THE CLASSIFICATION SYSTEM OF RIVER HEALTH FOR THE ENVIRONMENTAL WATER QUALITY MANAGEMENT

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Abstract: South Africa has developed a policy and law that calls and provides for the equitable and sustainable use of water resources. Sustainable resource use is dependent on effective resource protection. Rivers are the most important freshwater resources in the country, and there is a focus on developing and applying methods to quantify what rivers need in terms of flow and water quality. These quantified and descriptive objectives are then related to specified levels of ecological health in a classification system. This paper provides an overview of an integrated and systematic methodology, where, for each river, and each river reach, the natural condition and the present ecological condition are described, and a level/class of ecosystem health is selected. The class will define long term management goals. This procedure requires each ecosystem component to be quantified, starting with the abiotic template. A modified flow regime is modelled for each ecosystem health class, and the resultant fluvial geomorphology and hydraulic habitats are described. Then the water chemistry is described, and the water quality changes that are likely to occur as a consequence of altered flows are predicted. Finally, the responses to the stress imposed on the biota (fish, invertebrates and vegetation) by modified flow and water quality are predicted. All of the predicted responses are translated into descriptive and/or quantitative management objectives. The paper concludes with the recognition of active method development, and the enormous challenge of applying the methods, implementing the law, and achieving river protection and sustainable resource-use.

Keywords: environmental flows, environmental water quality, resource quality objectives, classification

1. INTRODUCTION

In 1994, South Africa welcomed its first democratic government, and the country embarked on a period of intense legal reform. Although water legislation had never been explicitly discriminatory, rights to water-use were linked to land ownership, which was discriminatory. A water law review process resulted in the drafting of a set of principles on which to base a new law, a National Water Policy (DWAF 1997), and finally the National Water Act (NWA) (No 36 of 1998). The NWA is based on two premises: equity and sustainability. There are therefore only two rights to water: 1) the right of people for sufficient water for basic health, cooking and drinking; and 2) the right for the water quality, and pattern of flow to ensure aquatic ecosystem sustainability. The two rights are termed the Reserve and are, respectively, the basic human needs Reserve, and the ecological Reserve.

As in any country, and especially in a developing country, there is pressure in South Africa to use resources. It is clear in the policy and the law that water resources are to be protected so that they can be used optimally. Many questions then arise: How much use? How much water can be abstracted for domestic use, agriculture, and industry? How much wastewater discharge can water resources accommodate? How can licences for abstraction and discharge be provided, while still ensuring healthy aquatic ecosystems? What kind of structural developments (e.g. dams) should be built? How should dam releases be managed?

In this paper, the focus is on rivers as one type of aquatic ecosystem. The aim is to show how the above questions have led to national initiatives such as the River Health Programme (RHP) and quantified ecological Reserve assessments. These programmes provide descriptive and quantified information on the current status of rivers. They also specify flows, habitat and water quality that are consistent with integrated river health goals. Where rivers have been over-utilised and are damaged, the policy and the law provide a framework for rehabilitation.

2. RIVER HEALTH MONITORING AND CLASSIFICATION

River structure, biota, and functions can range in health from natural systems to wastewater discharge canals. River health can be characterised by a range of physical, chemical and biotic criteria such as: geomorphology (bed and bank structure together with sediment transport), water physico-chemistry (temperature, pH, dissolved oxygen, suspended particles, and organic/inorganic solutes), and biota (fish, invertebrates, instream/riparian vegetation and microbes). Most river health assessment is reported in terms of the degree to which each, or some, of these components, and their integrated structure and function, is altered from the natural condition (Norris and Thoms 1999). There are many biomonitoring approaches such as SASS in South Africa (Chutter 1998), RIVPACS in the United Kingdom (Armitage 2000), AUSRIVAS in Australia (Davies 2000) and BEAST in North America (Reynoldson et al. 2000). Most of these are based on measures of the presence, absence and abundance of taxa and the use of multivariate statistics to relate biotic community composition to physico-chemical condition (Barbour and Yoder 2000). SASS includes a habitat and structural integrity assessment.

In many instances bioassessment measures are used to classify the health of rivers (Naiman et al. 1992, Uys et al. 1996, Resh et al. 1996). In South Africa the link between river health (identified using bioassessment and classification) and river management has been formalised. Bioassessment is undertaken nationally as part of the River Health Programme (State of Rivers Report 2001). In the classification system river health is ranked along a gradient from natural to poor (or even very poor). In order to manage ecosystems, it is necessary to impose boundaries along this gradient, and four river health classes have recognised: Natural, Good, Fair and Poor.

The river health classes are used to describe three conditions. 1) Reference condition: this is the natural state, and can be inferred from unimpacted sites or from historical data, and is often difficult to describe accurately (Reynoldson and Wright 2000). 2) Present ecological state: this is a qualitative and quantitative description of the present condition of the river and geomorphological, hydrological, hydraulic and biotic conditions are described (King et al. 2000). The present ecological state is compared with the reference condition. 3) Management class: this is the class for which the river is managed. The management class is constrained in some instances by the present state. Some developments, such as large dams, limit the degree of naturalness that can be achieved. The management class is decided by the regulator after a consultative process involving managers, regulators, specialist scientists and stakeholders. The descriptive and numeric resource quality objectives (RQOs) are defined for each ecosystem component for each class, and the RQOs for the selected management class guide future management actions.

However, there are some modifications to river structure and function that seem to preclude restoration to anything approaching natural function, such as concrete-lined canals. In South Africa these have been termed "artificial systems" and will have RQOs more appropriate to recreational amenity than to natural ecological function.

Since a wide range of stakeholders participate in agreeing on the management class for a river, it is important that people understand that the each class is associated with a particular level of ecosystem health (Table 1), and that each class offers a different range of goods and services (Palmer *et al.,* in press a). Possible goods and services include: water supply; waste transport, processing and dilution; natural products (e.g. reeds, fish, medicinal plants); nature and biodiversity conservation; flood control; recreation; aesthetic needs; and sites for religious rituals or spiritual needs. However, a river, or river reach, cannot offer the whole range of goods and services at the same time in the same place. For example, if heavy use is made of water supply and waste disposal – then the ecosystem is unlikely to provide well for nature conservation, recreation or aesthetic pleasure. Therefore people need to be able to choose which services they want from which ecosystems in time and space.

Although the present ecological state can range from Natural to Poor, it is recognised that the Poor class indicates such a severe deterioration in river condition, that the use being made of the river is not sustainable. Therefore no river should be managed to be in a Poor class, and all management options must aim at rehabilitation of structure and function, so that over time the river achieves at least a Fair condition (Table 2). In this way the South African NWA provides a rehabilitative framework for river management.

3. THE ECOLOGICAL RESERVE

The ecological Reserve is the main policy, legal, and management instrument available used to ensure river protection in South Africa (Palmer et al. 2000), and is defined in the NWA (Chapter 1:1.(xvii)(b)) as "The quantity and quality of water required to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource."

The concept of the ecological Reserve was successfully introduced into the NWA because a history of sound biological and ecological research (Palmer 1999) led to the development of methods to quantify ecological flow requirements (King and Louw 1998, King et al. 2000, King et al. in press). The NWA however specifies that resource protection must be in terms of water quality, as well as water quantity. The Act also calls for attention to be paid to the integrated water cycle and therefore to the links between structure and function, between surface and ground water, and to connectedness of river systems from their headwaters to the sea (DWAF 1997).

From 1998 there have been ongoing efforts to develop methods for integrated ecological Reserve assessments (King et al. 2000, King et al. in press). These integrated methods first of all pay attention to the abiotic template:

- Hydrology: hydrological data and modelling are used to design a modified flow regime that is predicted to potentially allow a specified level of river health to be achieved (Hughes 2001). The modified flow regime is then linked to the catchment scale structure of the river (fluvial geomorphology) and to the substrate scale of instream habitat (hydraulics)
- Geomorphology: a cost-effective spatial framework and classification system for geomorphology has been developed for use in ecological Reserve assessments and the River Health Programme bioassessments (Rowntree and Wadeson 1998, Rowntree et al. 2000).
- Hydraulics: "The flow of water in a river channel and the physical structure of the channel are intimately related in a cycle of cause and effect in space and time. .... Local hydraulics and channel morphology are the primary determinants of physical habitat which, in turn, is a major determinant of river ecosystem function" (Rowlston et al. 2000). Hydraulic modelling methods have been developed which effectively allow invertebrate, fish and vegetation specialist to assess changing habitat availability at the different patterns of discharge in a modified flow regime.
- Water quality: Although many books on river conservation include a focus on water quality and pollution (Boulton and Brock 1999, Boon et al 2000), it appears that little attention has been paid to the integrated assessment of environmental water quality and flows. A sequence of activities that make use of chemical, bioassessment and toxicological methods (Scherman et al. in press) has been developed to assess the responses of biota to changes in physico-chemical condition (Palmer et al. in press b). Chemical concentrations have then been related to modelled modified flow regimes (Malan and Day in press). The likely water quality consequences of modified flows can then be provided to resource managers, who decide whether to allocate water for dilution and/or to address the pollution problem directly.

At selected river cross-sections and in selected reaches, biotic responses to the stress imposed by an altered flow regime, and the related altered chemical regime, are recorded (O'Keeffe et al. in press). These responses are then translated into quantified and descriptive RQO for each ecosystem component – biotic and abiotic. The RQOs provide the guidelines for management decisions. It is hoped that the outcome of protective objectives, and responsive

Table 1. River health and integrity classes in relation to ecological and management perspectives (Roux pers. comm., Palmer et al. 2002)

Class	Ecological perspective	Management perspective
Natural	Minimal or negligible modification of in-stream and riparian habitats and biota. The best Natural rivers are in the Reference or unmodified condition.	Protected rivers; relatively untouched by humans; no discharges or impoundments.
Good	Ecosystems essentially in good state, biodiversity largely intact.	Some human-related disturbance but mostly of low impact potential.
Fair	A few sensitive species may be lost; lower abundances of biological populations are likely to occur, or sometimes, higher abundance's of tolerant or opportunistic species occur.	Multiple disturbances associated with need for socio-economic development, e.g. impoundment, habitat modification and water quality degradation
Poor	Habitat diversity and availability have declined; mostly only tolerant species present; species present are often diseased; population dynamics have been disrupted (e.g. biota can no longer breed or alien species have invaded the ecosystem).	Often characterised by high human densities or extensive resource exploitation. Management intervention is needed to improve river health (e.g. to restore flow patterns, river habitats or water quality).

Table 2. Ecological and management classes (A) and the unclassified artificial status (B) (Roux pers.comm.)

A

Ecosystem integrity status	Ecological Class	Management Class
Natural	Natural	Protected
Slightly or moderately changed from natural	Good	Good
Greatly changed from natural	Fair	Fair
Severely changed from natural	Poor	

B

Ecosystem integrity status	Description
So modified as to have lost most natural characteristics	Artificial – for example canalised rivers in urban areas

management will be rivers that are maintained in mosaic of health conditions, that will satisfy the long term needs and values of the people who live in, and use the catchment.

4. CONCLUSIONS

The most relevant word in the last sentence is hope. At present in South Africa there are very few examples of dam operating-rules that have been written in terms of environmental flows releases. There are no rivers where health and condition have been monitored before dam construction and after modified flow releases have been effected. There are no examples of integrated environmental flow and water quality management. Considerable effort has gone into the development of methods, and we have an exemplary policy and legal framework, but enormous challenges remain.

The value system of the people needs to encompass a real desire for protected rivers, and a recognition that to protect rivers at a variety of levels of health and integrity will entail flexible, responsive management, as well as restraints on conventional industrial and agricultural development in selected areas. There is a need to co-ordinate water resource management at the national regional and local level so that catchment management becomes a reality. There needs to be a shift in what and how we monitor rivers – paying attention to a variety of bio-assessment techniques as well at to hydrological and chemical monitoring.

There is also the need to persevere with the development of ecological Reserve methods, particularly for water quality. Methods for quantifying environmental flow requirements are well advanced. A methods manual has been published (King et al., 2000), and refined method development and applications have been undertaken in hydrology (Hughes 2001), flow stressor responses (O'Keeffe et al. (2002) and in holistic integrated methods (King et al. in press,) It is possible to provide both quantified and descriptive information about the pattern and reliability of environmental flows, with information on flow frequency, magnitude and duration, so that an entire modified flow regime is provided to the regulating agency (Department of water Affairs and Forestry) and used in water resource planning and management (e.g. DWAF 2000) .

However, methods for quantifying environmental water quality still focus on only magnitude (concentration), and frequency and duration are only taken into account via flow-concentration modeling (Malan and Day in press). The frequency of extremes in concentration and dilution, and the duration of extreme conditions are biologically important. In South Africa, there is a widespread nework of water quality monitoring sites, but most sites are only monitored monthly, and many sites have only an intermittent or recent records. Modeling based on mean or median monthly values (Malan and Day in press) will probably not adequately describe extreme events of their duration.. In addition There are important variables which are not routinely monitored in South Africa, these include suspended solids, temperature and in-stream toxicity.

Changes and additions to a national monitoring programme would have financial implications, and it will be the task of water quality scientists to provide data that demonstrate advantages to the regulating agency. The Department of water Affairs and Forestry plans to implement a toxicity monitoring programme, and the use of toxcity testing in the control of effluents over the next five years (DWAf 2002a). Changes to regulatory and water resource management activities require collaboration between researchers, water resource managers and water users (domestic, agricultural and industrial).

The National Water Resource Strategy for South Africa (DWAF 2002b), outlines the implementation of the NWA. The public has been invited to comment, and many of the scientists who have developed ecological Reserve methods will do so. South Africa has a good record of including recent scientific information in the development of policy and law (Palmer 1999). Scientists in the fields of ecotoxicology, biomonitoring and environmental water chemistry will continue to contribute to water resource management.. There is increasing attention paid to coordinating the control of licensed water use (both abstraction and waste disposal) with the stated goals for the river (RQOs) . Increasingly there is the recognition that science is applied in the context of society. In South Africa we have an extraordinarily vibrant society that has demonstrated an ability to grasp opportunities. The goal of river protection and rehabilitation lies ahead.

ACKNOWLEDGEMENT

This research was partly supported by Frontier 21 research fund. This support is gratefully acknowledged.

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