC contracts research in areas of national interest, and an extensive network of researcher-manager relationships exists through a system of project evaluation and steering committees. Most of the research on which the new legislation is based was funded by the WRC. The WRC also contributed directly to the water law review process by providing funds and allowing current projects to dedicate time to making research results available to the policy development team.

The Southern African Society for Aquatic Scientists

This learned society provided the forum through which scientists contributed to policy development and legal drafting.

The Water Law Review Steering Committee

The committee instituted 2 research portfolios, 1 scientific and 1 legal. Finnish and South African funds were used to collate and synthesize relevant research. International experts visited South Africa, and a national conference was organized. The senior legal representative on the committee took time to become familiar with the scientific basis of the ecological Reserve concept, and with the BBM method.

Political and administrative will

The environmentally sound basis of the new legislation was actively supported by both the Minister of Water Affairs and Forestry and the staff of the department.

Challenges

Difficulties encountered during the process included strict time constraints (the law needed to be enacted before the 1999 national elections), the inevitable conflicts that surround decisions about finite, essential resources, and the challenge of breaching the barriers of jargon and understanding that usually isolate the disciplines of science, law, and resource management.

The major challenge lies ahead. The greatest threat to the success of the new law lies in the lack of trained personnel and the capacity for implementation. The concept of the Reserve is not widely understood or accepted within DWAF and the engineering fraternity. Training, communication, and capacity building are essential. In addition, the results of applying the BBM
have never been monitored or evaluated, and political and administrative will is needed to do

this.

General
Ongoing ecological research continues to be driven by the urgent need to provide ecologically sustainable management options, and the answers to the acute problem of a growing human population and limited natural resources. Sound, basic, ecological research is the foundation and cornerstone of our ability to provide accurate answers to applied problems, especially when addressing complex management questions, such as the application of resource protection in the context of integrated catchment management (DWAF, 1996c).

However, although scientific, hypothesis-based research can provide objective and impartial information, the *application* of research results always involves judgement and values - neither of which is objective or impartial. It is just as important for scientists to be objective and detached as it is for applied scientists and managers to recognize when they are applying information in the framework of a value system, and to acknowledge and articulate that value system so that it can be debated. As ecological research is applied in processes such as the South African water law review, we move into new areas, such as the participation of stakeholders in deciding the level of ecological health and protection they want in a catchment. This integration of science and social processes may be the most challenging aspect of the application of ecological research efforts.

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