

Identifying and Protecting Rivers of High Ecological Value

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Identifying and Protecting Rivers of High Ecological Value

Helen Dunn



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List of abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AusRivAS	Australian River Assessment Scheme
BAS	Bioregional Aquatic System
CAR	Comprehensive, Adequate and Representative
DLWC	Department of Land and Water Conservation (NSW)
DNRE	Department of Natural Resources and Environment (Victoria)
EPA	Environment Protection Agency (Queensland)
GBRMPA	Great Barrier Reef Marine Park Authority
GIS	Geographical information system
JANIS	Joint ANZECC–MCFFA National Forests Policy Statement Implementation Subcommittee
LWRRDC	Land and Water Resources Research and Development Corporation
NRSMMPA	National Representative System of Marine Protected Areas
PLUC	Public Land Use Commission (Tasmania)
RCC	River Continuum Concept
RIVPACS	River Invertebrate Prediction And Classification Scheme
SERCON	System for Evaluating Rivers for Conservation
TWINSpan	Two Way Indicator Species Analysis
WIPDIP	Water Infrastructure Planning and Development and Implementation Plan (Queensland)
WREP	Water Resources Environmental Planning (Queensland)

Summary

The report describes, analyses and evaluates approaches to the assessment of river systems and conservation values in other types of ecosystem. The report concludes that there is no readily available strategy for identification of the ecological value of rivers. In addition, there is no overview of the aspects of river systems or river sections which constitute ecological value.

Themes, concepts and models applied in the assessment of conservation value of other ecosystems are melded with current approaches to river assessment for more limited purposes. This forms the basis of proposed approaches to identification of rivers of high ecological value. Four complementary processes are discussed: using principles of design for Comprehensive, Adequate and Representative areas for protection; classifying rivers into categories for management of conservation values; using indices to make comparisons and monitor the conservation status of rivers; and defining an ecological value profile for a river as a component of catchment management.

A series of criteria and attributes will form the basis of identification assessment. The attributes were confirmed and validated by an extensive survey of scientists and river managers. The attributes may be used Australia-wide and in any of the processes outlined.

Consideration is given to the bases of comparison for decisions about ecological value and information sources are suggested.

Mechanisms for the protection of rivers of high ecological value are briefly canvassed. Protection will need to be addressed on a number of fronts, including legislation, policy implementation, management and community support.

The report provides some key ideas, strategies and issues which will form a focus for implementation and further research. The report highlights the range of significant ecological values that reside in Australia's river systems and the need to address biodiversity conservation for riverine ecosystems.

1 Introduction

1.1 The conservation status of Australia's rivers

The Australia State of the Environment report (Department of Environment, Sport and Territories, 1996a) paints a bleak picture of the environmental status of Australia's rivers. In the 200 years since white settlement land clearance, water regulation, impacts on water quality, river engineering and introduced species have had a massive impact on natural riverine and floodplain environments. The report suggests that 'most rivers in the lowlands and in agricultural catchments are degraded, with moderate to severe disturbance of riparian and channel habitats as well as increases in salinity, decreases in flow, changes in flow regimes and increased sediment loads' (Department of Environment, Sport and Territories, 1996a, p7-6). Water storage for power generation, water supply and irrigation has permanently altered the nature of many of the largest rivers. This has had consequences not only for instream processes and biota but also for floodplains and wetlands. Most unregulated rivers occur in sparsely inhabited parts of the country such as far northern and central Australia. Australia has the highest per capita water storage of all countries in an effort to moderate the impact of its variable rainfall (Department of Environment, Sport and Territories, 1996a). The river systems of the more populous coastal plains in all parts of the country exhibit the greatest modifications to the natural condition.

Damage to river and stream ecosystems is widespread (Blyth, 1983; Lake & Marchant, 1990). In Victoria most streams and rivers exhibit seriously degraded water quality and aquatic life (Victorian State of Environment, 1988). In the South West Drainage Division of Western Australia, for example, there has been extensive disturbance of river systems (Western Australian Water Resources Council, 1992), with most dammed for water supply purposes. Changing flow regimes and agricultural activity have resulted in significant salinity problems and eutrophication of waterways. Well-preserved examples exist for only 2 of 11 representative river types for the area, with very few examples of a further three types. The remaining river types for this drainage division have all been substantially modified (Western Australian Water

Resources Council, 1992). In contrast, rivers of the Timor Sea Drainage Division, one of the northern drainage divisions with a sparse population, are mostly classed as 'pristine' or 'near-pristine' (Water and Rivers Commission, 1997). A similar picture emerges from state of environment reports in other States.

In summary, the Australia State of the Environment report (Department of Environment, Sport and Territories, 1996a) concludes that, in relation to rivers:

- Aquatic habitat quality has deteriorated markedly in areas of agriculture, urban land use and substantial water regulation.
- In many parts of Australia (such as the wet tropics and mountainous areas) where such changes have not occurred, aquatic habitat is still of high quality.
- The area of natural wetland has significantly reduced since European settlement.
- Regulation, physical barriers, erosion, de-snagging, channel modification, introduced species, pollution and algal blooms have all substantially altered and degraded river habitat quality.
- The range and abundance of many species of native aquatic biota have declined significantly, to the point where many are threatened and endangered.
- The introduction, spread and establishment of a large number of exotic biota... have had significant effects on the biological communities and habitats of inland waters (Department of Environment, Sport and Territories, 1996a, p7-33).

State of environment reports focus largely on condition. The wild rivers assessment (Stein et al., n.d.) was a measure of the level of river disturbance. None of these adequately provides a complete view of the conservation status of Australia's rivers. Conservation assessment should include aspects of geomorphology, hydrology and catchment factors, as well as evaluation of the levels of protection for conservation purposes.

The destruction of much of the ecological (and human) value of Australia's river systems is all the more disturbing given the distinctive character of the river systems and biota on a world scale. Australia is the driest of the inhabited continents. It has the lowest percentage of rainfall as run-off, the least amount of water in its

rivers and the most variable rainfall and streamflow in the world (Finlayson & McMahon, 1988; Puckridge et al., 1998). This creates rivers of varied and distinctive hydrological character. In addition, inland streams have high natural salinity and turbidity, with the chemistry often dominated by sodium chloride rather than the more usual calcium or magnesium carbonates (Department of Environment, Sport and Territories, 1996a).

River types vary from permanent upland streams to slow-moving lowland rivers and ephemeral dryland rivers. A climate range from wet tropical to cold temperate provides a range of temperature regimes for the associated biota. Australia's freshwater biota has several distinctive features: a large number of invertebrate species, genera and some families are endemic to the country or region; several groups that are widespread elsewhere are absent from Australian rivers; and some families have adapted to a wider range of habitats (Blyth, 1983; Lake et al., 1985; Lake & Marchant, 1990; Rutherford et al., 1998). Many invertebrate taxa have links to the ancient southern continent of Gondwana with their closest relatives in South America or New Zealand. There are fewer than expected freshwater fish species, many of which are endemic and apparently evolved from marine forms (Department of Environment, Sport and Territories, 1996a). Marsupial forms such as water rats occupy similar habitat niches to those occupied by eutherian forms in the northern hemisphere. The uniquely Australian platypus depends on freshwater habitats. Riparian plants and aquatic macrophytes and protista also exhibit endemism and Gondwanic affinities.

Australia's vegetation also differs from other world environments with evergreen hardwoods generating much of the energy source for many rivers. The different processing characteristics of this energy source create different food webs and carbon flows from other river systems of the world. Models of river ecology developed in the northern hemisphere are not necessarily applicable to Australia or other southern regions (Winterbourn et al., 1981; Lake & Marchant, 1990; Lake, 1995; Rutherford et al., 1998).

The neglect of protection for rivers as ecosystems is not restricted to Australia. Allan and Flecker (1993) suggest that in the 'biodiversity crisis' attention has been focused on tropical moist forests, with perhaps a growing interest in ocean conservation, but 'freshwater systems have received less attention. . . and rivers and streams perhaps least of all' (1993, p32). This neglect,

is despite the fact that 'running waters harbour a diverse and unique panoply of species, habitats, and ecosystems, including some of the most threatened species and ecosystems on earth, and some of those having greatest value to human society' (Allan & Flecker, 1993, p32). Collier (1993) noted a similar discrepancy in New Zealand, where conservation efforts have focused largely on terrestrial environments and wetlands. Historically, in New Zealand efforts to protect rivers were mainly to preserve fishery values and secondary importance was placed on natural value. Boon (1992) claims that, similarly, the focus on river conservation in North America was driven by a desire to protect habitat for sport and commercial fishing.

Australia's distinctive and important rivers and river sections are ecologically significant on a world scale. Much has already been lost – not only loss of biodiversity but also a lost opportunity to develop a better understanding of the complex ecology of many types of Australian river systems. Such lack of understanding and the absence of representative rivers with natural river processes will severely limit our ability to respond appropriately to river management issues. It is critical and timely that rivers of high ecological value are identified and protected, both to meet biodiversity commitments and to ensure that the best possible management of all rivers can be achieved.

1.2 Changing management and policy contexts

Protection of ecological values of rivers is one of a complex of issues facing river managers and policymakers. At the present time, protection of ecological values is not addressed directly, except within the context of the water reform agenda agreed between State and Federal governments (ARMCANZ & ANZECC, 1994). One element of the reform package comprises the protection of 'environmental values' and providing a water allocation for the environment. Implementation of these reforms is now occurring at State level and has led to a number of initiatives and programs, data collection and assessment of river condition, water quality and quantity.

The Monitoring River Health Initiative was a response to concern about water quality and indirectly the health of rivers. The initial stages of this program have provided a snapshot of rivers across Australia and reference sites have been identified against which

changes in river condition at a local level may be assessed (Simpson et al., 1999).

Point source discharges and impacts are largely controlled under legislation and monitored for their effect on water quality. Diffuse impacts such as nutrient enrichment from agriculture and other land uses are not legally controlled and are a major problem in river ecosystems.

Water reform is only one of several commitments that are relevant to river conservation albeit sometimes in general, rather than specific, terms. One agreement of prime significance is the protection of biodiversity, as embodied in the International Biodiversity Convention signed by Australia in 1993. Preparation of a national strategy (ANZECC, 1996) followed. This requires all States to address biodiversity protection through legislation and policy, and has led to a raft of policies, programs and, for some aspects, legislation. Legislation for protection of rare and threatened species exists in most States and under the Commonwealth, the latter also incorporating protection of threatened habitats. Some States are now producing policy and strategy documents for protection of biodiversity (NSW Parks and Wildlife Service, 1999) generally, or for protection of specific aspects of biodiversity such as Queensland's wetlands (EPA, 1999a).

No legislation or policies are specifically directed to protect rivers for ecosystem conservation. Unlike the treatment of forests (the range of forest types is progressively receiving systematic protection through Regional Forest Agreements), there is no attempt to protect representative river ecosystems, nor to protect ecological values of rivers per se. Some rivers may receive protection if they flow within a national park, though this protection will only apply to the area within the park and not necessarily protect the values if upstream activities (for example, logging) affect the river ecosystems. Some values of rivers may be protected through rare and threatened species legislation if amelioration of threatening processes or critical habitats protection lie within the scope of the legislation.

Numerous Acts and regulations address specific issues for rivers but are largely directed towards controlling use or impacts, rather than protection of values (Clement & Bennett, 1998). Impacts on river values may be an element of environmental impact assessments for developments affecting river systems. Some triggers exist for intervention under agreements such as the Ramsar convention on protection of wetlands of international significance, the Japan–

Australia Migratory Bird Agreement, the China–Australia Migratory Bird Agreement and threatened species legislation.

Some States are developing a more strategic approach to river management by assessing rivers under several criteria and assigning each river to a category for management intervention. In NSW the Stressed Rivers program identified those rivers under hydrological or environmental stress (NSW Department of Land and Water Conservation, 1998). The report also identified those rivers which were of conservation value. Although further refinement is needed, this assessment process begins to address questions of protecting rivers of special ecological value.

The legislative basis for protection of river values is negligible. Strategic directions or policies which could lead to better protection are complex and require considerable research into river ecology if they are to be effective. There is, however, considerable community interest in river management, including managing the ecological, aesthetic, recreational and social values of rivers as well as economic interests. Integrated catchment management is a growing response mechanism for such community interest and is encouraged by State agencies and Commonwealth funding programs such as Rivercare and Landcare and is now supported under the umbrella of the Natural Heritage Trust.

In summary, legislation, policy, management processes and strategies relevant to river conservation are in a state of change. Several States are engaged in processes towards more comprehensive assessments of river values, in which the assessment of the ecological or conservation value of rivers will be a strand. Concerns with conservation values are converging with river health issues and there is increasing recognition of the need to develop greater appreciation of the total river ecosystem as the basis for river rehabilitation (Rutherford et al., 1998). It is timely to develop a more systematic and widely accepted framework for identifying ecological value as a component of river management at all levels.

1.3 The River Restoration and Management Program

The aim of the Land and Water Resources Research and Development Corporation's (LWRRDC) River Restoration and Management Program is to 'support the community's desire for healthy, sustainable rivers for

future generations to use and enjoy'. The program was established in recognition of community concern about the degradation of riverine environments as a consequence of urban and industrial developments and activities and primary production and forestry activities.

Four projects were commissioned under the first round of the program. These were: development of a CD-ROM on river restoration strategies; analysis of the legal frameworks for river restoration; development of a generic framework for river restoration; and the present project on identifying and protecting rivers of high ecological value. All projects were short term and were primarily intended to draw together existing information and concepts.

A national perspective is essential. This relates not only to a national perspective on the diversity of river characteristics, but also to the diversity of structural arrangements for river management and the nature of river management activities.

1.4 The brief

Within the framework of the River Restoration and Management Program, the primary focus of the project was to 'provide key tools that can enhance the current high level of activity in river management. Principal among these is the ability to identify rivers, river reaches or floodplain features of high ecological value and/or in good condition, and to adequately protect them or provide management approaches for their protection from degradation.'

The brief for the project was to:

1. Review existing methods for identifying river systems, sections of river systems and floodplains of high ecological value and/or in good condition; and recommend a methodology that can be applied Australia-wide.
2. Review methods for protecting those river/reach/floodplains, including among others legislative and planning approaches and economic incentives, and make recommendations on the most effective suite of approaches for the Australian States, territories, federal governments and catchment management institutions.

The brief emphasised that the meaning of 'high value' is likely to change from region to region, but also sought a recommended method or approach for identification and an analysis of the current Australian river and environmental management culture. The brief sought an

assessment of approaches most likely to be successful in Australia and the most prominent barriers to their adoption and success.

A core strategy for the project was to consult with a wide range of river managers so that the objectives of any recommended approach could be clearly understood and highly relevant to managers' needs.

The scope of the project was very broad, the resources and time frame limited. A concurrent consultancy was to be undertaken on a 'comprehensive legislative analysis' which, it was expected, would inform legislative aspects of protection.

Given the broad scope of the project brief, the project focused on a conceptual framework approach to clarify the basis for identification of ecological value and to evaluate how this might be integrated into current assessment activities.

1.5 The task

The essential tasks in meeting the project brief included:

- defining the scope of 'high ecological value';
- specifying criteria for assessment of ecological value;
- summarising and evaluating current approaches to river assessment;
- documenting community pressures and management issues which may enhance or mitigate against river and river system conservation; and
- recommending an effective suite of approaches for conservation of Australian rivers and river values.

It was recognised that a variety of river assessment activities were already under way. It was important to make linkages between such activities and any proposals for assessing and identifying ecological value, that is, to build on and integrate with such activity and concerns rather than to create an entirely new process. It was also important to identify links with current policy issues and environmental commitments as a context for implementation of protection measures.

The development of a list of attributes of ecological value on which there is general consensus among the scientific and management community with an interest in rivers is a critical step in defining nature conservation values of rivers. Such a process of development had been conducted in South Africa (O'Keefe et al., 1987), New Zealand (Collier, 1993) and the United Kingdom (Boon et al., 1994; Boon et al., 1997; Boon et al., 1998). However, direct transfer of the attributes from

any of these inventories to an Australian setting was not appropriate, since some elements of significance in the Australian environment would not be covered. These include dryland systems and biogeographic significance. In addition, some elements of river ecosystems have become more prominent, including ecosystem processes, fluvial geomorphology and connectivity between riverine elements. Concepts of conservation assessment generally have evolved and been refined in recent years. A further important consideration was to generate ownership of the framework by Australian scientists and river managers through their participation in its development.

1.6 Limitations and assumptions

At the outset, certain limitations of the project were identified. Ecological values are only one set of a suite of values associated with rivers. Values and uses of rivers for a variety of economic and social purposes are a central strand to river management, but were not included within the present tasks. It is also recognised, however, that the boundary between ecological value and some human values is indistinct. For example, a river which has free-flowing, well-oxygenated, clean water is important for human use as well as being an indicator of a healthy ecosystem. A river with attractive pools, waterfalls and sculptured rockfaces may be of geomorphological significance as well as having aesthetic attraction and tourism potential.

A second important assumption was that a river or river section need not be unaffected by human activity in order to have ecological value. Many of Australia's rivers have been altered in a variety of ways by human use. Yet a particular river may be the last remaining example of a distinctive hydrogeomorphological character, sustain an important floodplain or wetland, or provide habitat for a rare and threatened species. Indeed, it may be argued that any river has ecological value because of its function within the broader landscape.

It was also acknowledged that the exercise was limited by being, at this stage, only a desktop project. Any framework needs field trialling before it can claim to be useful, valid and reliable. The development of the list of attributes and alternatives for their application is only a first step towards incorporating identification of high ecological value rivers into river management.

Some concern was expressed at the project outset about the question of defining scales for application of

the framework. A related question concerned defining a 'river'. There are several responses to these concerns. Firstly it was assumed that any framework for identifying and protecting rivers needed to be operable at different scales: one section of a river may be of particular importance for highly endemic or listed rare and threatened riparian flora and such a section might be identified as of high value and indicate the need for particular protection or management requirements. The other aspect of scale that was a fundamental assumption of the project was that assessment of the degree of significance or value can only be made by comparing situations of similar scale; that is, to compare like with like. This is addressed in the report in the section on evaluation (section 3.5).

The definition of river was deliberately left open. A working definition of a river was adopted along the lines of the World Conservation Monitoring Centre (1998, p5) definition: 'A river system is a complex but essentially linear body of water draining under the influence of gravity from elevated areas of land towards sea level.' The scope of the project included the notion of 'river section', that is, part of a river system or stream. Anything which was sustained by flowing surfacewater was considered under the umbrella of a river, even though the water may flow intermittently or seasonally. Habitats which are created or sustained by flowing water, such as estuaries and karst, were not included, although the value of rivers in sustaining these systems was included. Floodplain habitats were not dealt with in detail but are recognised as integral to river ecosystems. In line with the work on wild rivers (Stein et al., n.d.), a strict definition of river is not applied but rather left as self-defining within each management context.

River ecology was the key underpinning basis for the development of the criteria and attributes. The concepts included the environmental context, ecosystem processes and dynamics, ecosystem and community structure and species distribution. Thus ecological values were taken to include physical as well as biological riverine processes and features.

Exploration of the literature is illustrative rather than exhaustive. Research is continuing on appropriate indicators of aquatic ecosystems, riverine processes and river health. These are important and vital to refinement of approaches to the identification and protection of ecological value.

1.7 Data sources

1.7.1 Review of literature and overseas models

A literature search was undertaken using electronic databases and informal networks. Contacts were made with key individuals working or having worked in the fields of development and application of river assessment strategies. This often provided access to government reports and policies not available through normal library resources. The World Wide Web was searched for river conservation and assessment sites: this provided some further information particularly with regard to the North American situation.

1.7.2 Conservation assessment frameworks

Assessment frameworks applied to other selected ecosystem types and generic natural heritage criteria were identified. These included:

- the Register of the National Estate
- World Heritage
- the Regional Forest Assessment
- the Ramsar convention
- marine reserves
- the National Reserve System.

Criteria, indicators and thresholds were explored to see what parallels might be drawn for river systems. In addition, consistency, common use of terms and common ways to approach issues of thresholds and standards may be beneficial to facilitate implementation amongst natural resource managers.

1.7.3 Survey

A survey was undertaken of persons working in fields of river research and management. The survey was undertaken by electronic means. The purpose of the survey was to acquire feedback and endorsement for proposed attributes for rivers of high ecological value and some initial views on possible means for protecting high-value rivers. A second, smaller-scale survey was undertaken for a rough desktop validation of the application of the attributes in the assessment of particular rivers.

The survey also served to alert a wide range of people with an interest in rivers to the project.

1.7.4 State activities in assessment

In addition to participation in the survey, each State was visited to conduct discussions with river managers. The purposes of these visits were to:

- outline the project, including proposed criteria and decision rules;
- identify current activities in river assessment across Australia;
- identify management needs or contexts where identification of ecological value may be important; and
- discuss constraints on, and opportunities for, protecting ecological value.

Not only would the current activities provide a potential vehicle for use of the proposed assessment processes for ecological value, they would also reveal any relevant data already being collected. The final two points have implications for implementation and for possible future directions in river conservation and the place of ecological values in determining management decisions.

1.8 Project organisation and reporting

1.8.1 Reference group

A reference group was established to ensure that expertise in all aspects of the field of river ecology informed the progress of the project and that the proposals and approaches that emerged were widely applicable to Australia's river systems. The reference group was also broadly geographically representative and included people with experience in river systems across Australia's climatic regions. A river manager from the NSW Department of Land and Water Conservation provided a point of reference for issues relating to State agencies.

Members of the reference group were: Professor Peter Davies (University of Western Australia), Dr Peter Davies (Freshwater Systems and University of Tasmania), Dr Terry Hillman (Murray-Darling Freshwater Research Centre, Albury), Professor Henry Nix (Centre for Resource and Environmental Studies, Australian National University), Dr Gary Brierley (Macquarie University), Professor Richard Pearson (James Cook University), Dr Fran Sheldon (Adelaide University), Jim Puckridge (Adelaide University),

Dr Martin Thoms (Canberra University), Paul Wettin (Department of Land and Water Conservation, Orange, NSW) and Mike Askey-Doran (Department of Primary Industry, Water and Environment, Tasmania).

1.8.2 Report structure

The report draws findings from across the various data sources in an integrated fashion. The findings from the survey are incorporated at appropriate sections of the report. More detailed explanation of the methodology and results are provided in the appendix.

Section 2 of the report deals with concepts of river assessment and evaluation in natural systems generally and explores some current types of river assessment. Various models and strategies from Australia and elsewhere are outlined and some examples of conservation planning assessments from other ecosystem types are described. Section 3 integrates this information to outline a conceptual framework for identifying rivers of high ecological value in Australia. Section 4 discusses practical aspects of the implementation of such a framework. Section 5 considers possible strategies for protection of rivers of high ecological value and constraints on and opportunities for such protection under current conditions in Australia. Section 6 draws together the findings of the project to summarise a rationale for protection of rivers of high ecological value in Australia and proposes some elements of a key strategy and implementation.

1.8.3 Terminology used in this report

Ecological value

'Ecological value' for rivers is taken in its broadest sense. It includes not only the aquatic biota (fish, invertebrates and macrophytes) but also the biota of the riparian or foreshore zone, the river habitats and geomorphology. It is also taken to include the river processes, both physical and biological, and the roles a river may play in sustaining other systems such as karst, estuary, floodplains and wetlands.

The term 'conservation value' is sometimes used interchangeably to highlight the significance of such values in river management. There are, however, important other conservation values of rivers which are not covered in the present report. These include scenic and aesthetic values, Aboriginal cultural values and historic values, and values held by communities today through their sense of association with the river system.

All these other values should be considered in assessing conservation value as a whole.

Classification

'Classification' is generally accepted to mean to arrange in groups or assign to groups. Grouping in this way enables things to be sorted and described. The groupings may be arrived at by prior definition of criteria or by sorting according to observed features.

Some groupings or classification of river features or values may be arrived at by a statistical procedure also known as classification. Statistical classification is often undertaken using the polythetic divisive computer program TWINSpan. This program sorts species lists by occurrence and generates groupings. TWINSpan classifications, supported by other statistical procedures, are used in the analysis and description of floristic or macroinvertebrate communities.

Such statistical procedures are clearly inappropriate for classifying other aspects of river systems. However, it is possible to generate typologies based on characteristics or features – geomorphological features or substrate habitats for example – which enable particular rivers to be assigned to a category or class.

'Classification' is used in the common and general sense except where it is noted as the statistical procedure.

2 River assessment: concepts, models and approaches

2.1 River assessment concepts

2.1.1 Purposes of river assessment

It is crucial to be clear about the purpose(s) of an assessment process. The purpose will clarify, among other issues:

- the need for the assessment;
- the objective of the assessment;
- the possible management outcomes or options;
- who should be involved in or have input to judgments;
- the possible consequences of the information and assessments;
- the kind of data that should be collected;
- the scale at which data is to be collected;
- the basis for assessment;
- the resources available for the assessment, including financial, human resources and expertise; and
- the time frame.

Assessment of rivers may be prompted by different triggers or concerns. Water quality assessment is a long-established requirement for monitoring compliance with legislation, for example, laws governing drinking water standards or discharge of waste. Monitoring of river flows is important for hydroelectric power generation industries and for irrigation controls. Monitoring of river systems implies an ongoing assessment process, usually for a specific purpose.

Other purposes for assessing rivers include environmental impact assessment, resource assessment, environmental quality or conservation value. More recently, issues of establishing environmental flows for rivers have brought a raft of strategies for such assessment (Arthington & Zalucki, 1998). None of these is designed to identify rivers of high ecological value.

It is important to distinguish between the purposes and applications of the various approaches to river assessment. Over the years, various protocols and frameworks have been developed in Australia and elsewhere. Such developments differ in the legal, policy

and management contexts for application, as well as in their purposes.

The National River Health Program is an important and high-profile assessment process developed in recent years for Australia. A standard approach to data collection and analysis using multivariate techniques enables local interpretation of river health while maintaining a consistent methodology.

Assessing ecological value requires a different perspective from that of assessing the condition or health of a river. The data collected for assessment of river health may contribute to assessment for ecological value but the basis for comparison is likely to be different. The relationship between assessment of river health and assessment of ecological value is discussed in more detail in section 2.1.4.

2.1.2 Requirements for river assessment

Boon (1992) suggests that making the scientific case for river conservation has three basic requirements:

- description (to identify the species and habitats of interest);
- classification (to distinguish rivers of different types); and
- assessment (to identify, at least in a semi-objective way, rivers which have greater conservation value than others).

The classification process provides a context or reference for the consideration of evidence from the description of the river.

Assessment involves making judgments. This distinguishes assessment from description or classification and is the primary focus of the present report. It is inherently a subjective process, both in the selection of measures or indicators and in the setting of standards. For assessment of river health or condition, explicit or implicit standards or goals are set, against which the elements of the description of the river are measured. The standards may be defined by the concept of 'river health' or in terms of desired condition. To this end, various schemes for evaluation of river health have been developed. Comparison of the evidence (assessment) can then be made against agreed standards, thresholds, reference conditions or other rivers.

Assessment of ecological value demands a different approach. There are no absolute standards or thresholds, so judgments always have a subjective element, even if the results are presented in numerical form. Assessment of ecological value also requires criteria which define what is significant; even these criteria can change over time with greater understanding of what constitutes conservation value.

2.1.3 Description and classification

The description of river ecosystems is fundamental to understanding the nature and dynamics of rivers. It is an essential first step to subsequent classification and to an assessment process. Description of individual river ecosystems includes identification of taxa, macroinvertebrate or riparian communities, flow data and flow regimes, geology and geomorphology. Biological and hydrological descriptions have a long-standing history, though knowledge of rivers as a whole across Australia is patchy (Lake & Marchant, 1990). Basic descriptions of river structure and features may have been incorporated but development of systematic typologies to describe fluvial geomorphology is more recent (Naiman et al., 1992). Characterisation of rivers according to hydrology, geology, landscape and climate provides a core framework for describing rivers across the continent.

Descriptive information can be used to provide the basis for selection of indicator taxa or communities. Mapping of occurrence or distribution from descriptive information provides an understanding of species rarity, or rarity of geomorphological features.

Classification of rivers into groups or types provides higher-order descriptions of rivers which may be useful for river managers, or provide conceptual models for research. Classifying river systems into groups enables hypothesis testing or establishment of a norm, baseline or target. Once a classification scheme has been developed, it can be used to assess or describe individual rivers. Conversely, for conservation planning, classification of river types may be a starting point to ensure that all river types are represented in a reserve system. A further consideration is the protection of typical sections of rivers. For example, river sections which are poorly conserved and more frequently disturbed or subject to impacts include floodplains and wetlands, in contrast to some types of well-conserved upland stream sections of the same rivers.

Approaches to the classification of Australian rivers by different features or elements are discussed in more

detail in section 4.3.1. In Queensland, work is under way on an integrated approach to the description and classification of river systems using hydrology, habitat, and aquatic flora and fauna in a bioregional framework. This approach is called Bioregional Aquatic Systems (BAS) (EPA, 1999b).

Classification of the longitudinal dimension of rivers, that is the nature and functioning of the river corridor from source to mouth, has evolved from simple classifications based on size or catchment area (Naiman et al., 1992) to theoretical models such as the River Continuum Concept (RCC) (Vannote et al., 1980). The RCC attempts to summarise changes in organic matter processing and biotic communities in response to change in the physical environment. This model has been criticised, especially in the southern hemisphere (Winterbourn et al., 1981; Lake, 1995) where it has limited relevance to the observed river functioning, particularly with reference to the different types of organic matter. However, such models serve to highlight the need to consider food webs and organic matter processing in the longitudinal dimension. Simple typologies of rivers by size or catchment are still used as the basis for management prescriptions, for example, in the forest industry (Forestry Commission, 1993) where they provide a rough rule of thumb for delimiting streamside reserves.

Classification schemes have been an important tool in river management in recent years. In particular, classifications based on invertebrate taxa or communities have been developed as the basis for assessment of water quality and more recently river health. In the United Kingdom, the River Habitat Survey utilises selected and detailed habitat characteristics to describe and compare river reaches against reference sites defined using a classificatory approach (Raven et al., 1998). The River Habitat Survey provides a description of the nature and features of rivers and an analysis of condition. The data from the Monitoring River Health Initiative in Australia has provided the descriptive basis for classification and prediction using the Australian River Assessment Scheme (AusRivAS) (Simpson et al., 1999).

Wetlands and floodplain elements of riverine systems have also been classified (Semeniuk & Semeniuk, 1995; Environment Australia, 1997b; Ramsar Convention Bureau, 1996) in a broad classification used Australia-wide to describe and assess such systems.

Classifications are essential to provide a context or reference for assessment against which observed features

or conditions can be compared. Classification of rivers may also be used to develop predictive models of river behaviour or characteristics. However, they are only as robust as the statistical procedures on which they are based and whether these procedures are a genuine reflection of an ecological condition.

2.1.4 Assessing river health or condition

The definition and value of the term 'river health' has been debated (Karr, 1999; Norris & Thoms, 1999; Boulton, 1999). The term has support because of its simplicity and relevance to the wider community; although, conversely, this leads to ambiguity in interpretation. Rutherford et al. (1998) suggest there are five key interacting elements which define river health: physical structure, riparian zone, water quantity, water quality and organisms.

The National River Health Program adopts a definition of river health of 'the ability of the aquatic ecosystem to support and maintain key ecological processes, and a community of organisms with a species composition, diversity and functional organization as comparable as possible to that of natural habitats within the system' (Simpson et al., 1999). River health has been a major focus for river assessment, with a nationally agreed protocol applied in the Monitoring River Health Initiative providing baseline information of the status of Australia's rivers. Other assessments of river health or condition include the Index of Stream Condition (Victorian Department of Natural Resources and Environment, 1997; Ladson et al., 1999), used in Victoria, and the Foreshore Condition Assessment (Shepherd & Siemon, 1999), applied in Western Australia to assess the riparian zone.

The selection of appropriate indicators to measure river health has increasingly moved towards assessment of aquatic biota based on comparisons with reference sites. It is argued that the biota demonstrates in a more accurate and integrated way the structural and functional integrity of ecosystems (Norris & Thoms, 1999). Biota selected are frequently macroinvertebrates (Marchant et al., 1994; Marchant et al., 1997; Simpson et al., 1999; Marchant et al., 1999) and fish (Harris & Silveira, 1999).

Applying the definition used by the National River Health Program, it is easy to appreciate how assessment of river health may be seen to constitute an assessment of ecological value. River health data can inform assessment of ecological value but are not an equivalent process. Assessment of the elements of river health could

show that a river was in 'good condition' without reference to ecological significance or value. Outputs from river health assessment may point to rivers in relatively natural condition by virtue of comparison against reference sites. But this differs from comparison with a river in natural condition defined on a wider range of parameters including, for example, catchment land use, remoteness from settlement, or extent of regulation.

Although river health and ecological value share components, the latter term encompasses a wider range of river elements. These elements are discussed in section 3.4. A further ecological value of a river might be its importance as a site for research into fluvial ecosystems.

2.1.5 Identification of conservation value

The notion of conservation value may be based entirely upon ecological value but more often other issues are also taken into consideration. The present study does not address other aspects of conservation assessment or value such as cultural, historic or recreational value, or the value placed on a river by a community for aesthetic, spiritual or emotional reasons. These are undoubtedly important values and often crucial in the protection of ecological values through appropriate management. Ecological value is fundamental to these other values: a river which is in good condition and sustains a natural ecosystem is often associated with a community's affiliations with the river.

For the purposes of the present project, the terms 'ecological value' and 'conservation value' may be used interchangeably. Both indicate the assessment of ecological value only. Some assessment processes for conservation value include an element of assessment of condition and/or threats in order to arrive at a 'score' (Collier, 1993; Boon et al., 1997).

The assessment of conservation value requires a set of criteria and a process in which the assessment will occur. While description and classification may proceed independently (for example, performed by external researchers), a process of assessment is essentially a political process undertaken within a larger context of river or land management. If the assessment process is pursued independently, it is unlikely that conservation measures will be implemented.

Current management requirements for river information often lead to overlap or combinations of purposes and stages in assessment. Description and classification may be required to underpin assessment.

Application of alternative methods of data collection and analysis, and the production of relevant, local classifications, may be done simultaneously with the assessment process. For example, the development of a Regional Forest Agreement is a major process of identification of forests for conservation, harvesting or other purposes. The process includes elements of description, classification, assessment and identification.

Just as the identification of areas for protection of forest values incorporated all elements of an assessment process – description, classification and evaluation – these are also essential components for identification of rivers of high ecological value.

2.2 Some Australian initiatives in river assessment

2.2.1 The National River Health Program and AusRivAS

Concern about maintaining the ecological health of Australian rivers led to the formation of the National River Health Program. The first stages involved collecting data from a large number of rivers across Australia under the Monitoring River Health Initiative to establish baseline data. Sites in which water quality and biota were believed to have been modified were selected as monitoring sites and sites which were considered to be in relatively good condition were selected as reference sites (Simpson et al., 1999). A common protocol was used across all sites for collecting information and macroinvertebrate samples and for identifying and counting samples. The data from these sites were analysed using classification and ordination procedures to identify site types and groupings and to characterise the reference condition.

These results are now formalised in a computer-based program, AusRivAS, which is used to assess river health by predicting aquatic macroinvertebrate fauna that would be expected at a site in the absence of environmental stress. The AusRivAS models are calibrated for each region and for Australian river systems' main habitat types. AusRivAS provides a standardised sampling method requiring minimal equipment. Since it is based on family-level taxonomic resolution, it does not require a high degree of taxonomic expertise.

Samples of rivers other than those which form part of regular waterway surveys may be compared with the

relevant AusRivAS models to assess their condition or health. AusRivAS may be used in contexts such as environmental impact assessment or catchment management with confidence, provided it is used for the purpose for which it was designed and recognising its limitations.

AusRivAS data give a general picture of the health status of a waterway. Waterways can be broadly categorised according to level of impact compared with reference conditions in the same region (Simpson et al., 1999). However, a healthy river does not necessarily have any special features which would result in a classification of high ecological value.

2.2.2 Wild Rivers Project

The Wild Rivers Project is identifying Australian river systems which have been relatively unchanged since European settlement. This national study, coordinated and undertaken by the Australian Heritage Commission, uses input data from the States on various indicators of disturbance. The various data layers are combined using specific decision rules (Stein et al., n.d.) and converted to an index of 'river wildness' or disturbance.

All river sections across Australia have been given a score which can be mapped, providing an overview of the level of disturbance of river systems as measured by the selected criteria. The project is essentially an identification process although draft conservation management guidelines have been developed as a voluntary code for river managers.

The Wild Rivers Index has been used in other assessment processes such as Regional Forest Agreement (Tasmania) and the State of the Rivers project in WA (see section 2.2.5). Individual States are expected to produce lists of wild rivers.

2.2.3 Index of Stream Condition (Victoria)

Most of Victoria's lowland rivers are affected in some way by human activity. The Index of Stream Condition is a tool to aid integrated management of waterways (Victorian Department of Natural Resources and Environment, 1997). The assessment (1997, p2) will be used:

- To benchmark stream condition;
- To aid objective setting for waterway management;
- To judge the effectiveness of management intervention, in the long term. . . ;
- To provide feedback to waterway managers. . . ;

- To indicate long-term strategic performance by waterway management authorities.

The Index of Stream Condition comprises assessment of hydrology, physical form, streamside zone, water quality and aquatic life. Data on key indicators for each of these categories are collected and resulting scores or ratings converted to an index according to set rules or criteria. Descriptive categories are converted to an arbitrary numerical scale and values for each of the five subindices are combined to give an overall numerical value for the index.

The Index of Stream Condition is appropriate where there has been extensive modification of catchments from natural condition. The index contributes to the broadscale management of waterways by providing an integrated measure of their environmental condition (Ladson et al., 1999). It is not intended for identification of ecological value, though a high Index of Stream Condition value would be indicative of potential conservation value because of a relatively low level of disturbance.

2.2.4 Stressed Rivers (NSW)

The stressed rivers approach was one of the first steps in introducing a series of water reforms in NSW. A classification system was devised to enable prioritisation of catchments for immediate management

attention (NSW Department of Land and Water Conservation, 1998).

The stressed rivers approach separates each subcatchment into one of nine categories based on environmental and hydrological stress. Stresses are assessed on the basis of current water usage and environmental health measures. Possible future level of hydrological stress is also considered where there are a substantial number of undeveloped water entitlements. The resulting matrix of stress classifications and management categories is shown in table 1. Categories with high combined stress rating are shown in dark shading; lighter shading shows categories with medium combined stress rating. Absence of shading indicates a low combined stress rating.

The classification process also attempted to identify all subcatchments with special conservation value. This included not only many low-stress rivers but also some affected rivers which had remnant habitats or species of significance. The values identified provided information for the management of those rivers. In addition, a smaller number of rivers were identified as having a high overall conservation value which would justify a higher level of protection. Further refinement of the assessment of the conservation value of rivers is being considered (M. Conlon, NSW Department of Land and Water Conservation, pers. comm., 1999).

Table 1: Stressed Rivers (NSW)

Proportion of water extracted	Environmental stress		
	Low	Medium	High
High	Immediate indications are that water extraction is causing a problem. Requires more detailed evaluation.	Water extraction is likely to be contributing to environmental stress.	Water extraction is likely to be contributing to environmental stress.
Medium	No indication of a problem, low priority for management action.	Water extraction is likely to be contributing to environmental stress.	Water extraction is likely to be contributing to environmental stress.
Low	No indication of a problem, low priority for management action.	Environmental stress likely to be due to factors other than water extraction. Stress not high, so lower priority for management action.	Environmental stress likely to be due to factors other than water extraction. Stress high, so important to ensure that water extraction is not exacerbating the problem.

Source: NSW Department of Land and Water Conservation (1998)

2.2.5 State of the Rivers (WA)

The Western Australian Water Resources Council (1992) and later the Water and Rivers Commission (1997) documented the state of the rivers across all drainage divisions of the State. This was assessed by mapping the major forms of degradation to which rivers in the State are subject. These included pastoral land use, clearing for agriculture, introduction of weeds, mining, roads and tracks, dams, erosion and sedimentation.

Information from the Wild Rivers Project of the Australian Heritage Commission, aimed at identifying rivers in pristine and near-pristine condition, was also incorporated.

The Western Australian State of the Rivers assessment led to the assignment of rivers to one of five categories: A1 Pristine, A2 Near-pristine, B1 Relatively natural, B2 Altered, C Degraded. Rivers in categories B1 and B2 are considered to have potential for rehabilitation to stable, healthy functioning ecosystems. These reports have helped the Water and Rivers Commission to focus on the important issues and management objectives, but the location of restoration works has been driven largely by community interest (K. Trayler, WA Water and Rivers Commission, pers. comm., 1999). More recently, efforts towards a more strategic approach have been pursued through the Waterways WA Program (Klemm et al., 1999; Sparks, 1999).

2.2.6 Environmental flows

Agreement on a strategic framework to achieve an effective and sustainable water industry by the Council of Australian Governments in 1994 laid the foundations for addressing the issue of water allocation in river management. One major recommendation was the introduction of a system of water allocation which would address water entitlements, water trading and provision of water for environmental flows.

Subsequently a set of National Principles for the Provision of Water for Ecosystems was produced (ARMCANZ & ANZECC, 1996). This was followed by responses from States and Territories to develop practical methods for assessing water requirements for ecosystems, known as environmental flows. A review and evaluation of environmental flows assessment techniques has been undertaken recently (Arthington & Zalucki, 1998). Methods targeting different key ecosystem elements (including geomorphology and channel morphology,

wetland and riparian vegetation, aquatic invertebrates, freshwater and estuarine fish, and water-dependent wildlife and water quality) are evaluated. Arthington and Zalucki (1998) evaluated six major holistic methods of assessment.

Environmental flows assessments may be incorporated into a decision support system process such as the Queensland Water Allocation Management Planning process (Arthington & Zalucki, 1998). Other States are seeking to use environmental flows assessment as a key plank of water management planning.

The assessment of environmental flows presupposes that the ecological value of the river is known, and that flow requirements (amongst other habitat or system requirements) are also understood.

2.2.7 Water Resource Environmental Planning (Queensland)

The Queensland Government initiated in 1997 a process to identify potential water infrastructure projects to support economic development. The Department of Natural Resources prepared the Water Infrastructure Planning Development Implementation Plan (WIPDIP). The Environment Protection Agency is working with the Department of Natural Resources and other government agencies to assemble information about conservation priorities and the sustainability of future water resource developments. The Environment Protection Agency's work is termed the Water Resources Environmental Planning (WREP) for WIPDIP.

The work on this project is still in a developmental phase with a focus on developing a conceptual framework that incorporates description and classification of waterways, conservation value assessment and sustainability assessment. A protocol – the Biological Aquatic System – for delimiting the river sections for assessment on geomorphological, hydrological and biological parameters is also being developed.

Draft attributes for conservation value are shown in table 2. Work is continuing on refining attributes, determining thresholds or value, and data collection issues. Pilot projects on application are also under way (N. Phillips, Queensland EPA, pers.comm., 1999).

Table 2: Waterway Conservation Value Indicators (draft), WREP for WIPDIP (Queensland)

Conservation value criterion	Project level indicators (tributary (subcatchment) or segment of main river)	Planning level indicators (main catchment)
Uniqueness	<ul style="list-style-type: none"> • geomorphology • biology • hydrology • water quality • landscape • recreation 	<ul style="list-style-type: none"> • geomorphology • biology • hydrology • water quality • landscape
Condition	<ul style="list-style-type: none"> • catchment quality above waterway • channel and instream habitat quality • water quality • artificial barriers • macroinvertebrates • fish • other aquatic/riparian fauna • riparian vegetation species and cover • aquatic vegetation species • carbon and nutrient cycling • ecological processes 	<ul style="list-style-type: none"> • total catchment quality • channels quality • water quality • artificial barriers • macroinvertebrates • fish • other aquatic/riparian fauna • riparian vegetation cover • aquatic vegetation species
Naturalness	<ul style="list-style-type: none"> • catchment modification above waterway • floodplain modification • channel modification • inundated areas • water quality • hydrology • macroinvertebrates • fish • other aquatic/riparian fauna • riparian vegetation • aquatic vegetation • subregional/local corridor function 	<ul style="list-style-type: none"> • total catchment modification • floodplain modification • channels modification • structures and inundated areas • water quality • hydrology (including interbasin transfers) • macroinvertebrates • fish • other aquatic/riparian fauna • riparian vegetation • aquatic vegetation • regional corridor function
Threatened species or ecosystems	<ul style="list-style-type: none"> • taxa, ecosystems or habitats listed under applicable legislation • species, taxa, ecosystems identified as endangered, of concern or of significance • taxa, ecosystems or habitats protected by international treaties • areas protected by legislation 	<ul style="list-style-type: none"> • taxa, ecosystems or habitats listed under applicable legislation • species, taxa, ecosystems identified as endangered, of concern or of significance • taxa, ecosystems or habitats protected by international treaties • areas protected by legislation
Biodiversity	<ul style="list-style-type: none"> • genetic diversity • species diversity • community diversity • ecological process diversity 	<ul style="list-style-type: none"> • community diversity • regional diversity

Source: Environment Protection Agency Draft Guidelines Version 1.5, July 1999

2.3 Selected overseas river assessment models

2.3.1 Wild and Scenic Rivers (United States)

The United States Congress may list rivers under the Wild and Scenic Rivers Act after study of the river's eligibility and suitability for classification. Agencies are required to consider and evaluate all rivers for potential designation while preparing broad land and resource management plans. Numerous rivers and river segments have been nominated and legislated at State level. The National River Inventory lists rivers and river segments that appear to meet minimum eligibility requirements based on their free-flowing status and resource values, and which are therefore afforded some protection from the adverse impacts of federal projects until fully assessed. Study of the rivers applies a common inventory of values through resource assessment (eligibility), assessment of existing conditions and evaluation of alternative management scenarios (suitability).

Eligibility is an evaluation of whether a candidate river is free-flowing and possesses one or more outstandingly remarkable values. If found eligible, a candidate river is analysed as to its current level of development (water resources projects, shoreline development and accessibility) and a recommendation is made that it be placed into one or more of three classes: wild, scenic or recreational.

Table 3 shows the key criteria assessed for the United States Wild and Scenic Rivers Act and the standards applied for each category.

Table 3: United States Wild and Scenic Rivers Act

Attribute	Wild	Scenic	Recreational
Water resources development	Free of impoundment.	Free of impoundment.	Some existing impoundment or diversion.
Shoreline development	Essentially primitive. Little or no evidence of human activity.	Largely primitive and undeveloped. No substantial evidence of human activity.	Some development. Substantial evidence of human activity.
Accessibility	Generally inaccessible except by trail.	Accessible in places by road.	Readily accessible by road or railroad.
Water quality	Meets or exceeds federal criteria or federally approved state standards for aesthetics and propagation of fish and wildlife normally adapted to the habitat of the river.	No criteria prescribed by the Wild and Scenic Rivers Act.	No criteria prescribed by the Wild and Scenic Rivers Act.

2.3.2 River Invertebrate Prediction And Classification Scheme (United Kingdom)

The River Invertebrate Prediction And Classification Scheme (RIVPACS) is a software package developed by the Institute for Freshwater Biology in the United Kingdom for assessing the biological quality of rivers (Wright, 1995). Work commenced in 1977 to develop a classification of unpolluted sites based on the macroinvertebrate fauna and to determine whether the macroinvertebrate fauna at an unstressed site could be predicted on the basis of physical and chemical characteristics of the river only. The work drew on an extensive database of information about the distribution of fauna and has gone through a number of phases. It has the advantage of using species level taxonomic resolution.

Data were collected from hundreds of sites, along with data on environmental variables. These data were classified using TWINSPLAN. Multiple discriminant analysis was used to find combinations of variables which best predicted the identified groups (Wright et al., 1984; Moss et al., 1987; Wright et al., 1989; Wright 1995). Predicted taxa for any given site can be generated using 14 environmental variables and the frequency of occurrence of species in these classified groups.

The system has continued to evolve and is now applied in the River Quality Surveys (Raven et al., 1998) and the general approach was the foundation for development of the Australian Monitoring River Health Initiative and AusRivAS (Wright, 1995; Simpson et al., 1999).

2.3.3 River Habitat Survey (United Kingdom)

The River Habitat Survey is a system for assessing the character and quality of rivers based on their physical structure (Raven et al., 1998). Originally focused on providing a detailed information tool, the River Habitat System may be applied to a variety of management purposes. It has four components: field survey using a rigorous standard methodology; computer database for data entry and comparison with other sites; a suite of methods for assessing habitat quality; and a method for describing channel modification. 'Habitat quality is determined according to the occurrence and diversity of habitat features of known value to wildlife, and is derived by comparing observed features at a site with those recorded at sites from rivers of similar character' (Raven et al., 1998, p7). Thus the evaluation stage of the assessment is founded upon: knowledge and description of habitat requirements; classification of types of sites or reaches; assumptions concerning distribution and behaviour of rivers and associated flora and fauna; a large database; and a validated methodology. The River Habitat Survey is used in a variety of ways by various agencies and supports legal and political imperatives for river protection.

2.3.4 System for Evaluating Rivers for Conservation (United Kingdom)

The System for Evaluating Rivers for Conservation (SERCON) is a broadly based technique for assessing conservation value using six conservation criteria and an impacts criterion (Boon et al., 1997; Boon et al., 1998). The six conservation criteria are: physical diversity, naturalness, representativeness, rarity, species richness and special features (box 1). These criteria have been 'designed so that evaluation can be related to the wider field of nature conservation assessment, [which is] achieved by fitting each attribute into a framework of generally accepted conservation criteria' (Boon et al., 1997, p308).

Rivers are evaluated in discrete lengths, normally between 10 and 30 kilometres, known as evaluated catchment sections. A SERCON evaluation comprises three stages: a field survey using an extended form of the River Habitat Survey; the collection of a wide range of other data from available sources; and translation of all data into scores ranging from nought to five for each of the attributes using guidance from the SERCON manual. Scores are weighted and combined to provide separate indices of conservation value for each of the six conservation criteria (Boon et al., 1998). The indices are presented in the form of an A to E assessment of

conservation quality and other data such as region and catchment use are also collected for the overall conservation assessment.

Box 1: Attributes assessed by SERCON

Physical diversity
 Substrates
 Fluvial features
 Structure of aquatic vegetation
 Naturalness
 Channel naturalness
 Physical features of the bank
 Plant assemblages on the bank
 Riparian zone
 Aquatic and marginal macrophytes
 Aquatic invertebrates
 Fish
 Breeding birds
 Representativeness
 Substrate diversity
 Fluvial features
 Aquatic macrophytes
 Aquatic invertebrates
 Fish
 Breeding birds
 Rarity
 European Commission Habitats Directive/Bern
 Convention species
 Scheduled species
 European Commission Habitats Directive species
 Red Data Book macrophyte species
 Red Data Book invertebrate species
 Species richness
 Aquatic and marginal macrophytes
 Aquatic invertebrates
 Fish
 Breeding birds
 Special features
 Influence of natural online lakes
 Extent and character of riparian zone
 Floodplain: recreatable water-dependent habitats
 Floodplain: uncreatable water-dependent habitats
 Invertebrates of river margins and banks
 Amphibians
 Wintering birds on floodplain
 Mammals

Source: Boon et al. (1998)

SERCON was developed in parallel with the development of the River Habitat Survey. Work is proceeding on integrating the two processes (Boon et al., 1998; Raven et al., 1998). The River Habitat Survey provides an approach to describing physical features of the river corridor for use in wider conservation assessment such as SERCON.

2.4 Approaches to assessment for conservation in non-riverine ecosystems

Several approaches to conservation assessment for various ecosystems have been developed or applied in Australia. Common elements are notable with consistent themes among the criteria. These include naturalness or integrity, diversity, richness and representativeness. Where the criteria are associated with planning for conservation or reservation (sections 2.4.2, 2.4.4, 2.4.5), the selection of representative areas of ecosystem type is a fundamental parameter.

2.4.1 Register of the National Estate

The Register of the National Estate is a listing of places of natural, historic or cultural significance compiled and administered by the Australian Heritage Commission. It is proclaimed under a Commonwealth Government Act

(the Heritage Act 1974) and only has direct effect on Commonwealth agencies or in situations where Commonwealth legislation is in some way involved.

There are a number of specific criteria against which the value of the place nominated is assessed (box 2). These encompass three aspects of heritage: natural, historical and Aboriginal. Despite the interrelationships between these, they are generally assessed and listed under these separate classes of heritage in the register. For places nominated for natural values, only criteria A1–A3, B1, C1, D1 and E1 apply. Clear scientific evidence of the value must be provided and, as far as possible, comparisons made to show the significance of the place. Benchmark standards such as listing on national rare and threatened species lists apply for some criteria.

Decision rules for the threshold for entry in the register include agreement that a place need only reach significance on any one criteria in order to be listed.

National Estate criteria are increasingly being used as a framework for assessment of natural heritage in other contexts, perhaps because they have been widely used and applied to a wide range of system types and at different scales. A notable use of this framework is the assessment of forest values discussed under section 2.4.2.

The criteria for assessment of natural values may be applied to river systems and may be used to inform

Box 2: National Estate criteria and values for natural environments

A: Importance in the course or pattern of Australia's natural history

A1 Importance in the evolution of Australia's flora, fauna, landscapes or climate

A2 Importance in maintaining existing processes or systems at the regional or national scale

A3 Importance in exhibiting unusual richness or diversity of biotic features or landscapes

B: Possession of uncommon, rare or endangered aspects of Australia's natural history

B1 Importance for rare, endangered or uncommon flora, fauna, communities, ecosystems, natural landscapes or phenomena, or as a wilderness

C: Potential to yield information that will contribute to an understanding of Australia's natural history

C1 Importance for yielding information that will contribute an understanding of Australia's natural or cultural history, by virtue of its use as a research site, teaching site, type locality, reference or benchmark site

D: Importance in demonstrating the principal characteristics of a class of Australia's natural places or environments

D1 Importance in demonstrating principal characteristics of the range of landscapes, environments or ecosystems, the attributes of which identify them as being characteristic of their class

E: Importance in exhibiting particular aesthetic characteristics valued by a community or cultural group

E1 Importance for a community for aesthetic characteristics held in high esteem or otherwise valued by the community

development of a more specific understanding of the ecological values of river ecosystems.

2.4.2 Comprehensive, Adequate and Representative (CAR) reserves for forests

The Regional Forest Agreements being progressively negotiated for all major forest areas across Australia are an attempt to ensure protection of the full suite of forest values while providing for security of access to forests for timber production.

The basis of decision making on areas to be reserved for forest protection lies in the assessment process of three key forest-related criteria: biodiversity, old-growth forest and wilderness (JANIS, 1996). The design of areas of forest for reservation is based on three principles (box 3). The three criteria are expanded by expert technical committees in the region concerned to list particular aspects or expressions of those values. For example, the list of natural values identified by the technical committees and considered in the assessment process for the Tasmanian Regional Forest Agreement is shown in box 4. Notations after each value denote its location within the criteria of the Register of the National Estate, shown in box 2.

Box 3: Principles and criteria for forest reserves

The CAR principles:

Comprehensiveness – the forest reserve system includes the full range of forest communities recognised by an agreed national scientific classification at appropriate hierarchical levels.

Adequacy – the forest reserve system should ensure the maintenance of ecological viability and integrity of populations, species and communities.

Representativeness – those sample areas of the forest that are selected for inclusion in reserves should reasonably reflect the biotic diversity of the communities.

Criteria for assessment

Biodiversity

Old growth

Wilderness

Source: JANIS (1996)

Box 4: Regional Forest Agreement, Tasmania, National Estate criteria and values for flora and fauna

Biodiversity-related values

Flora and fauna species at the limit of their natural range (A1)

Disjunct populations of flora and fauna species (A1)

Centres of endemism (A1)

Phylogenetically primitive species of flora and fauna (A1)

Biogeographically relictual species of flora and fauna (A1)

Species refugia (arising from past processes) (A1)

Species refugia (arising from present processes) (A2)

Important fauna habitat (A2)

Remnant vegetation patches (A2)

Places important for primary and secondary vegetation succession (A2)

Flora and fauna species and community richness (A3)

Rare (including uncommon), vulnerable and endangered species and communities (B1)

Uncommon wetlands (B1)

Important natural history sites (C1)

Principal characteristics of wetland classes (D1)

Principal characteristics of vegetation communities (D1)

Broader landscape values

Wilderness (A2, B1)

Old growth (A2, B1)

Natural landscapes (B1)

Undisturbed catchments (A2)

Source: PLUC (1997)

Stages in the assessment process included describing and mapping the values, classifying forest types and evaluating the significance of the values against specified decision rules and thresholds. Other values such as historical, social and economic values were also evaluated. Finally, areas were identified and delineated for protection while others were set aside for forest operations.

2.4.3 Ramsar Convention for wetlands of international significance

Wetlands of international significance may be nominated for listing under the Ramsar Convention (Ramsar Convention Bureau, 1996). Criteria for Ramsar

listing are shown in box 5. Ramsar listing addresses criteria of diversity, richness, naturalness and representativeness.

Wetlands may be nominated if they meet at least one of the criteria.

Box 5: Criteria for identifying wetlands of international importance

A wetland should be considered as being of international importance if it meets at least one of the criteria set out below:

1 Criteria for representative or unique wetlands

A wetland should be considered internationally important if:

- it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographic region; or
- it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographic regions; or
- it is a particularly good representative example of a wetland which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a transborder position; or
- it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographic region.

2 General criteria based on plants and animals

A wetland should be considered internationally important if:

- it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of those species; or
- it is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna; or
- it is of special value as the habitat of plants or animals at a critical stage of their biological cycle; or
- it is of special value for one or more endemic plant or animal species or communities.

3 Specific criteria based on waterfowl

A wetland should be considered internationally important if:

- it regularly supports 20,000 waterfowl; or
- it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetlands values, productivity or diversity; or
- where data on populations are available, it regularly supports 1 per cent of the individuals in a population of one species or subspecies of waterfowl.

4 Specific criteria based on fish

A wetland should be considered internationally important if:

- it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global diversity; or
- it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Source: Ramsar Convention Bureau (1996)

Box 6: Criteria for the National Representative System of Marine Protected Areas

Representativeness

Will the area:

- represent one or more ecosystems within an Interim Marine and Coastal Regionalisation of Australia bioregion, and to what degree;
- add to the representativeness of the NRSMPA, and to what degree.

Comprehensiveness

Does the area:

- add to the coverage of the full range of ecosystems recognised at an appropriate scale within and across each bioregion;
- add to the comprehensiveness of the NRSMPA.

Biogeographic importance

Does the area capture important biogeographic qualities.

Naturalness

How much has the area been protected from, or not been subjected to, human induced change.

Ecological importance

Does the area:

- contribute to the maintenance of essential ecological processes or life-support systems;
- contain habitat for rare or endangered species;
- preserve genetic diversity, that is, is diverse or abundant in species;
- contain areas on which species or other systems are dependent, for example, contain nursery or juvenile areas or feeding, breeding or resting areas for migratory species;
- contain one or more areas which are a biologically functional, self-sustaining ecological unit.

International or national importance

Is the area rated, or have the potential to be listed, on the world or a national heritage list or declared as a Biosphere Reserve or subject to an international or national conservation agreement.

Uniqueness

Does the area:

- contain unique species, populations, communities or ecosystems;
- contain unique or unusual geographic features.

Productivity

Do the species, populations, or communities of the area have a high natural biological productivity.

Vulnerability assessment

Are the ecosystems and/or communities vulnerable to natural processes.

Source: ANZECC (1998)

2.4.4 Marine reserves

Australia's Oceans Policy has advocated implementation of a representative areas network. An ANZECC Task Force on Marine Protected Areas has been developing guidelines and a strategy for the implementation of a

national representative system of marine protected areas (NRSMPA) (ANZECC, 1998; ANZECC, 1999). Criteria for the identification of marine protected areas are shown in box 6.

A similar set of criteria are recommended for marine protected areas at the international level (Gubbay, 1995) shown in box 7.

The Great Barrier Reef Marine Park Authority (GBRMPA) has recently announced its intentions to provide specific protection to a suite of areas which are representative of the range of ecosystem types within the Marine Park (GBRMPA, 1999). The Representative Areas Program will maintain biodiversity and ecosystem processes across all ecosystem types within the Barrier Reef. The five principles for representative areas within the area of the marine park are: selection within a regional framework, application of the precautionary principle, comprehensive inclusion of all habitats, adequacy to sustain ecological integrity, and representativeness (GBRMPA, 1999).

2.4.5 The National Reserve System

In order to discharge Australia's responsibilities under the Biodiversity Convention, a system of national reserves has been proposed (Environment Australia, 1998a). A five-year funding program under the Natural

Box 7: Recommended criteria for the selection of marine protected areas

Social criteria

(12 measures of social benefit)

Economic criteria

(5 measures of economic benefit)

Ecological criteria

Diversity

Naturalness

Dependency

Representativeness

Uniqueness

Integrity

Productivity

Vulnerability

Regional criteria

Regional significance

Subregional significance

Pragmatic criteria

(7 measures of feasibility and timing)

Source: Gubbay (1995)

Heritage Trust has been provided to establish, in cooperation with States and Territories, a comprehensive, adequate and representative National Reserve System. Under this program, the objectives include the 'establishment and management of new ecologically significant protected areas which will be added to Australia's terrestrial National Reserve System' (Environment Australia, 1998a, p43). Australia's Biodiversity Strategy (Department of Environment, Sport and Territories, 1996b) identifies three components of Australia's biological diversity: 'terrestrial, marine, and other aquatic' (1996b, p7). Currently, a system of Comprehensive, Adequate and Representative reserves is being developed for terrestrial and for marine systems. A similar case may be made to identify and protect 'other aquatic' biodiversity components under the National Reserve System.

2.5 Requirements for assessment of the ecological values of rivers

Ward (1989, cited in Boon, 1992) highlights the need to consider four dimensions in assessing river values:

- longitudinal – the linear ecosystem of the river corridor from source to mouth;
- lateral – the connections between the river and its riparian zones, valley and floodplain;
- vertical – including the relationship between groundwater and stream flow and the organisms and processes in the water column and hyporheic zone; and
- temporal – changes in river behaviour over time.

Boon (1992) suggests that it is important to consider a fifth dimension in making the case for river conservation. He adds a conceptual dimension. This dimension addresses the questions of philosophy, politics and practice which will drive the conservation assessment process and lead to management decisions. As noted previously, the assessment of ecological values is an inherently subjective process and therefore issues such as 'What makes a river of high ecological value?', 'How do we select between rivers for conservation (or other uses)?' and 'Who determines what are the important values to protect?' must be addressed.

These questions are central to the proposals for identification which follow. In developing the conceptual model, the other four dimensions must be considered in the development of criteria for ecological

value. For example, values should include criteria reflecting the landscape or river corridor dimensions and criteria associated with values beyond the boundaries of the river banks such as floodplains and wetlands. In addition, the proposals should be amenable to application at different scales, and for rivers at different status of conservation or protection.

2.6 Developing approaches to identifying high ecological value rivers in Australia

The aim of this LWRRDC project links identification of rivers of high ecological value with their protection. Approaches to identification of rivers of high value are premised on the assumption that action towards protection will follow. It is clear from the lack of progress in New Zealand (K.J. Collier, National Institute for Water and Atmosphere Research Ltd, New Zealand, pers.comm., 1999), South Africa (J.H. O’Keeffe, Institute for Water Research, Rhodes University, South Africa, pers.comm., 1999) and, to some extent, the United Kingdom (H. Dawson, Centre for Hydrology and Ecology, United Kingdom, pers.comm., 1999) that establishing an agreed set of criteria is not sufficient to ensure that protection of river values proceeds. Other institutional and practical issues can usurp efforts for protection. Therefore, a multi-purpose framework is suggested for assessing values of Australia’s rivers. A multi-purpose framework is not reliant on ongoing institutional arrangements and can address river conservation via several different avenues.

Other reasons for addressing the task in this way include the great variability of Australia’s riverine environments, variations in institutional responsibilities for river management, and the need to provide approaches which can be applied at different scales and through different levels of conservation provision. The same multi-purpose framework may be used as a means of identification of rivers for legal protection, a checklist for ecological values in planning for integrated catchment management or identifying priorities or possibilities for rehabilitation.

3 Identifying rivers of high ecological value in Australia

3.1 Why identify rivers of high ecological value?

A major concern of river managers in Australia has been to maintain and improve water quality and to distribute water resources.

New triggers or drivers are affecting water resource management and catchment management. These include: elements of water reform which are based on the ecologically sustainable development of water resources; elements of biodiversity and threatened species agreements and policies; setting priorities for allocation of money from funding programs; competing priorities within catchments, including cross-border issues resulting from State boundaries; environmental impact assessment and infrastructure proposals; and community concerns such as a decline in the population health of flagship taxa.

Increasingly, the management of land and water resources is acknowledged to be an integrated and collaborative process. This means that agencies and interest groups with a wider range of perspectives are brought to the management of water resources. This is reflected, for example, in NSW where a high-level inter-agency Policy and Technical Committee meets regularly to consider issues of catchment management. In this situation, parks authorities can bring more of a conservation perspective to river management. In addition, water authorities recognise that an ecosystem perspective is necessary to sustain a healthy river to meet the requirements of water users. More and more, water management will need to be considered in regional as well as catchment or local terms. Approaches to the assessment of rivers of high ecological value will also inform the conservation values and status of other rivers.

Identification of rivers of high ecological value is important for:

- planning for protection of river, wetland and floodplain values;
- assessing important ecological values in catchment management;
- providing information to determine environmental flows;
- infrastructure planning and decision-making;

- addressing compliance with biodiversity agreements, including protection of rare and threatened species;
- setting priorities and goals for river rehabilitation;
- providing important research data on river ecosystems and their management;
- establishing a suite of rivers which can be used as reference rivers for the management of particular ecological values; and
- undertaking environmental impact assessment.

3.2 The conceptual framework

The conceptual framework specifies for Australian rivers the elements required for a process of assessing high ecological value. The framework has three main elements:

- definition – laying out those criteria and attributes which define ecological value;
- evaluation – specifying the basis on which comparisons will be made and making judgments; and
- selection – choosing sites and determining management approaches.

The definition of what constitutes ecological value is central to the development of common and appropriate approaches to assessment of ecological value. Definition of values will largely remain constant, but will be refined over time as ecological concepts and values evolve. Such an evolutionary process has refined the criteria for assessment of World Heritage value, Ramsar listing, and listing on the Register of the National Estate.

The definition of criteria and attributes for high ecological value is a key element in the case for conservation of rivers. The project focused on developing these attributes through a widely consultative process.

Evaluation and selection processes will differ according to the context and purpose of the assessment. Standard principles of evaluation and common approaches to and examples of selection are outlined.

The conceptual framework may be applied in different contexts and for different purposes for the

assessment of ecological values of rivers. Consistency is achieved through common criteria and attributes; flexibility is achieved through selection of attributes applicable to rivers of the particular region or type.

Practical aspects of applying the framework, including data collection and classification, are considered in section 4.

3.3 The process of defining criteria and attributes

Defining criteria and attributes is central to a systematic assessment and evaluation process. The criteria and attributes form the basis for describing characteristics of rivers considered to be important from an ecological perspective. They should therefore reflect an holistic and integrated interpretation of river ecology and be consistent with current perspectives on conservation value generally.

A set of criteria and attributes for ecological value that is widely accepted within the scientific community and among river managers may be used for a variety of purposes. The nature of the evaluation stage of the assessment process and its consequences for the river will be determined by the particular management context. The criteria may form a checklist to determine values for a river within an individual catchment management plan or the basis for determining which, if any, rivers in a given bioregion should be protected as a commitment to protect a State's biodiversity.

A consultative approach was used to develop the attributes for ecological value of rivers. The draft list of attributes was drawn up using:

- existing models such as SERCON;
- ecological values of Australian rivers identified in the literature and suggested by reference group members;
- current perspectives on river ecology;
- criteria from conservation evaluation models for other ecosystems or general criteria such as forest assessment or the National Estate criteria; and
- emerging value systems, especially fluvial geomorphology.

A survey of river experts was conducted to canvass opinion of the proposed criteria and attributes.

The survey results are reported in detail in the appendix. In summary, the 73 respondents from across Australia:

- endorsed the criteria and attributes of rivers of high ecological value;
- rated all attributes as important, though representativeness scored slightly lower;
- nominated an Australian river which they considered to be of high ecological value; and
- identified and scored the attributes which were appropriate for that river.

The resulting list of attributes is longer and covers a wider range of attributes than similar systems elsewhere, notably SERCON. It also extends concepts embodied in assessment criteria such as the Register of the National Estate. Several factors contribute to this situation:

- River systems in Australia differ in some significant ways from other parts of the world where such assessment processes have been devised.
- The scale of the continent and its climatic and geological diversity lead to a broader scope of river characteristics.
- The Register of the National Estate deals with place-based localities and cannot readily accommodate values such as the importance for maintaining downstream habitats.
- Geomorphological perspectives are now more generally accepted as integral to the notion of ecology.
- The dynamics and pressures on river systems mean that ecological processes are critically important and require promotion as central to the values of a river.

The list of attributes was generally endorsed and few additional attributes were offered. In most cases these could be accommodated within other attributes.

3.4 The criteria and attributes

Attributes agreed by survey respondents are shown in table 4. These criteria and attributes form the conceptual framework for the assessment of the ecological value of rivers in Australia.

3.4.1 Scope

Ecological value is taken to include values that relate to the physical environment, physical river processes and ecological processes as well as biological ecosystem features. Aspects of river geology and landscape features such as floodplains or waterfalls of significant size are therefore included. Such attributes or features are important contributors to the river ecosystem as a whole. Geomorphological and hydrological processes are integral to the nature and patterns of instream ecosystems and affect food sources, habitat availability and life cycles of instream biota. These processes also exert a great influence on the development and maintenance of surrounding vegetation. The values represented by geomorphological and hydrological features and processes are central to understanding river ecosystems and are important controls on the biological values. Therefore, values associated with geomorphology and hydrology are included within the scope of the attributes used for assessment of high ecological value.

Attributes related to geomorphology and hydrology are less frequently encountered in overseas models. In the Australian context, there is a wide variety of river systems reflecting diversity of geomorphology and hydrology. These processes are also fundamental to protection of river ecosystems and to rehabilitation efforts. Other factors contribute to the greater emphasis placed on geomorphology and hydrology in Australia. One is the development of approaches characterising rivers which integrate geomorphology and hydrology (Brierley & Fryirs, in press). Such analyses are now being applied in some assessment and rehabilitation contexts (Brierley, 1998; Rutherford et al., 1999). Another factor contributing to greater attention to geomorphology is the growth and broadening of the notion of geoheritage. The concept of geoheritage focuses on the intrinsic conservation value of geological and geomorphological features and processes. Proponents of the concept of geoheritage also promote the need to protect such values which are irreplaceable in the sense of human time frames. Attention is also drawn to the sensitivity and vulnerability to many types of geomorphological features and processes, which contrasts with the more generally held belief that geological values are robust (Sharples, 1995).

The inclusion of geomorphological and hydrological values in the set of attributes was confirmed through survey responses. Irrespective of the specific area of expertise of respondents, these values were rated within a similar range to the more traditional biological values

(see appendix), although some respondents indicated that this was a field in which they had limited knowledge.

Some attributes of rivers which have a strong correlation with the riverine environment and ecosystems are not included within the scope of the proposed framework, even though such attributes may be critical to the overall river values and to the management decisions. These include aesthetic aspects of rivers, recreational uses and spiritual or cultural associations. Since these values do not control or contribute to the natural ecosystem within most rivers, they are not considered within the assessment framework for ecological value. Nevertheless, they should be included in an overall assessment of all river values.

3.4.2 Criterion 1 – Naturalness

Naturalness is considered to be of high ecological value in itself. The term causes some debate since it is argued that humans have modified river systems for thousands of years. The definition of 'naturalness' is generally accepted to be pre-European condition or a lack of disturbance. This too is problematic since the extent of catchment disturbance is an additional factor. Nevertheless, naturalness is a widely accepted term in conservation assessment and broadly understood to mean lack of human-induced disturbance.

Naturalness also reflects the condition or health of a river and therefore is important in the selection of reference rivers for assessment of river health. Some would argue that the term 'reference condition' ought to replace 'naturalness' but this suggests 'best available' rather than undisturbed. It also has the disadvantage of being a scientifically or statistically derived term of little relevance to the wider community.

The concept of naturalness embodies ecological integrity. Integrity may be defined as the capacity of an ecosystem to sustain itself and remain robust in the face of natural forms of disturbance.

Many of Australia's rivers and most of its major river systems have been modified either by impoundment or changes in the catchment, or both. The Australian Heritage Commission's Wild Rivers Project sought to map the location and extent of disturbance to the nation's rivers and identify remaining rivers which might be considered wild rivers. There was, however, no direct link into protection or conservation of these high value rivers.

Table 4: Criteria and attributes for assessment of ecological value of rivers

Criterion	Attributes
1 Naturalness	1.1 undisturbed catchment 1.2 unregulated flow 1.3 unmodified flow 1.4 unmodified river/channel features 1.5 natural water chemistry 1.6 absence of interbasin water transfer 1.7 intact and interconnected river elements 1.8 natural temperature regimes 1.9 natural processing of organic matter 1.10 natural nutrient cycling process 1.11 intact native riparian vegetation 1.12 absence of exotic flora or fauna 1.13 habitat corridor 1.14 natural instream faunal community composition 1.15 natural ecological processes, including energy base and energy flow in food webs
2 Representativeness	2.1 representative river system or section 2.2 representative river features 2.3 representative hydrological processes 2.4 representative aquatic macroinvertebrate communities 2.5 representative instream flora or riparian communities 2.6 representative fish communities or assemblages
3 Diversity and richness	3.1 diversity of rock types or substrate size classes 3.2 diversity of instream habitats, for example, pools, riffles, meanders, rapids 3.3 diversity of channel, floodplain (including wetland) morphologies 3.4 diversity of native flora or fauna species 3.5 diversity of instream or riparian communities 3.6 diversity of floodplain and wetland communities 3.7 diversity of endemic flora or fauna species 3.8 important bird habitat
4 Rarity	4.1 rare or threatened geomorphological features 4.2 rare or threatened ecological processes 4.3 rare or threatened geomorphological processes 4.4 rare or threatened hydrological regimes 4.5 rare or threatened invertebrate fauna 4.6 rare or threatened fish or other vertebrates 4.7 rare or threatened habitats 4.8 rare or threatened fauna 4.9 rare or threatened communities or ecosystems 4.10 rivers with unusual natural water chemistry

continued

Table 4: Criteria and attributes for assessment of ecological value of rivers (continued)

Criterion	Attributes
5 Special features	5.1 karst, including surface features 5.2 significant ephemeral floodplain wetlands 5.3 dryland rivers with no opening to ocean 5.4 important for the maintenance of downstream or adjacent habitats such as floodplain or estuary 5.5 important for the maintenance of karst system of features 5.6 important for migratory species or dispersal of terrestrial species 5.7 drought refuge for terrestrial or migratory species 5.8 habitat for important indicator or keystone taxa 5.9 habitat for flagship taxa 5.10 refuge for native species and communities in largely altered landscapes.

Criteria developed in the Wild Rivers Project were applied to river sections on a geographical information system (GIS) base and summed according to specific decision rules. The resultant River Wildness Index provided each river unit with a score ranging from 1 to 17+; the higher the score, the less river disturbance.

Criteria for the River Wildness Index focused on the landscape and hydrological context of the rivers. Additional attributes reflecting lack of disturbance from an ecological and instream perspective were added to the naturalness criterion in the ecological value framework. These include absence of interbasin transfer, interconnected river elements, natural processing of organic matter and nutrient cycling processes, natural instream faunal community composition and natural ecological processes. The natural value of the river as a habitat corridor was also included: although a river might not score highly on the River Wildness Index, it might still play an important part as a wildlife corridor sustaining other biotic elements of the landscape.

Some of the attributes for the naturalness criterion may be implicit in the measures or criteria used in compiling the River Wildness Index, but they require highlighting as special components of a river's natural state for the purposes of ecological assessment. Such attributes include absence of interbasin transfer, natural water chemistry or natural water temperature regimes.

Some scientists argued in their survey responses that any river which was more or less undisturbed was therefore of high ecological value. Given the limited number and distribution of such rivers, and the ongoing pressures for development, such a perspective may be

valid. Conversely, some respondents suggested that too much emphasis was given to naturalness as a benchmark for identifying a river of high ecological value. An unintended consequence of this could be that rivers with other ecological values were overlooked and might be left to deteriorate if all conservation efforts were focused on rivers of high naturalness. However, it was a basic assumption at the project outset that rivers which had some human disturbance could nevertheless have high ecological value for other characteristics.

Naturalness of river processes is generally inferred from the biota or from the capacity of the river to maintain its natural chemical properties and balance.

Natural water chemistry is an aspect of naturalness which may be at odds with some assessments of river value. For many years, standards for water quality used the quality required for suitable human drinking water as a reference. For example, the acceptable standard for acidity was pH neutral whereas many rivers in Australia tend towards the acidic as they drain off poor leached soils or through wetlands. New standards based on ecosystem health use natural condition as the benchmark (ANZECC, 1999).

More difficult in some ways is the acceptance of silt loads as a natural ecosystem value. Turbidity of watercourses not only renders them unsavoury for drinking without treatment, but is also visually unattractive. The loss of particulate matter may also be of concern because of its association with undesirable land management practices. Nevertheless some rivers, for example rivers in arid areas such as Cooper Creek (Queensland/South Australia), naturally carry heavy silt

loads, particularly under certain conditions or at certain times of year. Sediment transport patterns constitute an element of the ecological value of such rivers.

The River Wildness Index is available across Australia. It provides useful information in river assessment but, as with any compound index derived from ordinal scales, must be treated with caution. Other data should be used alongside the River Wildness Index in assessing the naturalness of the river section.

Assessments for indicators or evidence for each attribute under the criterion of naturalness are either nominal (absence of interbasin transfer, habitat corridor) or ordinal (extent of exotic species, natural energy base and energy flow) scale. Several of the naturalness attributes are likely to be correlated.

3.4.3 Criterion 2 – Representativeness

Any assessment of the representativeness of an ecosystem assumes that data are available to confirm comparison with all examples of that type or feature. This implies that appropriate data collection (description) has been undertaken across an appropriate range and number of situations and that this has been analysed to provide classifications against which a particular site can be assessed. Thus Attribute 2.4, 'representative aquatic macroinvertebrate communities', presupposes that information is available about aquatic communities generally in that region or habitat type. Work is proceeding to fulfil this requirement, for example, through the AusRivAS program (Simpson et al., 1999).

Attributes 2.1, 'representative river system or section' and 2.2, 'representative river features', will draw upon classification procedures for fluvial geomorphology such as the River Styles approach (Brierley & Fryirs, in press) or river types classifications (Western Australian Water Resources Council, 1992; Water and Rivers Commission, 1997). As yet, there is not a widely used national classification for river types or styles.

It is suggested by some (N. Phillips, Queensland EPA, pers.comm., 1999) that representativeness might more properly have been regarded as a conservation priority rather than a value. Nevertheless, some rivers which might otherwise not have specific attributes of high value may achieve that status because there are few other examples of that river type or river process left.

Inclusion of representativeness as a criterion was seen by some respondents to imply that a minimalist view of protecting rivers could be adopted, or might be used as a rationale for abandonment of other rivers of similar type. Thus it might be argued that if a

representative river was protected in some way, this was all that would be required to fulfil conservation goals. Representativeness was considered by respondents to be somewhat less significant as a criterion than the other four criteria, yet concern was expressed about the loss of examples of some river types in unmodified condition. Other rivers were nominated as being of high value because they were the last or only river of that type in more or less natural condition.

Protection of representative rivers and river sections is also important in order to provide for research and reference for better river management generally.

3.4.4 Criterion 3 – Diversity and richness

The eight attributes listed under the diversity and richness criterion demonstrate the complexity of river systems. River diversity has many faces reflecting the behaviour of the river and interaction between the hydrology, landscape, processes and biota. Of course, some aspects are correlated: for example, high diversity of instream habitats leads to high diversity of instream communities, and diversity of wetland morphologies leads to diversity of bird species.

Assessment of diversity also requires some kind of norm or standard for comparison. This in turn requires detailed data, description (including distribution) and classification into typologies as the basis for diversity evaluation. Not all groups of taxa are known adequately or to the same level of taxonomic resolution in order for such assessment. Birds are probably the best known. Macrophytic flora species and communities are relatively well known. Species-level analysis for instream invertebrate species and communities is very patchy from both geographic and taxonomic perspectives. Knowledge of floodplain and wetland morphologies and communities is increasing but also geographically patchy. The diversity of Australia's bioregions means that data cannot be readily transposed across the continent.

Geological and geomorphological features are included because of their importance in shaping the river processes and ecosystems. Geoheritage also has intrinsic values which are as yet poorly acknowledged. Description and classification of such fluvial features is in its infancy in the Australian context, though some simple analysis is used in some measures of stream condition including the Index of Stream Condition (Victoria) and the River Habitat Survey (United Kingdom).

It is important to note that some rivers may be naturally species poor. The concept of diversity is

sometimes misinterpreted to suggest that more is always better. Rivers that are naturally species poor, such as rivers in which the water chemistry is naturally acidic (Dunn, 1998), or rivers in low rainfall areas, may nevertheless have high ecological value. Such sites demonstrate biodiversity, with some species more tolerant of such conditions or favouring such habitats. Low diversity sites could be important as being representative of that class of site type.

Diversity also varies with the position of the river section within the whole catchment and therefore assessment of diversity must be made at similar sites and at similar scales.

The inclusion of diversity as a criterion is seen by some respondents as reflecting a populist view of significance. Nevertheless, the term has gained some popular credence and biodiversity is a mainstream conservation focus. It is also generally considered that places of high species diversity, or 'hot spots', are of particular importance from a management perspective since protection of such areas is a cost-effective way to protect a larger number of species (World Conservation Monitoring Centre, 1998).

3.4.5 Criterion 4 – Rarity

The value of rarity is self-explanatory. Anything that is uncommon, whether biota, river form or process, is of value in the global biodiversity or geodiversity context. Protection of biodiversity has focused in a significant way on rare and threatened species. Rarity of species, communities and habitats is the only aspect of ecological value which has the backing of legislative protection in most States. Rivers themselves may be regarded as threatened systems because of the pressures upon them. Even large-scale features can be obliterated in aquatic systems by the construction of major dams or excessive water use. Rivers with unusual natural water chemistry or hydrology are in many cases distinctive of inland Australia and contribute understanding of the continent's history as well as being of significance for their present-day characteristics.

3.4.6 Criterion 5 – Other special features

The other special features criterion includes features which are uncommon within the landscape generally, or which sustain other important or interesting ecosystems, such as karst, estuary or floodplain wetlands. It also includes other important functions that rivers may provide in maintaining the wider context, such as drought refuge or avenue for dispersal. Other special

features also capture those species which are not uncommon but are otherwise of importance, such as keystone or indicator species. The criterion also includes species which might be termed flagship species, that is, those species which are especially important to the community, often in a symbolic sense or by association. These include species such as platypus, river red gum and Murray cod which are also important indicators of the state of Australia's rivers generally.

A river may have special value not so much for its instream characteristics, but for the role it plays in sustaining terrestrial species. Where there has been extensive alteration to the wider landscape, the river environs may be important as a refuge and corridor for terrestrial species and communities.

3.4.7 Rivers nominated by survey respondents

Respondents to the survey were asked to nominate a river in Australia which they considered to be of high ecological value using a list of suggested attributes (see appendix). A wide range of rivers was nominated. These included: Acheron River, Broken River, Upper Colo River, Upper Yarra River, Paroo River, Franklin River, Magela Creek, Snowy River, Cooper Creek, Daintree River and sections, or all, of the Murray River and its catchment. Thus a wide variety of rivers was recognised across Australia differing in scale and characteristics. Not all the rivers nominated were undisturbed; the majority had been affected by human activity to some degree over the past 200 years.

A full list of rivers nominated may be found in the appendix. It is important to note that in the context of the survey, rivers were nominated to focus suggestions about preferred or desired protection. The identification was not a systematic or representative process.

3.4.8 A desktop validation of the attributes

In order to validate the framework, at least at a desktop level, a second survey was conducted. A list of six rivers, selected from those nominated by more than one respondent in the original survey, was provided and respondents asked to rate the rivers on those attributes which they considered a value for that river. Among the responses it was noted that:

- there was reasonable consistency in attributes selected;
- there was reasonable consistency in ratings of the attributes; and
- these rivers tended to have important natural values, that is, were at the upper end of River Wildness Index.

These initial attempts at validation indicate that the framework was considered an appropriate basis on which to begin the process of river assessment. Of course, much further work needs to be undertaken in validation. This would include a wider desktop assessment process, for example, using an expert panel approach, and working on a wider range of river types, including rivers which clearly have human impacts. A subsequent validation step would be to undertake a practical exercise on a small scale, such as a region or catchment, to verify data sets, scale issues and application of ratings.

3.5 Evaluation – rating and comparisons

3.5.1 Data collection issues

Data collection for assessment of the ecological value of rivers may be seen to be a major task. However, existing data collected for other purposes, remote techniques and local knowledge may all contribute useful information. Suggestions for some data sources are given in section 4, 'Applying the framework'.

Some issues relating to data collection must be addressed in setting up the assessment process. The range of data required or considered most appropriate must be determined. Relevant indicators or taxa may be selected, depending on the focus for the assessment. Realistically, in some situations, choices must be made about where to put sampling or investigatory effort. Availability of existing information should be assessed. The use of particular information in the assessment may be determined by the availability of appropriate classifications and taxonomic information.

The scale of the assessment process will determine the scale at which data is collected. Some aspects of river characteristics operate at different scales from others, although they may be intrinsically linked. For example, geomorphology has a determining influence on vegetation though each may be assessed at different scales. For some types of dataset, extrapolation to other scales may be possible. In practice, the scale for assessment should generally reflect the scale at which management will operate. The most effective management occurs at catchment scale.

Some datasets, such as riparian vegetation or instream habitat diversity require longitudinal assessment of the river reach or section. Other data, such

as macroinvertebrate data, are collected at a point and are representative of only the immediate area and habitat.

The primary requirement for data collection is that the data are compared with reference data or other rivers at the same scale (Boon, 1992).

3.5.2 Classifications and typologies

Classifications and typologies of river characteristics are necessary as a basis for interpretation and comparison. These are available for a range of attributes or groups of attributes. They range in scale from general (river or wetland types) to specific (fauna or flora species). Classifications of communities such as macroinvertebrate communities or fish are particularly useful as indicators of ecological processes within the river system. There are several classifications of rivers as landscape features (Naiman et al., 1992; Western Australian Water Resources Council, 1992; Water and Rivers Commission, 1997). Brierley's (1996, 1999) river styles approach provides both a means of describing the general river behaviour and a typology for analysis of a range of hydrogeomorphological characteristics. Other familiar typologies include habitat type, instream substrate composition, particle size and aquatic macrophyte architecture (Harper et al., 1995; Holmes et al., 1999). Classifications for specialised geomorphic features (Australian Nature Conservation Agency, 1996; Ramsar Convention Bureau, 1996) and karst (Kiernan, 1998) are also available.

Instream macrophytes provide a means of classifying streams and rivers in the United Kingdom (Holmes et al., 1999), but this approach has not been applied in, at least, temperate Australia (L. Metzling, Victorian EPA, pers.comm., 1999). Broad groupings of riparian vegetation communities usually focus on vegetation height, architecture or complexity and naturalness (Raven et al., 1998, Pen & Scott, 1995; Shepherd & Siemon, 1999). Statistical classifications of macrophyte or riparian communities have been applied in local settings. Macroinvertebrate communities are an important component of assessment of ecological value. AusRivAS adopts standard statistical classification and ordination techniques to describe in situ communities which may then be compared with communities in other rivers (Simpson et al., 1999). Since AusRivAS is based on family-level analysis it provides only a broad view of the community structure. An Index of Biotic Integrity using fish species has been devised for the rivers of NSW (Harris, 1995; Harris & Silveira, 1999). This

provides statistically based classifications of the biotic status of rivers and fish communities.

Some of these classifications have national application but, in other cases, work remains to be done at a regional level in order to provide the contextual information necessary for an assessment of the value. For example, while core work on river styles has been completed for parts of NSW, this does not necessarily provide an appropriate characterisation of rivers for Queensland, Western Australia or Tasmania. More detail of classifications and examples are provided in section 4, 'Application of the framework'.

3.5.3 A basis for comparison

The core of determining what constitutes 'high' value lies in making judgments from the evidence in comparison with some external standard or benchmark. The evaluation may be on the basis of comparison with:

- a desired or ideal condition
- an actual condition
- a benchmark
- similar sites
- the range of similar sites.

For each attribute, thresholds or standards need to be applied. Setting the thresholds and standards is central to determining ecological value within each particular policy or management context. As a general rule, the closer a river or its attributes comes to an ideal or actual condition, the higher the value (Criterion 1 naturalness, Criterion 2 representativeness). For rarity (Criterion 4), the higher values are attributed to taxa, features or communities that occur less frequently, either in number or range. The higher the number of features, communities or taxon units compared to similar sites, the higher the value for diversity, Criterion 3. It is important to note that streams with naturally low diversity may rate highly on naturalness and representativeness and are not necessarily rejected as high ecological value on the diversity criterion alone. Special features (Criterion 5) include the concept of 'uniqueness' and also broadscale landscape or process values with special significance in river systems. These features may be relatively rare, especially where they are in relatively natural condition. A fundamental consideration is to compare like with like (Boon, 1992), that is, to compare rivers or river sections in the same bioregion and of more or less the same size, order or types.

3.5.4 Approaches to setting standards

If a system of rivers is to be protected for conservation value at national or State level, then an extensive, high-level collaborative effort of developing a process and standards will be required. The State of Queensland has, for example, released a strategy for the protection of wetlands (Environment Protection Agency, 1999a). One objective of the strategy is to 'Ensure a comprehensive and adequate representation of wetlands in the conservation reserve system.' (Environment Protection Agency, 1999a, p8). It is noted in the document that Queensland has the most diverse array of wetlands in Australia, with all but one of the 40 Ramsar wetland categories (including saline as well as freshwater wetlands) occurring within the State. Thus a framework may be established for the application of criteria and standards to select which wetlands should be included in a reserve system.

Assessment of values and standards must be referenced to a specified context and scale. Each attribute should be assessed as objectively as possible, although the significance of any rating may be interpreted somewhat subjectively when weighed up with other attributes. For example, a river may score only moderately on a naturalness scale, but if that river is the only, or best preserved, river of a particular type, then it would still be considered of high value.

Descriptive categories of relative value are often converted into numerical form (range of 1 to 5) to permit graphical summaries or summation of scores. It must be remembered that such scores are purely arbitrary and not absolute values. The advantages and disadvantages of the index approach are discussed further in section 4. A less quantified approach is to convert the classes to ranks A to E and examine the frequency of each rank for all attributes. This strategy is used in SERCON (Boon et al., 1998). Conversion of scores to colour coded schemes may be used for visual representation (Western Australian Water Resources Council, 1997; Brierley, 1998). This avoids some of the caveats for numerical representations and creates an overall visual image of the condition or conservation priorities of a catchment.

The Queensland WREP approach suggests that standards may be set by assessing evidence of each value into categories (levels) and then assessing relative values by applying a weighting (Environment Protection Agency, 1999c). At the scale of the criteria (uniqueness, rarity and so on), the WREP approach translates from numerical values to a descriptive scale (very high to low)

Box 8: World Heritage criteria

For a property to be included on the World Heritage List as natural heritage, the World Heritage Committee must find that it meets one or more of the following criteria:

- i. be outstanding examples representing the major stages of the earth's evolutionary history;
- ii. be outstanding examples representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment; as distinct from the periods of the earth's development, this focuses upon ongoing processes in the development of communities of plants and animals, landforms and marine areas, and freshwater bodies or;
- iii. contain superlative natural phenomena, formations or features, for instance outstanding examples of the most important ecosystems, areas of exceptional beauty or exceptional combinations of natural and cultural elements; or
- iv. contain the most important and significant natural habitats where threatened species of animals or plants of outstanding universal value, from the point of view of science or conservation, still survive.

Source: World Heritage Unit, Canberra

which is then used in the decision-making process.

Table 5 is an extract, reproduced with permission, from the working guidelines (Environment Protection Agency, 1999c) being developed for conservation assessment for Queensland rivers.

The descriptive approach applied to river rehabilitation may also be used to define levels of significance. The technique, sometimes referred to as Goal Attainment Scaling or GAS, (Malavazos & Sharp, 1997) sets goals for particular elements of a rehabilitation project as the basis for evaluating progress. These authors translate the assessment category into a score on a five-point scale from -2 to +2. A profile of performance can be obtained by summing the scores from a number of assessments of similar sites with similar rehabilitation requirements on the same project.

For some criteria and attributes, external reference points provide the basis for determining value. Rarity is often referenced to standards such as listing on International Union for the Conservation of Nature or national or State lists of rare and threatened species. This apparent objectivity is biased towards certain taxonomic groups such as higher plants and vertebrates. Distribution of some aquatic taxa or groups is poorly known and taxonomy may be inadequate to support analysis.

3.5.5 An hierarchy of significance or ecological value

World Heritage and Ramsar listing offer criteria for international significance for places of natural value, including rivers (see boxes 8 and 5).

In addition, World Heritage listed places must meet requirements for integrity, sustainability (including an appropriate size to be self sustaining) and completeness (range of characteristic features) and be capable of protecting ecosystem requirements.

A recent discussion paper from the office of the Minister for the Environment, Senator Hill, indicates standards for 'national significance' under new Commonwealth environmental legislation. The draft criteria for national significance are shown in box 9.

Each of these sets of criteria and standards requires interpretation. National standards are a matter of ongoing debate (P. Matthews, Australian Heritage Commission, pers. comm., 1999). For example, if a river has highly endemic taxa, does this make it of outstanding value for Australia or only for a region? It may be argued that the commitment to the Biodiversity Convention supports a national perspective. Agreement on national significance based on ecological value might therefore be underpinned by the recognition of bioregional occurrences and representation. The term 'outstanding' in itself does not provide guidance as to what attributes are important, nor what standards or thresholds might be applied.

Table 5: Examples of scaling of indices, WREP for WIPDIP (Queensland)

Indicator measure	Scale	Rating (R)					Weighting (W)	Max. score (R x W)	
		1	2	3	4	5			
Uniqueness									
Geomorphology (eg. gorges, rock features, waterfalls, wetlands, substratum, longitudinal channel shape, channel cross-section)	c, s	Frequent examples			No other examples (unique)		4	20	
Biology (eg. riparian, floodplain and instream communities, level of endemism)	c, s	Frequent examples			No other examples		5	25	
Naturalness									
<i>Hydrology:</i>									
• median annual (percentage of median natural flow)	c, s	<50%			100%		1	5	
• annual interbasin transfers (percentage of median natural flow)	c	100%			Nil		1	5	
• floodplain inundation frequency (percentage of natural)	c, s	<60%			100%		1	5	
• bank full flow frequency (percentage of natural)	s	<60%			100%		1	5	
• depth of baseflow (variation from natural)	s	>50% (higher or lower)			Nil		1	5	
<i>Macroinvertebrates:</i>									
• composition of flow preference groups (variation from natural)	c, s	High			Low		5	25	
Condition									
<i>Macroinvertebrates, variation from reference condition for:</i>									
• expected/observed ratio	c, s	High			Low		1.7	8.5	
• signal expected/observed ratio	c, s	High			Low		1.7	8.5	
• composition of functional feeding groups	c, s	High			Low		1.7	8.5	
<i>Fish, variation from reference condition for:</i>									
• species richness	c, s	High			Low		1.3	6.5	
• composition of trophic status groups	s	High			Low		1.3	6.5	
• composition of movement categories	s	High			Low		1.3	6.5	
• age distribution	s	High			Low		1.3	6.5	
Rarity									
Taxa, ecosystems or habitats identified as endangered, of concern or other conservation significance, but not listed under legislation.	c, s	None		Of concern		Endangered		5	25

c = catchment scale; s = subcatchment or project scale

Box 9: Criteria and thresholds for national heritage significance

Places of national heritage significance are outstanding examples of places of aesthetic, historic, scientific or social significance or other special value at a national level.

These places will meet one or more of the following criteria:

- of outstanding importance to the course, or pattern of our national natural or cultural history;
- possession of uncommon, rare or endangered aspects of our natural or cultural history of outstanding national values;
- potential to yield information that will make an outstanding contribution to an understanding of our national natural or cultural history;
- of outstanding importance in demonstrating the principal characteristics of a class of natural or cultural places or environments valued by the nation;
- of outstanding importance in exhibiting particular aesthetic characteristics valued by the nation;
- of outstanding importance in demonstrating a high degree of creative or technical achievement at a particular period;
- of outstanding importance for social, cultural or spiritual reasons in the context of national natural or cultural history;
- having a special association with the life or works of a person, or group of person, of outstanding importance in our national natural or cultural history; and
- places that are listed on the World Heritage List will be automatically regarded as being of national heritage significance.

Source: Hill (1999)

International significance is also addressed in the World Conservation Monitoring Centre report (1998), shown in table 6.

Based on these criteria in an international context, Australian rivers of international significance would include:

- ecosystems or features that are uncommon on a world scale, with high integrity;
- sites providing habitat for high diversity of species which are limited in distribution (highly endemic) and particularly those species of biogeographic significance;
- representative examples of large-scale ecosystems which are severely threatened on a world scale;
- places or systems which demonstrate aspects of world history or biogeography; and
- places which provide habitat for large numbers and high diversity of migratory species.

The draft criteria for national significance (Hill, 1999, box 9) also cover issues of naturalness, representativeness, uniqueness and diversity. The

standard used is 'outstanding' although this is not defined. If representativeness is assumed to be important in the context of protected area design, as is the case for forests (JANIS, 1996) and marine reserves (Gubbay, 1995; ANZECC, 1998; GBRMPA, 1999), then representativeness should also be a fundamental element of protected area design for rivers.

Based on the draft criteria and criteria for marine reserves and forests, rivers of national significance would include:

- representative examples of river types by bioregion, selecting those in best condition;
- rivers which are particularly significant for large numbers and high diversity of species with habitat requirements or needs which differ by season;
- river types or styles which are unusual in the Australian context;
- rivers which provide habitat for a high percentage of endemic species;
- rivers which provide habitat for species with Gondwanic affinities or of taxonomic significance;

Table 6: Some important world biodiversity values of Australian rivers

Area	Taxa of significance	Values
SE Australia	Crayfish	Large area of high species richness and endemism, centred on Victoria, 35 spp, and Tasmania, 19 spp
SW Australia	Fairy shrimp	19 spp, 12 endemic
Kimberley district, WA	Fish	47 spp, 14 endemic
SE Australia	Fish	42 spp, 11 endemic in coastal area
SW Western Australia	Fish	14 spp, 9 endemic
Tasmania	Fish	24 spp, 12 endemic (greater number per area than rest of Australia)
Great Artesian Basin	Molluscs	Spring and underground aquifers important area for gastropod diversity
Western Tasmania	Molluscs	Spring and underground aquifers important area for gastropod diversity, high endemism

Source: World Conservation Monitoring Centre (1998)

- rivers which provide habitat for species demonstrating biogeographic patterns for Australia;
- rivers which demonstrate hydrological and geomorphological processes important in Australia's landscape history and development;
- rivers which are in largely undisturbed condition;
- rivers with a high diversity of habitats, communities or species; and
- rivers which are important for sustaining significant floodplain habitats and diversity or significant estuaries or karst systems.

Rivers, river sections or wetlands may be of high ecological value at a State or local scale. A similar set of levels of significance and decision rules may be established for assessment of these scales.

Determining 'high value' is, to a degree, a political process involving dialogue among stakeholders since some elements of the process are subjective. Establishing standards does, however, need to have a sound ecological basis. Section 4.3.2 outlines some guidelines for assessment within such a process.

3.6 Identification, selection or nomination of high ecological value rivers

3.6.1 Decision rules

Decision rules are inherent in any approach to identification. In some cases these decision rules may be implicit in the attributes or the standards to be applied. Explicit rules are necessary where attributes are complex or where there are no agreed external points of reference. Rules or guidelines for applications include such things as agreement on:

- scale of assessment – reach, length of river in kilometres, catchment
- scope – which attributes are cost-effective, appropriate, useful or should be excluded
- choice of classification base – river classification scheme, biotic classifications
- thresholds – extent, significance, minimum standards
- rating or weighting systems – numeric, classification, multipliers
- rules for combining information – where attributes are correlated, summation of criteria.

Decision rules are widely applied in Regional Forest Agreements. Rules might apply to the minimum area considered acceptable for a self-sustaining forest reserve, to the scale of analysis, to thresholds for indicative values or for trade-offs between competing values. Such rules may have a superficial appeal as a rational approach to determining what is important, but may not necessarily be based upon sound understanding of the underlying ecosystem processes. The advantages of decision rules are that they should be agreed *a priori* by the various parties involved and therefore are perceived to be objective, and that they clearly lay down the scope of data collection.

On the other hand, parties may disagree at the outset that the decision rules are reasonable and appropriate to ecosystem functioning.

Providing appropriate decision rules for evaluating and protecting river systems may be more difficult because of the complexity of ecosystem functioning. Nevertheless, decision rules are fundamental to any process of identification of values.

An example of the articulation and application of decision rules is provided by the Queensland WREP for WIPDIP (Environment Protection Agency, 1999c). Criteria are laid out but not prescribed for every

assessment. Setting weightings is also left to the discretion of the assessor in conjunction with those managing the conservation assessment process. Basic decision rules are set for minimum levels or classifications on the criteria and combining the assessments with those of other criteria, as shown in box 10.

3.6.2 Alternative approaches

The process of identification or nomination of rivers of high value is dependent upon the purpose of the assessment, the consequences for river management and the political and legislative context.

Depending on these parameters, choices are available as to how the notion of high value is translated into a protocol for identification. These fall into four categories: a classification system, reserve design, development of indices and an ecological value profile. The choice of approach to identification will depend on purpose, management context and institutional culture, and management issues to be addressed.

Each of the approaches has a place in a strategy for identifying and protecting rivers of high ecological value. The approaches will be complementary.

Box 10: Draft decision rules (optional) for Queensland WREP for WIPDIP

Decision Rule #1: The following three criteria will govern the minimum conservation value for a waterway unit. For example, if any of the following criteria is rated very high, then the waterway has a very high conservation value:

- uniqueness
- support for rare or threatened species/taxa/communities/habitats
- indigenous or historic cultural heritage.

Similarly, if any of these three is rated high, then the waterway conservation value is high; and if any of these three is rated medium, then the waterway conservation value is medium.

Decision Rule #2: For the remaining criteria, if at least two of the following criteria are very high, then the waterway has a very high conservation value:

- condition
- naturalness
- biodiversity
- archaeological significance.

Similarly, if any two of these are rated high, then the waterway conservation value is high; and if any of two of these is rated medium, then the waterway conservation value is medium.

Source: Environment Protection Agency (1999b)

Consistency will be achieved by use of the common agreed criteria and attributes shown in table 8. Four approaches are explored:

- reserve design
- classification
- indices
- ecological value profile.

3.6.3 Reserve design

It is widely agreed that in order to achieve biodiversity protection, a systematic approach to reserve design is required. The principles of reserve design have been proposed for marine reserves (Gubbay, 1995; ANZECC, 1998; , GBRMPA, 1999), forests (JANIS, 1996) and biodiversity (Environment Australia, 1997a). The principles for reserve design have been applied for conservation of forest communities and species (JANIS, 1996; various Regional Forest Agreements). Implementation of Australia's responsibilities under the Biodiversity Convention is to be supported by a comprehensive, adequate and representative National Reserves System for terrestrial ecosystems (Environment Australia, 1998a).

Principles for reserve design begin with the recognition of the importance of assessment in the regional context. This ensures that the protected areas encompass a wide range of communities, species and genetic biodiversity. Representativeness is, therefore, the first principle of a reserve system. The JANIS criteria (JANIS, 1996) add the notions of comprehensiveness and adequacy. Reserves need to provide for comprehensive protection of all species and communities (and geoh heritage values). If the natural ecosystem processes are to be maintained, the individual reserves and the entire reserves system must together be of adequate size. All required environmental components of the ecosystem must also be present on a sustainable basis.

Reserve design requires knowledge and understanding of the suite of ecosystems to be protected and the ecological values associated with them in order for a comprehensive, adequate and representative system to be implemented. The Government's strategy on biodiversity (Environment Australia, 1997a) commits to the establishment and management of a comprehensive, adequate and representative system of protected areas covering Australia's biological diversity (Environment

Australia, 1997a, section 1.4, objective 1.4). The strategy acknowledges that there are 'many gaps, including ecosystems in arid and semi-arid environments, and native grassland, wetland and marine ecosystems' (section 1.4).

There is evidence from a preliminary study in Victoria (Marchant et al., 1999) that there are difficulties in applying to lotic communities a priori regionalisation based on terrestrial features of the landscape. This suggests that if a bioregional approach is to be pursued at a national level, consideration should be given to the need to develop more appropriate bioregional divisions for application to lotic environments. Nevertheless the present bioregional classification (Thackway & Cresswell, 1995) has some value as a starting point.

3.6.4 Classification system

The United States Wild and Scenic Rivers is an example of a classificatory system for nominating the value of a river (see box 3). Descriptive classifications are first established with agreed benchmarks for various key criteria. If a river (or river section) can be demonstrated to reach these benchmarks, then it may be classed as 'wild', 'scenic' or 'recreational'. (Note that other procedures would be included before such a river was to be listed under the Wild and Scenic Rivers Act.)

An Australian example of a classificatory approach, albeit for a somewhat different purpose, is the NSW Stressed Rivers approach. Here rivers are classed on two key dimensions (hydrological stress and conservation value) and the resulting matrix interpreted to identify the broad management category for each river type. However, while providing an initial assessment of the status of a river, such a classification has proved too coarse to resolve management priorities or specific needs (M. Conlon, NSW DLWC, pers.comm., 1999).

A classification system could be appropriate to identify and protect rivers of high ecological value (and of more general conservation value) in Australia, provided such a classification system had appropriate benchmarks and was embedded in appropriate legislation.

Identification might for example be undertaken with the purpose of listing in the Register of the National Estate. This process identifies the significant values but legislation applies only for federal agencies and therefore this has limited power of protection.

3.6.5 Indices

A numeric index of ecological value has appeal as a simple means to convey an order of importance or significance. SERCON provides indices for each of the six criteria for conservation value (box 1). These are derived from scores and weighting of the component attributes for each criterion. While a numeric index appears to offer an objective basis for judgment, there is danger in this approach. Boon (1998) sees the misinterpretation of the numeric index as a drawback for the system. He perceives that 'there is a danger that SERCON may be seen (and used) as a generator of "magic numbers" with the data that underlie the final output scores and indices obscured' (1998, p611). This is exacerbated by the use of the computer version of SERCON which results in an index which appears with the 'mystique' of computer-generated data. The SERCON team rejected the reduction of the six indices to a single overall conservation score, unlike the system proposed for South Africa (O'Keeffe et al., 1987), which was one of the earliest attempts at a systematic conservation assessment process.

The progressive amalgamation of data into an index loses useful information and leads to incorrect interpretations. Rivers which have a similar score on a criterion do not necessarily have similar attributes or management requirements. Boon argues that the index data must be further interrogated at the level of individual attributes and raw data in making the conservation assessment (Boon et al., 1998).

From an arithmetical perspective, the summing of arbitrary numbers ascribed to a value in the form of an index is also invalid. Although SERCON uses a weighting procedure, this in itself is a subjective assessment of importance. Further, some attributes may be auto-correlated, that is, scoring on one attribute is drawing on fundamentals shared with another attribute. Thus, species and community diversity is correlated with diversity of substrate class.

The Victorian Index of Stream Condition (Department of Natural Resources and Environment, 1997) adopts the use of indices as a means of summarising the health of a river. Since much of the index is based on numerical data, it seems logical to reduce this to a smaller number of categories. However, the real values are not absolute values and ranges do not necessarily have an ecological foundation. In this case the index is used as a means of summarising stream condition across the State under relatively similar types of environmental conditions. It is also used as a

benchmark against which changes in the health of each river can be measured.

The Queensland WREP for WIPDIP (Environment Protection Agency, 1999b, 1999c) suggests use of indices arrived at by rating on a scale of one to five, applying a multiplier for weighting the item and summing the resulting scores under each criterion to provide an overall measure.

The Wild Rivers Project generated output data in the form of indices which enabled maps to be produced showing the relative distributions of disturbance of river systems. A numerical system is necessary in order to display data in this way. Alternative approaches such as colour coding have been used for geomorphic status (Brierley, 1998) and river condition (Western Australian Water Resources Commission, 1992; Water and Rivers Commission, 1997). This avoids some of the caveats about numerical indices and provides an overview in a visual manner which can be easily understood by non-experts.

3.6.6 Ecological value profile

The list of criteria and attributes lends itself to the development of an ecological value profile for a given river. This information may then be used to provide evidence for identification of significance against pre-established criteria, as in the Register of the National Estate (box 2). Provided that the minimum requirements of listing are met, the river would be accepted as being of high ecological value. Such an approach could be applied where it is important to identify all rivers of high value. The profile approach could also be used to determine whether a specific river was of high value, identifying the particular attributes and setting directions for protection and management.

An ecological value profile may be used for different purposes, depending on the issue to be addressed. If a suite of rivers representative of the region was to be nominated, then the starting point would be the representativeness criterion. All rivers considered representative for that class of rivers and in that bioregion could be further analysed with a view to assessing other ecological values, competing values, threats and risks in an overall identification process to ensure aquatic biodiversity protection in that region. Since the ecological value profile criteria and attributes are consistent with other conservation criteria such as Ramsar and the Environment Protection Act 1999, it can be used for other assessment purposes.

3.7 Evaluating existing approaches to river assessment

Existing approaches to the assessment of rivers may now be evaluated in comparison with the requirements of the conceptual framework outlined above. They are not necessarily designed to assess ecological values, although may sometimes be perceived as such and equally may provide information which can be used within an assessment of ecological value.

3.7.1 Purpose and context

Each of the strategies discussed under sections 2.2 and 2.3 is undertaken within a specific policy, legislative or management context and for a specific purpose. None of the Australian initiatives is designed to assess ecological value and only SERCON (United Kingdom) is designed specifically for this purpose. The United States Wild and Scenic Rivers program contains elements of ecological value, as does the Australian wild rivers assessment process. The former, however, is directly linked into legislation which can provide appropriate protection.

3.7.2 Scope and attributes

None of the examples encompasses all attributes survey respondents considered important in identifying high ecological value, although the conservation assessment strand of Queensland's WREP for WIPDIP (Environment Protection Agency, 1999c) plans to cover most of these strands. The key criteria of SERCON match those of the framework, but only at a general level and elements considered important in the Australian context are not included.

The Wild Rivers Project has provided a national perspective on naturalness of rivers as determined by the selected criteria. This will contribute valuable, standardised datasets which can be incorporated into an assessment of ecological value of rivers, but does not replace the need for a wider assessment. Because most of the rivers assessed wild are in more remote areas, they are not considered by some to have high priority for management intervention. The wild rivers assessment does not capture rivers which are of high ecological value even though they are subject to some level of disturbance, nor does it address the criterion of representativeness.

3.7.3 Classifications

All the assessment protocols use classifications as the basis for comparison. These may be descriptive classifications (United States Wild and Scenic Rivers, NSW Stressed Rivers, River Habitat Survey), classifications derived from statistical analysis such as RIVPACS, AusRivAS, classifications based on decision rules (Wild Rivers, State of the Rivers WA), or classifications generated by numerical indices (Index of Stream Condition).

An assessment of ecological value will need to draw on a range of classifications to enable comparison to be made on each attribute.

3.7.4 Evaluation

The basis for comparison for assessment of river health or condition (AusRivAS, RIVPACS, Index of Stream Condition) is distance from a reference condition or agreed standard. One of the difficulties of environmental flow assessment is the poor understanding of the reference condition and ecosystem requirements for many rivers. SERCON uses external reference points, such as listing on schedules of rare and threatened species, as standards where possible. Similar approaches to setting standards and bases for comparison will be required for assessment of ecological value in Australia. This distinguishes assessment of many attributes of ecological value from assessment of river health.

3.7.5 Identification

The approaches considered adopt different strategies for identification of rivers which are targeted by the assessment purposes. Classification is used for United States Wild and Scenic Rivers, Stressed Rivers, State of the Rivers WA, while the Index of Stream Condition is the only approach which relies solely on an index. A combination of indices and profiles results from SERCON.

Assessment of river health (AusRivAS and RIVPACS) provide decision support information which can be incorporated into both broad management policies and into catchment management at a stream level. Several approaches may best be considered a river profile (environmental flows, River Habitat Survey, WREP for WIPDIP). The River Habitat Survey has also served other purposes including environmental impact assessment, monitoring, national and regional reporting

and prediction of species distribution based on habitat requirements, with other types of use in planning stages (Raven et al., 1998).

It will be recommended that, in Australia, all approaches to the identification stage of an assessment, as outlined in section 3.5, have a place in identifying rivers of high ecological value. Selection of an approach will depend on the purpose and context in which it is to be undertaken.

4 Applying the framework

4.1 Establishing a process

Assessment of the ecological value of rivers must take place within some kind of process. This may be within an existing process, such as catchment management planning, or a particular one-off process such as determination of priorities for intervention by river managers. It is possible, and in fact will be recommended, that a suite of rivers might be identified as having ecological value and be set aside for conservation.

The process should address questions of who should be involved (stakeholder analysis), resources available, including taxonomic or other technical expertise, time frame, scale and how other interest, values or use may be addressed. The process should also establish at the outset the basis and standards to be used for evaluation (making comparisons and judgments) and the way in which selections or choices, if necessary, will be made. Clear criteria for establishing priorities will also need to be defined from the outset.

The decisions about the process must be made before data collection commences; otherwise time will be wasted on data collection for which no comparative basis is available or for which the necessary expertise for interpretation is not available. In addition, legitimate values and interests may be overlooked and the strategy for selection may be seen as inappropriate by some parties.

In Queensland, the Department of Natural Environment is developing an approach to the evaluation of conservation values (WREP) to be integrated within a process of river assessment (WIPDIP). In NSW, the outcomes of the Stressed Rivers program has identified rivers broadly into categories of conservation value, but a more detailed assessment of ecological value is required in order to target and focus management efforts. Assessment of ecological value for individual rivers or river systems may be taken up by catchment management authorities or by groups lobbying for conservation of the river (Kingsford, 1999).

At a national level, identification of wild rivers has been undertaken (Stein et al., n.d.). States have been going through a process of agreement on which rivers might be recognised as wild rivers, but without a clear

commitment to protection since the original purpose was limited to identification and not to action.

The data from other assessments, for example river health, may be used in a wider process of assessment of ecological value if other elements of the model are addressed. For example, the bases for comparison or standards are likely to be different, additional data may be required, and identification or selection must be defined.

4.2 Data collection

4.2.1 Issues

The geographic scale on which data is to be collected should be determined by the purpose of assessment. A fundamental issue is the need to compare like with like. This requires that the scale of the assessment be the same as the scale of any classification used – catchment, river section, reach – and the same as other systems which are to be compared. Similarly, information about biotic communities can only be compared with information from similar habitat types and on similar habitat scales.

Extrapolation of data from point sources, for example sample sites for macroinvertebrates, must be done with care but may reasonably be assumed to represent the reach as a whole. Some attributes, for example quality of the riparian vegetation, require continuous survey of an entire reach.

Resources invested in data collection are always likely to be limited or more data would be desirable. Therefore, the choice of the method of data collection should be guided by the importance of those attributes in the particular setting and level of accuracy required for a valid judgment to be made. The first criterion for information collection is to collect that information which will be most useful. It must also be as accurate as possible.

Some attributes are complex and not directly measurable or may require complex and expensive methods for direct assessment. In this case, surrogates or indicators may be used, but these need to be based on a sound understanding of the system they are being used to measure and established as valid measures. For

example, evidence of healthy and natural instream food webs may be provided by analysis of the biotic communities. Hydrology or chemical composition may be reflected in the presence of certain species tolerant of particular conditions or by patterns in life histories such as initiation of a reproductive phase.

Where existing data are available they may be appropriately used for interpretation of ecological value. Data from the AusRivAS collections in each State may be used to characterise macroinvertebrate communities or species distributions. Evaluation of the significance of this information is then made against the criteria and standards established for the particular process of identification of ecological value.

Information should be collected with the greatest possible accuracy and consistency. However, the contribution of local knowledge and informal groups should not be discounted.

4.2.2 Possible data sources

Data collection for assessment of the ecological value of rivers may be seen as a major task. However, existing data collected for other purposes, remote techniques, and local knowledge may all contribute useful information.

Tables 7, 8, 9, 10 and 11 illustrate some possible sources of information.

The listing of possible sources of data is only indicative. Information will vary greatly between rivers. Some datasets will only provide point data, such as AusRivAS samples. Some data collection approaches have only been validated for limited regions or river types. Some remote datasets such as airborne video, remote sensing and air photos may require ground-truthing. Datasets will vary in scale and resolution and may be unsuitable for assessment purposes at the required scale. In other instances, the resolution may be inappropriate taxonomically. If necessary and feasible, source material for assessments such as AusRivAS may be available for further taxonomic resolution, as has been done in Victoria (L. Metzling, Victorian EPA, pers. comm., 1999). Community data collections such as Waterwatch programs may provide some basic information to target further investigation, or provide a context for assessment.

The list of possible sources illustrates the range of information which may be available to contribute to assessment of ecological value. In addition to the general or local community, community data could include information from many kinds of interest groups and

groups such as Waterwatch actively involved in the study of the river. Interest groups includes various natural history groups, groups with interests in native plants and rehabilitation, recreational fishing clubs, historical societies and so on. Some data collection methods may serve several purposes. Air photos can provide information on present (and sometimes past) general form and behaviour of the river, assessment of the riparian zone, catchment use and extent of clearing and so on.

4.3 Evaluation

4.3.1 Contexts or bases for evaluation

The basis for evaluation will depend on the particular attribute. Information is required about features or species distributions or rarity, or predictive models of a natural or reference condition. Descriptions or classifications for similar rivers, in similar bioregions, form the basis of comparison of other attributes. Some classifications or typologies relevant to assessment of rivers or streams in Australia are summarised in table 12.

Some of the methodologies for assessment of river health or condition are appropriate to assessment of ecological value. The biota provide an integrated response to environmental conditions and therefore may be used as surrogates to demonstrate the underlying ecological processes (Norris & Norris, 1995). A range of biota may be used including algae (Whitton & Kelly, 1995), macroinvertebrates (Wright, 1995; Marchant et al., 1997) and fish (Harris, 1995; Harris & Silveira, 1999).

Description and classification of rivers may in itself provide such contextual information for the first time. The Queensland Environmental Protection Agency WREP for WIPDIP assessment will develop an overall picture of subcatchment sections, or Biological Aquatic Systems for Queensland. The Stressed Rivers program in NSW provides a general picture of the status and values for rivers in that State.

A national scheme for the characterisation of rivers according to hydrology and geomorphology is urgently needed to further the understanding and assessment of the conservation status of Australia's rivers. An hierarchical approach may be appropriate in order to accommodate interpretation at different scales (Frissel et al., 1986; Naiman et al., 1992). Young (1999) and Puckridge et al. (1998) provide examples of local or

Table 7: Possible sources and methods of information collection, criterion 1 – naturalness

Attribute	Indicator/evidence	Information sources
1.1 Undisturbed catchment	Wild Rivers Index	Australian Heritage Commission Wild Rivers database, geographic information system, land use, vegetation mapping, land tenure
1.2 Unregulated flow	Wild Rivers Index, absence of dams	Environment Protection Agency gauging data, water authorities, environment and heritage agencies, hydroelectricity authorities
1.3 Unmodified flow	Degree and timing of abstraction, diversion, permits	Water authorities, environmental flows assessment
1.4 Unmodified river/channel	Absence of modification, training, snag removal	River habitat survey, air photos, water authorities
1.5 Natural water chemistry	Comparison with expected water chemistry	AusRivAS, Environment Protection Agency, councils, Waterwatch, Ribbons of Blue, water authority
1.6 Absence of interbasin water transfer	Presence of diversions between catchments	Water authority
1.7 Intact and interconnected river elements	Natural associations between river and its floodplain elements	Index of Stream Condition, river habitat survey, air photos, vegetation mapping
1.8 Natural temperature regimes	Intactness of native vegetation cover, absence of regulation (dams etc.), absence of discharge	River habitat surveys, AusRivAS, Environment Protection Agency, water authority, hydroelectricity board
1.9 Natural processing of organic matter	Oxygen concentration, macroinvertebrate communities and functional feeding groups	AusRivAS
1.10 Natural nutrient cycling processes	Nutrient fluxes, NPC loads and processes, phytoplankton loads, algal communities,	AusRivAS, monitoring of occurrence of algal blooms
1.11 Intact native riparian vegetation	Extent to which riparian vegetation represents natural vegetation and its continuity	River habitat surveys, AusRivAS, Environment Department data, airborne video, vegetation mapping
1.12 Absence of exotic flora or fauna	Percentage of taxa, individuals, area or mass comprised of non-native instream or riparian species	Index of Stream Condition, river habitat survey, Index of Biotic Condition, museum/parks and wildlife service records
1.13 Habitat corridor	Evidence of use as a corridor by terrestrial species, fish migration	Parks and wildlife service records, museum records, community data, water authority
1.14 Natural instream faunal community composition	Consistency with expected communities, AusRivAS score	AusRivAS, Frogwatch, Index of Biotic Condition (fish)
1.15 Natural ecological processes, energy base and flows	Macrophyte and macroinvertebrate communities, algal communities	AusRivAS, river habitat survey

Table 8: Possible sources and methods of information collection, criterion 2 – representativeness

Attribute	Indicator/evidence	Information sources
2.1 Representative river system or section	River system or section typical of bioregion	Remote sensing, airborne video, river styles assessment, river habitat survey
2.2 Representative river features	River features typical of river type or style	River styles assessment, river habitat survey
2.3 Representative hydrological processes	Fluvial and hydrological characteristics typical of that class of river processes	Long-term, continuous and consistent datasets only available for certain river types
2.4 Representative aquatic macroinvertebrate communities	Biota typical of macroinvertebrate communities for the river type and region	AusRivAS, surveys
2.5 Representative instream or riparian flora or communities	Instream or riparian macrophyte communities typical of biota for the river type and region	AusRivAS, surveys
2.6 Representative instream fish communities	Fish communities typical of the river type and region	Biotic Index (fish, NSW)

Table 9: Possible sources and methods of information collection, criterion 3 – diversity

Attribute	Indicator/evidence	Information sources
3.1 Diversity of rock types or geomorphological substrate size classes	Several rock types and/or size classes represented within section	Geological maps, AusRivAS, survey, river habitat survey, river styles
3.2 Diversity of instream habitats, eg. pools, riffles, meanders, rapids	Wide range of habitats	AusRivAS, river habitat surveys
3.3 Diversity of channel, floodplain wetland morphologies	Wide range in type or style of channel or floodplain	Remote sensing, air photos, airborne videos, maps, survey
3.4 Diversity of native flora or fauna	High diversity of native species compared with similar habitats or river sections	AusRivAS, survey, databases and records
3.5 Diversity of instream or riparian communities	High diversity of instream communities compared with similar habitats or river sections	Databases, records of museums, interest groups, survey
3.6 Diversity of wetland or floodplain communities	Diversity of types of habitats	Wetlands Directory, survey, aerial survey, community and historical data
3.7 Diversity of endemic flora or fauna	High diversity of endemic taxa compared with similar habitats or river sections	Databases, records of museums, interest groups, survey
3.8 Important bird habitat	High diversity or richness of taxa, or different ecosystem associations	Databases, records of museums, interest groups, survey

Table 10: Possible sources and methods of information collection, criterion 4 – rarity

Attribute	Indicator/evidence	Information sources
4.1 Rare or threatened geomorphological features	Features known to be uncommon or vulnerable	River habitat surveys, river styles survey, geoheritage inventories
4.2 Rare or threatened	Processes known to be uncommon ecological processes	Survey, community and historical information
4.3 Rare or threatened geomorphological processes	Processes known to be uncommon	Survey, research, community and historical information
4.4 Rare or threatened hydrological regimes	Regimes which are uncommon or threatened by infrastructure development or use	Water authorities records, community and historical information
4.5 Rare or threatened invertebrate fauna	Species on rare and threatened lists or known to be uncommon or threatened	Secondary analysis AusRivAS collections, survey, community, museum records, parks and wildlife service inventories, research
4.6 Rare or threatened fish or other vertebrates	Species on rare and threatened lists or known to be uncommon or threatened	Survey, community, museum records, parks and wildlife service inventories, research, angling clubs
4.7 Rare or threatened habitats	Habitats known to be uncommon or threatened	Wetlands Directory, parks and wildlife service databases, community, research
4.8 Rare or threatened flora	Species on rare and threatened lists or known to be uncommon or threatened	Survey, parks and wildlife service databases, community research
4.9 Rare or threatened communities or ecosystems	Communities or ecosystems known to be uncommon or threatened	Wetlands Directory, parks and wildlife service databases, community and historic records, State condition mapping
4.10 Unusual natural water chemistry	Water chemistry characteristics outside normally expected range for fresh water	Survey, community records, Waterwatch data, research

regional characterisations. These integrate hydrological and geomorphological information and demonstrate the crucial linkage with ecological processes of rivers.

4.3.2 Thresholds, benchmarks or standards

The setting of thresholds or standards should be a collaborative process, based on sound ecological knowledge. Assessment of river values and management of catchments are moving towards more collaborative approaches involving the local community, river scientists and managers, and recreational and economic interests (NSW Department of Land and Water Conservation 1999; Environment Protection Agency, 1999a, 1999b). It is, therefore, critical that ecological values are clearly articulated and justified with all parties.

Comparison with relevant data classifications applied at the same scale will permit interpretation of the relative value of occurrence (rarity, diversity) of features, communities, species and assemblages. Thus a river might be considered of high value if it provides habitat for the full range of fish assemblages predicted for the region and river type and of moderate value if more than three-quarters of fish assemblages are found there. The presence of species with limited distributions or endemic to an area is also rated more highly than a similar number of species which are widespread (World Conservation Monitoring Centre, 1998). Diversity is rated more highly if there are more representatives from higher taxonomic levels (ie. groups higher than species level, such as genera, families or classes) (World

Table 11: Possible sources and methods of information collection, criterion 5 – other special features

Attribute	Indicator/evidence	Information sources
5.1 Karst, including surface features	Presence of significant, extensive or unusual karst features	Geological survey, geoheritage survey, karst mapping, community data
5.2 Significant ephemeral floodplain wetlands	Ephemeral wetlands which sustain river ecology, provide habitat for distinctive fauna or flora	Wetlands Directory, survey, community data, parks and wildlifeservice and museum records
5.3 Dryland rivers with no opening to the ocean	Rivers with drainage into dryland areas, mostly not connecting to ocean under natural flow regimes	Mapping, survey, community and historical information, hydrological data
5.4 Important for the maintenance of downstream or adjacent habitats	Rivers, not necessarily otherwise of high ecological value, the waters of which sustain high-value estuaries, floodplain wetlands or other dependent habitats	Mapping parks and wildlife service and museum records, community data
5.5 Importance for the maintenance of karst system or features	Rivers, not necessarily otherwise of ecological value, the waters of which sustain karst features and habitats	Geological mapping, survey, community data
5.6 Important for migratory species or dispersal of terrestrial species	River corridor provides routes for migratory birds or terrestrial species	Survey, species mapping, community data, museum and parks and wildlife service records
5.7 Drought refuge for terrestrial or migratory species	River corridor provides critical habitat during drought periods	Survey, species mapping, community data, museum and parks and wildlife service records
5.8 Habitat for important indicator or keystone taxa	Presence of indicator or keystone taxa which can be used for monitoring and research	AusRivAS collections, survey, community data, museum and parks and wildlife service records
5.9 Habitat for flagship taxa	Presence of taxa held as icons by the public	Surveys, community data, parks and wildlife service and museum records
5.10 Refuge for native species and communities in largely altered landscapes	Communities, ecosystems and species restricted to river habitats	Surveys, air photos, historic records

Conservation Monitoring Centre, 1998). The occurrence of species which are of biogeographic interest are also rated more highly (World Conservation Monitoring Centre, 1998; JANIS, 1996). This includes species belonging to ancient groups, taxa with Gondwanic affinities or at the limit of distributional range. Such species are of particular interest in Australia.

Geomorphic classifications and standards for geoheritage conservation are not widely used, understood or developed. Sharples (1995) suggests that

comparison at the same scale is central to interpretation of values. For example, a feature may be highly significant if it represents or demonstrates geological processes operating at a world scale. Geomorphological features or processes which demonstrate aspects of Australia's history are also highly significant elements which require recognition and protection. Geoheritage conservation is poorly addressed even in the most current Commonwealth legislation (Commonwealth of Australia, 1999).

Table 12: Examples of classifications which may be used for Australian rivers and riverine ecosystems

River feature	Source	Scope
River type or characterisation	Western Australian Water Resources Council (1992) Water and Rivers Commission (1997)	Broad class of rivers in landscape context. Eg. between 4 and 11 types for each drainage division of WA.
River styles	Brierley (1996, 1999)	Means of characterising catchments and river sections, developed for NSW; needs further development elsewhere.
Geomorphic characteristics	Frissell et al., (1986)	Hierarchical approach to describing valley forms.
Stream order	Strahler (1957)	Classification of stream by catchment area.
Hydrology	Naiman et al. (1992)	Require hydrogeomorphic characterisation of Australian rivers.
Habitat types	Harper et al. (1995)	Typology of functional instream habitats. Selected habitats used in AusRivAS sampling protocol.
Substrate types	Harper et al. (1995)	Size of substrate units.
Instream functional habitats	Harper et al. (1995)	Instream flora, including algae and non-vascular plants.
Riparian habitats	Harper et al. (1995)	Based on vegetation structure and geomorphic structures.
Riparian vegetation communities	Raven et al. (1998) Pen & Scott (1995)	River habitat survey and manual developed for United Kingdom uses broad riparian architecture categories. Foreshore assessment of condition. No Australia-wide classifications.
Macroinvertebrate communities	Simpson et al. (1999)	AusRivAS provides information on expected communities for region and river type.
Wetlands	Ramsar Convention Bureau (1996) Environment Australia (1997b) Kingsford & Porter (1999)	Essentially very similar classifications of freshwater wetlands into 19 or 20 types. Defines seven types of wetlands for the Paroo River based on hydrology.

Rarity is often measured by the listing under relevant rare and threatened species legislation (Boon et al., 1998; Australian Heritage Commission, 1974). The more restricted the range, the higher the value. Rarity amongst aquatic groups varies considerably according to dispersal mechanisms and, in the case of insects, adult requirements (World Conservation Monitoring Centre, 1998). For many aquatic species, taxonomic and

distributional data are quite insufficient to have appropriate standards on which to base assessment of rarity.

Many of the criteria provided for SERCON (box 1) and some of those for WREP for WIPDIP (table 2) require setting of arbitrary decision rules for assessment of individual attributes, as well as for an overall

conservation assessment (Boon et al., 1997; Environment Protection Agency, 1999c).

Drawing on these trends in conservation assessment, in general, rivers are of higher value in relation to others assessed at the same scale if they:

- have greater diversity of features, communities or species
- are closer to typical rivers for that region
- are less disturbed
- have features of ecological significance not possessed by other rivers
- have more rare features, species or communities
- have higher species richness
- have a greater proportion or number of endemic species
- have a greater proportion or number of endemic species with narrow distributions
- have a greater proportion or number of species of biogeographic significance
- have a greater proportion or number of species of taxonomic significance
- have a greater proportion of the diversity attributable to representatives of more higher taxa (genera, families, classes)
- have representatives of more phylogenetically 'primitive' taxa such as lungfishes, Anaspides
- are an essential link between other habitats
- sustain important systems beyond the river banks.

These assessments may then be presented as:

- straight descriptions
- descriptive categories
- numerical categories based on a priori groupings and standards
- colour-coded categories based on numerical categories
- colour-coded or numerical categories based on combinations or algorithms
- locus in predetermined classification.

4.3.3 Using the results

The initial purpose of the assessment should determine how information is used. If the assessment is not applied to management, it remains a purely academic exercise. The wild rivers assessment for example was seen as a process of identification and development of a methodology (Stein et al., n.d.). Others have taken up the information (Pen & Scott, 1995) and suggested some implementation, but this lies in the hands of river management authorities. The methodology has been applied in an international context (World Conservation Monitoring Centre, 1998). However, there are views that the focus on wild rivers has deflected interest in other rivers which have may have human impact but also have important ecological values (survey respondents, see appendix).

Data from assessments for other purposes such as wild rivers assessment or assessment of health or condition may be used within the assessment of ecological value. These data need to be reviewed and reassessed, however, according to the criteria for ecological value and applying relevant standards.

Actions based on the assessment of ecological value may include:

- nominating rivers for protection;
- identifying rivers which may be managed for multiple use while protecting ecological values;
- selecting river sections which have robust values;
- determining cost-effective ways to meet biodiversity commitments with respect to aquatic systems;
- identifying rivers which require particular management strategies;
- focusing on or delineating rehabilitation efforts;
- setting priorities for funding allocations; and
- focusing the efforts and resources of community groups.

The evaluation process must be publicly defensible and appropriate. It needs to be readily understood at the community as well as technical level. It needs to be undertaken in a visible and transparent manner. If the assessment is embedded in an established process with particular conservation or river management goals in mind, then implementation should follow.

4.4 An initial application of the framework

Survey respondents were asked to nominate a river which they considered to be of high ecological value. A range of rivers was suggested and respondents were able to nominate and provide an expert rating for various appropriate attributes. Details of the ratings are given in the report of the survey in the appendix.

A further assessment was requested using six selected rivers. Choosing rivers which were mentioned by more than one individual in the survey responses, people who had responded to the survey were asked to rate each attribute for the selected river. This would provide a rough desktop evaluation of the consistency with which expert persons might rate the values of a given river.

The results of this exercise, which provided the estimate of ratings for attributes considered important by three or four independent individuals, indicate that there is a fair consistency in knowledge of values and in applying ratings. Similar attributes were selected in every case, and the ratings for any individual attribute varied only ± 1 on a 10-point scale. Respondents were given no explicit decision rules.

The results of the desktop assessment exercise are taken to confirm the validity of the attributes and the capacity of the attributes to provide discriminatory information between various values and between different rivers. The use of an expert panel approach has not been explored. It is possible that this approach to identification of high value rivers could be useful in situations where knowledge of river values is reasonably extensive, as an adjunct to other approaches, and as a substitute if a quick and superficial identification process is acceptable.

5 Protecting rivers of high ecological value

5.1 Threats to river values

Categories of threats to river values have been well documented (Boon, 1992; Allan & Flecker, 1993; Department of Environment, Sport and Territories, 1996a). Boon's classification, shown in box 12, was adopted recently by the World Conservation Monitoring Centre (1998) in its report on the assessment of global freshwater biodiversity.

Dams and abstraction have had possibly the largest overall effect on river systems in Australia. Dams for hydroelectricity generation have left some rivers (eg. the Snowy in Victoria and the Mersey in Tasmania) virtually dry downstream for months of the year. Abstraction for irrigation and other purposes has not only damaged riverine ecosystems but also created wholesale damage to the water table and hence surrounding catchment areas (Western Australian Water Resources Council, 1992).

There has been extensive documentation of human impacts on Australian waterways (Lake & Marchant, 1990; Barmuta et al., 1992; Department of Environment, Sport and Territories, 1996a). It is not intended to reiterate these threats and impacts. An approach could be developed of assessing what impacts exist on Australia's river generally. A further approach to assessing the specific impacts, threats and risks is another component of strategies for rehabilitation. In some cases, the only rehabilitation necessary might be to remove the threatening process or to restore previous conditions. For some identified values, the nature of the threat might be highly specific, for example, a rare insect species may be dependent on certain temperature regimes for successful mating. A combination of strategies changing flow rates and rehabilitating riparian vegetation may be required to reduce water temperature. A systematic assessment is required, on which appropriate strategies can be devised.

Once ecological values have been identified, rivers with high values will need to have the threats to those values identified specifically. This step also should form part of a river rehabilitation process.

5.2 Means of protection

Collating, identifying, classifying and evaluating ways to protect the ecological values of rivers is a major task. A Land and Water Resources Research and Development Corporation project (Maher & Cooper, 1999) is addressing legal frameworks with respect to only three aspects of river rehabilitation and is not addressing conservation values directly. The limited time and resources for the project prevented coverage of all aspects of legislation relating to rivers. Similarly, the present project will only deal with the broad categories for protection and the views of survey respondents on rivers of high ecological value on issues and strategies for protecting these values.

Box 11: Major anthropogenic activities affecting river systems

- Supra-catchment effects
- Acid deposition
- Interbasin transfer
- Catchment land use change
- Afforestation and deforestation
- Urbanisation
- Agricultural development
- Land drainage/flood protection
- Corridor engineering
- Removal of riparian vegetation
- Flow regulation – dams, channelisation, weirs and so on
- Dredging and mining
- Instream impacts
- Organic and inorganic pollution
- Thermal pollution
- Abstraction
- Navigation
- Exploitation of native species
- Introduction of alien species

Source: Boon (1992)

Much of the potential for protection of river values is indirect, or a secondary aspect of the prime purpose for which the legislation was framed. Similarly, non-statutory measures may not be originally developed for riverine ecosystems and require adaptation from a terrestrial focus.

In practice, several approaches will be necessary to protect the ecological values of some rivers. These may include statutory means directed to species or habitat protection, conservation policy implementation, application of indirect statutory means such as controls on water abstraction and community involvement in river rehabilitation.

The NSW Biodiversity Strategy (NSW Parks & Wildlife Service, 1999) provides a summary of the categories of activities which form the context for the strategy and identifies the major ones under each heading. The categories include: local policies and programs; State legislation; State policies; national agreements, strategies, and programs; Commonwealth legislation; and international agreements (1999, p12). A much larger list could be generated to define the operational context for river management as a whole, since biodiversity is only one aspect of river values. It is this vast and diverse context for river management which is a major factor in impeding protection of ecological values.

Targeting appropriate measures for protection will be an important component of river and catchment planning and management. There is little legislation that directly addresses protection of rivers of high ecological value, while at the same time, a large range of related legislation has an impact on the conservation outcomes for river management.

5.2.1 Legislation

Formal protection of ecological value of rivers is limited at State level to national parks Acts or similar and, for most States, threatened species legislation. At Commonwealth level, the Heritage Commission Act 1974 provides for the identification of places of national heritage value and listing in the Register of the National Estate. The protection that this listing offers is, however, minimal, being restricted to activities controlled by Commonwealth legislation and the activities of Commonwealth agencies. Identification or entry in the register does not lead to any management prescription or commitment to protection. In practice most sites on the register are terrestrial rather than riverine.

Commonwealth intervention has been used in the past to protect river values, most notably in the past by preventing the damming of the Franklin River in Tasmania. However, it is argued that the new Commonwealth Environment Act 1999 will abrogate this possibility for intervention.

The Commonwealth and State in agreement are moving forward on a water reform agenda which will result in revision of much State water-related legislation in order for the State to achieve compliance. The reform agenda does address protection of environmental values but the primary context lies in sustainable use or development of water resources (ARMCANZ, 1996).

5.2.2 Agreements

International agreements offer some recognition and protection for aspects of riverine systems. These include:

- biodiversity
- guidelines for marine and freshwater quality
- Ramsar Convention
- World Heritage Convention
- Murray–Darling Commission.

Agreements set the framework for subsequent policy or implementation. The role of the Commonwealth government is to provide leadership and coordination since most land (and water) management is a State responsibility. Compliance may be enforced or encouraged by financial incentives or penalties and through formal and informal public accountability mechanisms.

5.2.3 Policies

All States now have a commitment to sustainable development as the basis for a wide range of policy areas. Queensland is attempting to make this operational for river systems through the WIPDIP program. Other States are developing programs and strategies for assessment of environmental flows (Arthington & Zalucki, 1998). The WREP program in Queensland is attempting to define sustainability of aquatic systems. Difficulties lie in the inadequate understanding of river ecosystems and ecological needs of all elements of the biota.

All States are developing biodiversity policies to implement agreement under the Biodiversity Convention. However, interpretation, resources and implementation vary.

5.2.4 Programs and community support

Funding programs such Landcare, Fishcare, Rivercare and Ribbons of Blue, now all under the umbrella of the Natural Heritage Trust, can foster and target community and government effort towards better river management. Other specialised interest groups such as Birds Australia, the Australian Plants Society and Field Naturalists clubs can also become involved. Community involvement in river management can be a powerful avenue to engender support.

5.3 Barriers and constraints to protection

There are some legislative, policy and program measures in place which address the more obvious impacts of human activity on water quality and the natural values of riverine systems. But there are also less obvious factors which mitigate against the protection of ecological values of rivers. These factors are a wide range of management-related issues arising both from the nature of rivers themselves, and from the range of users and interests.

Problems that distinguish river management from management of terrestrial ecosystems relate to the linearity of the system and the consequences of this for management. The resources within the river – water, organic matter and sediment – are more or less continuously transported through the system in a largely unidirectional manner. As a result, management needs to consider issues in relation to upstream, downstream and lateral elements of the river.

Another factor which distinguishes river management is that the primary resource, water, is essential to life, and is not replaceable with any alternative. There are no choices about the requirement for water. Rivers also serve a wide variety of uses: water supply for human use and irrigation, means of transport, source of power, recreational facility, source of food supply, removal or dilution of waste and other less widespread uses such as cooling systems for electricity generation and fish farming.

As a result of the multiple interests in rivers, there is a range of agencies and individuals, operating under a vast number of legislative and policy frameworks, traditions and expectations, impinging on river management. In some cases the management may be implicit rather than explicit and serve only limited functions. Often use and management of the river can

be fragmented and uncoordinated. Individuals may not understand or be willing to accept the effects of their actions on other users or other values. The NSW Biodiversity Strategy (NSW Parks and Wildlife Service, 1999, p12) lists numerous agreements, legislation, policies and programs at all levels of government which form the context for biodiversity: river management should relate to the majority of these together with a vast parallel suite for rivers and water supply.

The Australia State of the Environment report (Department of Environment, Sport and Territories, 1996a) assesses the effectiveness of responses to water-related environmental issues (pp7.44–7.45). Some aspects are judged to be reasonably effective, but most areas at that time had much room for improvement. The report concludes that:

- policy development is ‘inadequate’ and that although it is improving in some areas this is not the case for privatised or corporatised organisations, and the use of economics is often inappropriate;
- big picture management and decision-making issues result in many single issue policies which are developed without consideration of whole policies;
- much greater action is required to protect and repair riparian zones, based on research and action at a whole-catchment level;
- agriculture and land clearance issues have generated a poor response;
- agricultural irrigation developments have been locally effective but the problem is transferred further downstream;
- responses to forestry activities are inadequate because of poor integration of land and water management; and
- there has been almost no response to the destruction of wetlands.

The report also notes that the effectiveness of response in these and other cases are often hindered by a lack of knowledge and understanding of ecosystem functioning.

5.3.1 Commonwealth/State responsibilities

States have responsibility for land management which results in sometimes inconsistent practices between States. The Commonwealth attempts to provide a leadership role but generally has little legislative influence over State decisions. More recently, collaboration through the Council of Australian

Governments has sought through the mechanism of bilateral agreements to develop more consistent approaches on a number of fronts.

Each State has a responsibility to its own constituencies and this may be in conflict with a national perspective or that of another State.

5.3.2 Legislation

There is a wide range of legislation that relates to rivers (Clement & Bennett 1998; NSW Parks and Wildlife Service, 1999). Much of the legislation relates to only a single aspect of water use or management, such as control of point source discharge or water allocation. Different agencies may be responsible for administering the legislation, with differing outcomes in mind. Interaction effects and overall management are not considered through the legislative process (Department of Environment, Sport and Territories, 1996a).

Determinations may be made legitimately under one piece of legislation only to violate prescriptions under another. Decisions taken for upstream sites can ignore the downstream interests and needs. Lateral (floodplain and riparian zone) and vertical (groundwater) concerns and issues can be totally overlooked. Serious salinity problems in the south-west of Western Australia may be attributed in part to permitted water use (Western Australian Water Resources Council, 1992) and its impact on groundwater.

There is a plethora of State legislation which may affect the conservation outcomes for rivers. The Environmental Defenders Office in Western Australia summarised the legislative context for that State, suggesting that around 15 major Acts, administered by several different agencies, might affect various aspects of river management (Clement & Bennett, 1998). The report (Maher & Cooper, 1999) of the legislative aspects of rehabilitation will provide illustrative examples of the range, nature, extent and complexity of river-related legislation.

Aspects of river management addressed by legislation include:

- water quality
- effluent or sewage discharge
- heavy metal contamination
- water use
- riparian rights

- protection of rare and threatened aquatic species
- harvesting of some aquatic species
- engineering works such as major dams.

5.3.3 Multiple management responsibilities

The various different pieces of legislation are often administered by different government agencies. Because of the different agencies involved they bring different perspectives and institutional cultures to management issues. Some agencies may have a perception of a predominant right over water use, as happened with the Tasmanian Hydro-Electric Commission in the period from the 1950s to the 1980s. Little consideration was given to the interests of other users downstream of some major dams.

Agencies which have the responsibility for primary industry may believe, as do many farmers, that water is wasted if it flows past down river, and so as much as possible should be used for irrigation purposes. Agencies with the mandate to promote and sustain farming interests may encourage agricultural practices which in the long run are unsustainable for the river system.

State government policies and public commitments may be made without consideration of the overall river management requirements, and local government interests, policies and responsibilities may be overlooked.

Recent moves towards integrated catchment management have begun to address these issues but institutional culture and community expectations are slow to change.

5.3.4 Responsibilities for implementation

Governments at national and State levels make policy commitments which require local government support for implementation. This applies to many aspects of environment protection and conservation. In addition, cooperation of property owners is particularly crucial for the achievement of environmental outcomes. Internationally this may be achieved through conservation agreements (European Commission, 1999), financial incentives or other fiscal measures. Implementation strategies for recent Commonwealth–State forest agreements in Australia have canvassed incentives such as land buyback in order to achieve required levels of forest protection.

5.3.5 Interstate boundary issues

Protection of ecological values of rivers may also be hindered by the many major river systems which cross state boundaries. Legislation and policies may differ between the State involved. Issues of economic development versus river conservation may cross State boundaries. Kingsford (1999) describes the likely consequences for the ecology of the Paroo River and economy of downstream communities in NSW if major irrigation developments for the cotton industry are put in place upstream in Queensland. The Murray-Darling Commission has sought to negotiate such issues with all States in the catchment of Australia's largest river system. Caps on extraction of water for a period of three years were negotiated but NSW has now indicated that it plans to exceed its cap. The resultant debate has put river management high on the political agenda.

As well as boundary issues in the longitudinal dimension, there may be issues in the lateral dimension, for rivers often form a boundary between municipalities. Different management priorities and strategies may then be applied to each bank of the river.

5.3.6 Riparian rights

Many Australian landowners are firmly committed to their rights to water if they own land adjacent to a watercourse. Such riparian rights have largely been preserved in recent legislation along with the need to have permits to use certain approved quantities for irrigation purposes. This has led to potential for trading in water, suggesting that the property owner actually owns the water available under riparian rights. This is a contentious and complex issue which merits further analysis.

5.3.7 Community expectations

The general community often has unrealistic expectations for river management. Flood control is often regarded as essential, without understanding the natural river behaviour and the effect of human influence on it. Inappropriate engineering responses which simply shift the 'problem' to another part of the river system can exacerbate the problem.

Wetland areas may be regarded as unpleasant, unsightly or dangerous. Wetlands are also regarded as wasteland which can only be made productive by draining for rural uses or land reclamation.

There are numerous other examples of erroneous perceptions of river behaviour and management issues

which can impede appropriate river management to protect ecological values. Community education is required to raise the level of understanding and to convey the importance of maintaining river values in the interests of managing for all uses.

5.3.8 Communication

It is often claimed that there is insufficient communication between river ecologists and other researchers, and river managers. If the ecologists are not providing managers with information about what is ecologically important, what is required to maintain the values and what processes threaten those values, then managers cannot provide the necessary protection. The extent, nature and possibility for greater collaboration between researchers and policy makers and managers has long been debated. Some researchers believe such interaction is outside their responsibilities, skills and priorities. Moves towards cooperative research centres have begun to overcome this, but the issue of integrating the latest knowledge into management of individual rivers needs to be further pursued.

A related problem lies in the use of specialist language in dialogue about river management. River management encompasses a range of specialist areas including hydrology, geomorphology, biology and so on; not one, but several, technical languages. All these disciplines use sophisticated techniques to study and analyse river behaviour which can create barriers with the local community whose support is necessary to achieve protection.

5.3.9 Conceptual complexity

Rivers are conceptually difficult systems to understand and describe. They are distinctive in their unidirectional flow and high level of constant and irregular stress. They function in several dimensions – vertical, longitudinal, lateral and temporal – and can change dramatically in nature in a short period of time. Changes also occur over the medium and short term as well as seasonally. These are not just changes to the biota but changes to the habitat, sometimes on a very large scale. The river-land junction is a major interface of two quite different ecosystem types.

The river is also inextricably linked to the catchment, yet this link is not readily evident except on drainage lines. Similarly, the river is linked to the groundwater system which plays a crucial role in river and catchment dynamics. Protection of ecological values should be based on sound ecological knowledge but the

complexity of river systems means that a precautionary approach is essential, both by ensuring full protection of undisturbed systems as a model and by adopting a minimal impact approach to any changes in river ecosystems.

5.3.10 Natural Heritage Trust and other funding issues

Although the Natural Heritage Trust provides an avenue to encourage protection of river values, it can also act as a deterrent to holistic river management. Some projects focus on singular elements of stream or river conservation or rehabilitation which may not even be highest priority for action in that particular system. Projects and activities may not be the most cost-effective means of managing the issue and may have only short-term outcomes. The allocation of funding to individual groups with interest or encouragement to address a perceived local problem does not sufficiently allow for priorities to be set at a regional scale.

There is no overall national framework to target funding from the Natural Heritage Trust for river protection. This is echoed at State level. In Tasmania, for example, very little funding is directed towards protecting places which are in good condition or have important ecological values which should be protected. Instead, funding is applied to site-based works such as willow removal, bank stabilisation and drainage works.

5.3.11 Economic interests

Perhaps the greatest hindrance to protecting rivers of high ecological value lies in the economic pressures on river systems. This is further exacerbated by the belief of those who regard water that flows down a river bed as wasted. The Australia State of Environment report (Department of Environment, Sport and Territories, 1996a) suggests that the 'use of economics [is] often inappropriate' (1996a, p7-45) in determining policy development in relation to water and river management. While the various uses for water are undeniable, economic models should be only one of several approaches to be incorporated in river management. Economic models tend to have a limited geographic base and time frame, whereas river management requires a catchment approach which will be viable for the long term.

New draft water quality guidelines (ARMCANZ & ANZECC, 1999) are an example of the difficulties caused with a single issue focus on rivers. Three levels of

ecosystem condition are identified: high conservation/ecological value systems; slightly to moderately disturbed systems; and highly disturbed systems. For each condition, levels of protection and recommended objectives are made. For high conservation value systems, no detectable change in indicators of biological diversity is the suggested objective. Rivers with some disturbance can allow 'some relaxation of the more stringent management approach...with consideration of either increased level of acceptable change or reduced statistical power for detecting any change in biological diversity' (1999, p19). Such an approach could fail to meet the ecosystem needs for protecting ecological values. The possibility that highly disturbed systems may have ecological or conservation value is recognised along with the likelihood that water quality objectives will need to be tailored to the particular situation. The water quality guidelines have yet to be endorsed.

Determination of water quality standards cannot be made without an assessment of values, risks and threatening processes for the particular system.

Another dimension to the economic issues lies in the limitations of resources to adequately manage river systems. Despite the central and crucial role that rivers and water supply plays in human existence, resources for management are a seriously limiting factor.

5.4 Views of river managers and researchers about strategies for protection

Respondents to the project survey (73 river managers or researchers) provided a perspective on what types of protection might be appropriate for the river of high ecological value which they had nominated (see appendix). Some of the rivers nominated were in protected areas such as national parks and therefore did not require further measures. Although the protective measures were specific to a particular river, the overall pattern of responses provides some evidence of what researchers and managers consider to be the most effective means of protecting a high ecological value river. They were asked to provide suggestions for protection for a particular river they had nominated.

All those strategies for protection listed in the survey were considered useful for at least some rivers. Since the question being addressed related to rivers of high value, some required little in the way of further protection if they were already protected within National Parks.

Conversely, although some strategies apparently were less important than others, these could be critical in the protection or management of particular rivers.

A summary of responses is shown in box 12. A more detailed analysis of the responses is provided in the appendix.

Preferred strategies for protection relate to different rivers and therefore should be regarded as only indicative of the relative importance of various strategies. Strategies considered most important for protecting rivers of high ecological value operate at a catchment or landscape scale. They are largely preventative. Primary means for protecting high-value rivers are recommended to avoid deterioration, perhaps reflecting that the respondents generally suggested rivers in more natural condition. Protection measures most frequently mentioned and most frequently given a high score for utility include control of land clearance, maintenance of natural flow regimes, and protection of riparian vegetation.

The next most important group of strategies could be applied to rivers which had experienced some human disturbance and were also used for multiple purposes. These strategies focus on control measures designed to ameliorate the effects of grazing, land clearance (by the establishment of riparian reserves), non-native species and abstraction of water. Integrated catchment management was seen as a key strategy, implying that rivers with high ecological value could also provide for a range of human activity, provided that appropriate controls were in place.

It is notable that the strategies considered most important by researchers and river managers are generally not covered by legislation. Strategies considered moderately important include some which are presently at least partially covered by legislation, such as point source discharge, removal of materials and control of recreational activities. The least important strategies for high ecological value rivers may be inappropriate for the types of high-value rivers selected by survey respondents and do focus more on restoration than protection.

The results suggest that legislative protection is believed vital to protect rivers with high conservation values, but this needs to be supported by other strategies particularly where the river provides for multiple use. Legislative protection needs to address issues at catchment level including control of land clearance, maintenance of natural flow regimes, protection of riparian vegetation and integrated catchment management.

Few of the protection measures are supported by legislation. Point source discharge is usually controlled if it contains noxious chemicals but not necessarily if it brings 'clean' water into a system which may have ecological impacts via change in water temperature, water chemistry balance or non-provenance taxa via interbasin transfer. In some States some land clearance controls exist but do not necessarily protect rivers of high value.

Water abstraction is subject to control, but the agency with this responsibility does not necessarily confer with other interested parties. Increasingly, however, such integrated assessment is coming into place

Box 12: Most effective protection measures for rivers of high ecological value

Most important

Protection of natural flow regimes of unregulated rivers

Legislated protection of rivers

Protection of riparian vegetation

Control of land clearance

High importance

Integrated catchment management

Control of diffuse discharge into rivers

Control of grazing

Control of feral animals and non-native plant species

Control on the timing and level of abstraction of water

Establishment of riparian reserves

Moderate importance

Control of point source discharge

Control on abstraction of materials – sand, gravel

Control of recreational activities – boating, fishing

Restoration of riparian vegetation

Avoidance of inter-basin transfer

Least importance

Land buyback schemes

Removal of infrastructure such as channels, dams

Restoration of instream coarse woody debris

Restoration of natural flow regimes

Source: Responses from survey April 1999; see appendix.

supported by environmental flow assessments. Such assessment may be reliant on limited available long-term datasets and inadequate understanding of the particular river ecosystem. Protection of the flow regimes of presently unregulated rivers is a critical issue: without examples of unregulated rivers the opportunity for improving reference data and developing a greater understanding of ecological processes and sustainability of river systems will be lost. Already, there are river system types in Australia without a single unregulated example (Western Australian Water Resources Council, 1992).

The results also suggest that the work currently done by many community groups through the auspices of the Natural Heritage Trust are more likely to address local water quality issues rather than be effective for protecting those rivers which are considered to have high ecological value. Restoration of riparian vegetation or modification of in-channel habitat such as willow removal, reinstatement of woody debris or installation of training walls only address local problems and will do little in improving the overall conservation value of the river.

5.5 Opportunities

The proposed framework for identification of rivers of high ecological value may be used as a vehicle to facilitate assessment and promote protection of rivers in Australia. These opportunities can be made through formal channels such as current State programs and through informal channels by supporting community interests and values. Awareness raising amongst the community is a powerful vehicle for protection and in the United States much of the impetus for river protection and management has come from active community groups.

5.5.1 Links with current State assessment activities

All States are engaged in some form of river assessment, including the National River Health Program. All State or river management authorities will have access to a range of data which may be useful in determining high ecological value. All authorities are also familiar with basic concepts of assessment – classification schemes, making comparisons, scoring or categorising. Thus many of the basic elements of an assessment are already

available. What in most cases is lacking is a process and commitment to identifying and protecting rivers of high ecological value.

Work in Victoria is focused on the Index of Stream Condition, although an earlier project had identified rivers of conservation value under the Wild and Scenic Rivers program. It appears that no management consequences arose from this latter project. The primary management task on which Victorian river managers are focused is the management of river condition.

South Australia faces the situation where its major river system (Murray) is severely altered by activity beyond State borders. Management of other catchments is progressively being handed to individual catchment boards, where an analysis of ecological value may be useful as one strand of integrated catchment management assessment.

WA has undertaken an assessment of the state of the rivers and developed a broad understanding of the status of the rivers in the various drainage basins. A needs analysis is being developed and the framework for identification of ecological value might be used in a parallel assessment.

The NSW Stressed Rivers Program has identified rivers of conservation value, and has sought to apply the draft framework and attributes to a more detailed assessment of these rivers to determine management needs and priorities.

The Queensland WREP for WIPDIP has a similar range of attributes in its component for assessing conservation value suggesting that there is a reasonable consistency in approach possible in that State.

Tasmania is approaching implementation of water reform through the State Policy on Water Quality Management (Sustainable Development Advisory Council, 1997). The policy advocates a value-setting approach to establishing sustainable water quality management through integrated catchment management. Work has begun on identifying protected environmental values through analysis of land tenure and use and community consultation. At the same time, specialists will collate information on significant ecological values for the rivers. The protected environmental values will form the basis for specifying a set of water quality objectives. Assessment of ecological values in the form of an ecological value profile would complement both elements of this value-setting process.

5.5.2 Links to other values

The framework only addresses ecological values, though the boundary between ecological value and other related values is indistinct. Values such as aesthetic appeal, recreational value, spiritual value and sense of place and ecological value are closely interrelated. Indeed ecological value also underpins more pragmatic human values in providing for a clean and safe water supply, water for irrigation and power generation and so on. The Queensland WREP for WIPDIP includes a strand of conservation value which takes account of the values held by the community.

If connections can be made with these community values, this will strengthen the case for protecting the ecological values.

5.5.3 Community interests

Communities have great affinities with the local river system. River and landscape are integral to Aboriginal culture and daily life. Rivers have always been a focus from human settlement. Later settlers in Australia adopted the river as a focus for settlement areas, growing crops and transport. Rivers provided a food supply and a place for recreation and renewal. Rivers form one of those foci of affiliation between humans and nature. Local communities and people who visit certain rivers or wetlands have a particular sense of place centred on the river. The river is seen as the lifeblood of the community and the settlement. Literature and art capture aspects of the role of rivers and wetlands in human life. Community interests and affiliations may be harnessed in identifying and protecting important natural values for the river.

6 Conclusions and recommendations

6.1 The conservation of Australian rivers

6.1.1 Australia's rivers have high conservation significance

Aspects of Australia's rivers are of conservation significance on a world scale. Rivers and associated ecosystems are notable for:

- variable and distinctive hydrology;
- unusual ephemeral dryland rivers;
- inland streams with high natural salinity and turbidity;
- internationally significant wetlands;
- river systems dependent on distinctive energy sources and food webs derived from sclerophyllous forests;
- a very high degree of endemism amongst the flora and fauna, across a wide range of groups and taxonomic levels;
- taxa of phylogenetic or biographic significance;
- many invertebrate taxa of Gondwanic significance;
- marsupials and the monotreme *Ornithorhynchus* (platypus), which are unique to Australia; and
- significant karst systems and associated biota.

The importance of the biodiversity of Australia's rivers, floodplains and wetlands is acknowledged (Department of Environment, Sport and Territories, 1996a; World Conservation Monitoring Centre, 1998). Other values are recognised through inscription at international level, such as the World Heritage listing of the wetlands of Kakadu and Franklin River in the Tasmanian Wilderness World Heritage Area, and Ramsar listing of 49 wetlands (not all riverine wetlands) in Australia. A preliminary assessment of Australia's biodiversity (Department of Environment, Sport and Territories, 1997) identifies four significant themes for wetlands: the high degree of endemism; the unusual composition of the fauna; ancient and relict components of Pangaean and Gondwanan origin; and adaptations to special conditions including salinity, ephemeral water and variable hydrology.

Australia's rivers have high conservation values but are yet to be protected in any systematic way and conservation values play a minor role in catchment management and funding programs.

6.1.2 Rivers of high ecological value also have practical values

Rivers in good condition provide a range of ecosystem services including: access to water resources, sediment transfer and soils formation, nutrient cycling, dispersion of wastes, system maintenance and systems recovery (Department of Environment, Sport and Territories, 1993). In addition, local communities and economies are dependent on the maintenance of the ecological values of the rivers to protect economic values of a river system. Aesthetic and recreational values and the value of rivers as a food source are important aspects of community values for rivers which depend on protection of the landscape and ecosystem.

From the perspective of river management it is vital to have examples of rivers of ecological value, in healthy and undisturbed conditions to provide a reference and standards for water quality and ecosystem health. In addition, rivers which are of high ecological value are important for scientific research to develop better understanding of river and ecosystem functioning.

6.1.3 Government and policy commitments for biodiversity protection should be applied to river systems

There are a number of international and intergovernmental agreements which act as drivers for conservation measures to be initiated and implemented.

The International Convention on Biodiversity 1993 has been signed by Australia and endorsed by State governments. The Commonwealth Government has also signed international agreements on behalf of the nation on World Heritage (IUCN), wetlands (Ramsar), migratory birds (Japan–Australia Migratory Bird Agreement) and China–Australia Migratory Bird Agreement). These agreements place responsibility on member states (signatories) to identify and protect these values.

The commitments by the Commonwealth Government are transferred to other levels of

government through various intergovernmental agreements. In 1992 all spheres of Australian government became party to the Intergovernmental Agreement on the Environment, which defined a framework of environmental responsibilities and interests for each level of government. Importantly, the agreement recognised that all levels of government share the responsibility for protecting Australia's environment. In relation to water and river management, key groups are ANZECC, ARMCANZ and the Intergovernmental Committee on Ecologically Sustainable Development.

The National Strategy for Conservation of Australia's Biodiversity (ANZECC, 1996) states 'conservation of biological diversity is a foundation of ecologically sustainable development'. The Convention on Biodiversity (1992) requires identification and monitoring of: 'ecosystems and habitats: containing high diversity, large numbers of endemic or threatened species, or wilderness; required by migratory species; of social, economic, cultural or scientific importance; or, which are representative, unique or associated with key evolutionary or other biological processes' (Annex I).

The Conservation of Biological Diversity is a foundation of ecologically sustainable development and is one of the three core objectives of the National Strategy for Ecologically Sustainable Development. The Convention on Biological Diversity was ratified by Australia in 1993. The National Strategy for the Conservation of Australia's Biological Diversity (1998) was developed and endorsed by ANZECC and ARMCANZ with other intergovernmental councils and thus has endorsement of all States and Territories. The strategy pursues the directions of the convention, and includes reference to identification, bioregional planning, protected areas and off-reserve conservation. 'Water' is specifically discussed with reference to integrating conservation of biological diversity with natural resource management. It is recommended to 'manage water resources in accordance with biological diversity conservation objectives and to satisfy economic, social and community needs' as well as to improve knowledge about the biological diversity of aquatic and associated systems and to protect aquatic ecosystems by introducing effective legislative and policy frameworks.

Thus there are a number of international and nationally agreed commitments to the identification of significant areas of biodiversity and protection of biodiversity and other ecological values which may be applied to riverine environments. These are significant

policy drivers for initiation of more systematic identification and protection of rivers of high ecological value in Australia. Similar directions are progressing elsewhere, for example, members of the European Community are committed under the Habitats Directive to identify and protect representative habitats across all ecosystem types (European Commission, 1999).

6.1.4 River conservation is an urgent and important issue for Australia

The range of threats and pressures on river systems is well documented. Many of Australia's river systems are already irreversibly altered. Continuing pressure for water resources is pushing some major river systems to a point where any attempt to sustain those values, or to rehabilitate the environmental values, will be exceeded. River systems with flow regimes previously little affected by regulation or abstraction are now under threat of development.

Use and distribution of fresh water is a crucial environmental management issue for Australia. Within this context, authorities in several States are becoming concerned that the pressure to access every available water source could have dire consequences for river conservation. Developing a sound, scientifically based way to assess the values of rivers and then to develop appropriate conservation and protection strategies is a matter for immediate resolution.

6.2 The protection of rivers of high ecological value in Australia

6.2.1 The nature of rivers creates special issues for protection

Rivers supply a resource which cannot be substituted by any other. There are no alternatives to fresh water for many of the functions which rivers provide. The rivers themselves are only part of the total water cycle so that other activities in the catchment such as land use and water capture also affect the river function. Unlike terrestrial environments, the management of river value cannot be limited spatially to a particular site. A site where particular ecological values have been recorded is likely to be affected by what happens over many kilometres of catchment. Rivers are also characterised by linearity in the system – where processes and systems downstream are continually modified and dependent

upon a unidirectional flow from upstream and sometimes, as in flood plains, laterally.

The very nature of riverine systems demands a somewhat different approach to the management of ecological values from that for terrestrial environments.

6.2.2 Legislative and management complexity compounds measures for protection

River systems are subject to a remarkable range of legislation, some of which is poorly integrated or even has competing objectives. Management of rivers on a whole-catchment scale involves numerous landowners and agencies with an interest or stake in the water resource itself. Many rivers cross State boundaries so that the complexity is further compounded by differing goals and expectations between States.

Management issues were raised as a key area which will need to be addressed if protection of rivers of high ecological value is to progress.

6.2.3 There is limited legislative protection for the ecological values of rivers

The legislative protection for ecological values of rivers is generally believed to be poor though no detailed study was undertaken within the present project. Some values considered of ecological significance are not specified within the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. These include geomorphological or hydrological values. These are fundamental elements of the ecosystem, are of natural heritage value in themselves and are also critical for the maintenance of ecosystem health. While some biotic elements may be protected by various rare and threatened species legislation, this is limited in its scope. Species must be formally listed but criteria for listing may be inappropriate for aquatic systems. 'Ecological communities' may be scheduled under the Act if threatened, but 'communities' are less readily defined in aquatic systems than for floral communities on which the concept appears to be based. Non-vascular plants and invertebrates are generally less well represented in formal rare and threatened species listings yet these are critical elements of the aquatic biota.

Rivers may be captured within the boundaries of reserved areas such as National Parks, but have not been systematically reserved. In addition, upstream activities beyond the reserve boundaries may impact on the riverine values since such activities lie outside the scheduled reserve.

River managers and river researchers surveyed believed that legislation to protect rivers of high ecological value was the most important strategy. Gaps in legislative processes need to be addressed so that riverine values receive at least the same attention as terrestrial values.

6.2.4 National and catchment approaches are seen as essential

A national strategy for identifying and protecting rivers of high ecological value is considered essential. Just as the Commonwealth Government has taken a leading role in the protection of other habitats and systems such as forests (under Regional Forest Agreements), marine reserves (under the marine strategy and Environment Protection and Biodiversity Conservation Act 1999), grasslands (under the National Reserves program) and wetlands (through the Ramsar Convention), rivers are considered to warrant a national strategy.

River systems and sections should be identified and protected within a bioregional context. That is, that a full range of river types should be protected across the nation. Protection of river values must occur at a catchment scale. This is likely to demand different approaches to protection, reservation and conservation from those applied in other ecosystems.

6.2.5 Community support for river conservation is growing

Media reports and the activities of some Rivercare and Landcare groups suggest that support at community level in the protection of river values is growing. River conservation in some other countries, such as the United States, is sustained by powerful community-based river conservation groups. Building community support will be a key element of a river conservation strategy.

6.2.6 Experts from across Australia agree on the key criteria for ecological values of rivers

The survey of river managers and researchers provided a valuable Australia-wide perspective on what was considered by experts working with rivers to be important in river conservation. There was overall endorsement of the proposed criteria and broad consensus on appropriate and necessary strategies for protection.

The need for a broad interpretation of 'ecological value' was evident in the responses. The inclusion in the criteria of geomorphology, hydrology and riverine processes in the list of criteria and attributes was a

significant finding. Inclusion of such values appeared to be independent of the role or expertise of the respondent. In any scheme adopted for the assessment of ecological value of rivers, these fundamental components must be included.

The range of criteria endorsed by those surveyed is also indicative of the holistic understanding of river systems which must underpin river management.

The criteria and attributes (table 4) should form the basis of future assessments of the ecological value of rivers.

6.2.7 Experts from across Australia agree on the need for flexibility in identification and assessment processes

The river managers and others in management agencies generally agreed that there needed to be flexibility in the identification process. The set of criteria and attributes provides common reference points between different approaches to assessment. This strategy (common criteria, different ways of assessment) is already well established in the National Estate (Australia), Regional Forest Agreements (Australia) and Ramsar (international). The purpose of the assessment determines the process, including setting decision rules, thresholds and standards.

Diversity is important to harness existing processes and to allow for some interpretation in the regional context. If a standard process and scoring method were to be imposed, some values may be not applicable in certain areas. This is a further reason for requiring identification and protection of high value rivers to take place within a bioregional framework.

Protection of rivers of ecological value will have to occur under different management regimes, from total protection from any development, through managed reserves, integrated catchment management and focused rehabilitation.

6.3 Recommendations for river conservation in Australia

6.3.1 A strategy for identification and protection of rivers of high ecological value should be developed and implemented

A clear case has been made demonstrating the ecological significance of Australia's rivers. However, it is also evident that river conservation has been poorly addressed in

legislation and in the implementation of government commitments on biodiversity protection.

Protection of conservation values of rivers will be a complex process, requiring the cooperation of a number of parties and the development of new approaches to conservation management. Nevertheless, it is critical not only from a conservation perspective but also in order that we can develop ways to better manage all river systems and water resources.

The strategy needs to address issues at both national and catchment scales. There is a need for over-arching guidelines for river management which acknowledge community expectations for protection of a range of river values, and the governments' own commitments to protection of biodiversity. This is necessary as a balance to the prescriptions providing for economic, development and human needs, and as a context for determining environmental flows. Such a policy framework is needed to guide water resource allocation decisions on a bioregional and national scale, establish priorities for rehabilitation focusing on the most cost-effective sites for biodiversity conservation and determine funding allocations.

The strategy needs to be developed collaboratively between State and Commonwealth governments. It is needed as a matter of urgency and some interim measures may need to be taken to ensure that some types of rivers in more or less natural state are not lost entirely as a result of imminent development pressures.

6.3.2 Policy endorsement should begin with implementation of current legislation

There are already in place some elements of policy and legislation which could be focused on river conservation issues. The commitment to biodiversity conservation by both State and Commonwealth governments needs to encompass river ecosystem values in a clearer and more active way. Conservation of riverine biodiversity should be a cornerstone of decisions regarding rivers in the same way as biodiversity conservation applies to other habitats. At this stage, these biodiversity commitments are poorly reflected in decisions concerning river management. River ecosystems are clearly lagging behind forests, grasslands and marine systems in the commitments, effort and funding vested in their protection.

6.3.3 A variety of approaches to protection must be adopted

A continuum of river conservation practices is advocated. It is not adequate or appropriate to consider that a few rivers or river sections may be worthy of protection and to ignore the remainder.

Rivers of very high ecological value may achieve total protection in a World Heritage Area or possibly National Park. A national system of river reserves may identify other riverine habitats where ecological values must be given priority over other uses. Other high-value rivers should be protected by prescription and management within the context of multiple use of the waterway. Specific individual values may be protected, for example, by ensuring that all ecological requirements for a species are fulfilled. Rehabilitation to encourage revival of ecosystems which approach a natural or at least healthy condition will also be appropriate to promote species reservoirs, corridors and habitat continuity.

6.3.4 A national system of river reserves should be a core strategy for protection

A national system of river reserves should be established in line with the reserve systems for other habitats. Such a system needs to be developed at a national level in order to ensure that the full range of river types is protected. Some rivers included in such a representative reserve system will of necessity not be in fully natural condition. Nevertheless they will contribute to a reference suite of rivers or river sections.

Development of an appropriate bioregional framework or river classification scheme to underpin a reserve system is a priority.

6.3.5 Identification of ecological values of a river or river section should be standard management practice

Any evaluation of river values for catchment management planning should include assessment of ecological values according to the agreed criteria. This is a fundamental element of decision making for the various uses of the river. It is important in determining how to maintain the health of the river and for any rehabilitation efforts.

The term 'ecological value profile' is used for this assessment process. Using the common criteria and attributes for ecological value will enable managers to

assess ecological value in a local regional and national context.

6.3.6 Several approaches to identification should be encouraged

The different strategies for protection will require somewhat different approaches to identification. The same set of criteria and attributes can be used to provide overall consistency. Table 13 summarises the four major types of assessment process. Various different applications or purposes for identification are given for the different types of assessment process.

Each of the first three approaches to identification and assessment requires the prior establishment of decision rules, thresholds and standards.

It is recommended that work proceed to refine and articulate such rules and standards within particular management contexts.

It is recommended that the criteria and attributes (table 4) defined in this project be accepted as the key elements of ecological value for Australian rivers.

6.3.7 River management practices needs to better address ecological values

More effort should be made to respond to the National Strategy on Biodiversity (1998) which recommends a number of strategies to improve river management with respect to protecting the ecological values of rivers. These include minimising the impacts of barriers and modification to river flows, sustaining natural flow regimes and habitat complexity, reducing impacts on floodplains and minimising the effects of the use of artesian water.

6.3.8 Agreed conservation principles should be applied to the management of river systems

It is recommended that widely accepted conservation principles be applied to the protection of the ecological values of rivers. There are a number of established principles of conservation practice which are applied for conservation in other types of ecosystem. These are articulated in the principles for conservation of biodiversity (ANZECC, 1996), the Natural Heritage Charter (Australian Heritage Commission, 1997), planning principles for reserve systems (ANZECC 1998; Environment Australia, 1998a) and in key management plans (Parks and Wildlife Service, Tasmania, 1999) for example). Conservation guidelines for the management of wild river values (Environment Australia, 1998b)

Table 13: Major types of assessment process

Model	Application
Reserve design	To identify a suite of protected rivers which are comprehensive, adequate and representative of Australia's river systems. Application: National and State level.
Classification	To group rivers according to general levels of ecological value and the level or type of management intervention or protection required. Application: National and State level.
Indices	To assist in selecting rivers as priorities for management intervention, funding or community involvement. To provide a summary of the state of rivers. To monitor change in river status. Application: State or regional level.
Ecological value profile	To identify ecological value of a river system, subcatchment or section to determine value to be protected in integrated catchment management. To describe conservation values of a river for National Estate or other heritage listing. To provide the basis for an environmental impact assessment. To define values requiring sensitivity assessment for infrastructure proposals. To describe values of the river for community awareness and education. Application: Catchment or local scale.

provide guidelines widely applicable to the protection of ecological values of rivers.

It is recommended that work be undertaken to develop a set of principles for the protection of the ecological values of rivers. This should take into account the special features of river ecosystems but be consistent with and reflect principles for biodiversity conservation and geoconservation generally. Promotion and dissemination of the principles should then be undertaken.

6.3.9 Harness existing protection mechanisms and extend scope of legislative protection

More efforts should be made to invoke existing mechanisms for identification and protection such as Ramsar or Register of the National Estate listing. Both these systems incorporate criteria and attributes which can accommodate many of the ecological values which are important in riverine systems.

Existing legislation should be extended in scope to incorporate other aspects of the natural environment. Inclusion of geoheritage is vital, not only for rivers systems. Threatened communities need to be broadened to include threatened ecosystems or habitats since these concepts better reflect river structure and function.

6.4 Recommendations for action by LWRRDC

6.4.1 Dissemination, promotion and general awareness raising

The project has provided an initial overview and raised some issues for the identification and protection of rivers of high ecological value. Some key elements have emerged: the agreed set of criteria and attributes; the need for a variety of protection strategies; the critical need to protect representative examples of rivers in good condition; the need to promote better river management to incorporate protection of ecological values.

Dissemination, promotion and general public awareness raising of the project findings should be supported by LWRRDC. This should be targeted at different levels – politicians, policymakers, river management authorities, state agencies, scientific bodies, communities and so on.

Workshops should be conducted to enable river managers to explore how the proposals might be applied within their own sphere of operation.

6.4.2 Lobby group at national policy level

LWWRDC lies in a pivotal position to provide a national focus and initiative to lobby government. It is recommended that LWRRDC establish a working group to identify mechanisms for the systematic protection of rivers of high ecological value, to liaise with policymakers, and to coordinate a program of research and development which will address practical elements of identification and protection, such as those listed below.

6.4.3 Research and development projects

The purpose of future research and development on issues of river conservation is to build on, clarify, extend and validate the findings of the present project. It should also seek to integrate these findings with other projects recently funded under the River Restoration and Management program and to cover elements which were not addressed to date. These include:

- Define a bioregional and broad hydrogeological classification or characterisation of Australian rivers.
- Explore options for protection of ecological values of rivers and river sections.
- Assess the legal and policy frameworks for conservation of river systems.
- Identify tools for determining ecological requirements of threatened river systems.
- Identify and document particular rivers of high ecological value which urgently need protection.
- Develop some scientifically based thresholds, standards and decision rules which might be appropriate for riverine systems.
- Define community social values of rivers.
- Develop appropriate decision rules for defining rare and threatened aquatic taxa.
- Develop an overall framework for a national reserve system for rivers (and possibly other aquatic habitats).
- Develop a set of principles for the protection of river biodiversity ecosystems and processes.
- Undertake case study validations of the criteria and attributes.

Appendix: The survey of river experts and managers, April to June 1999

Methodology

A survey form was devised to canvass opinion on issues of identifying and protecting high ecological value rivers. The purposes of the survey were:

- to assess whether there was general endorsement of the proposed attributes of ecological value;
- to identify any omissions from the list of attributes;
- to allow respondents to nominate Australian rivers they considered of high ecological value;
- to assess whether the attributes could be applied to such rivers;
- to get respondents' opinions on key strategies for protecting rivers; and
- to involve a wide range of stakeholders and experts in the development of the framework.

Target respondents

The primary targets for completed surveys were people with particular expertise in any aspect of river ecology, taken in its broadest sense. A list was compiled from personal knowledge, advice of the reference group and names taken from contributions to the recent literature. In addition, a notice about the project was posted on the Australian Society for Limnology listserv and advised in the society's newsletter, inviting anyone to indicate their interest in completing the survey form. Key agencies in each State were also listed. 'Ecology' of rivers was interpreted in the broadest possible sense. Geomorphology (and hence geoheritage values), landscape, floodplains and river processes were to be included in the scope of the framework. Therefore, people working in these research fields were targeted to participate in the survey.

No statistical operations were planned with the possible exception of non-parametric Chi-square tests to compare results of different respondent groups. Therefore, there was no limit on the number of respondents and no constraint imposed by a sampling strategy. Efforts were made to ensure all States were represented in responses (although of course many

researchers have interests which extend beyond their home State boundaries).

The survey was to be conducted by email correspondence. It could, therefore, be claimed to have had an inherent bias. Since the purpose of the survey was to gain expert opinion, it was considered that the electronic approach was appropriate. Most individuals actively engaged in river research are regular users of the email. A notice was also placed in the Australian Society for Limnology newsletter, received by all society members. A handful who preferred to complete and return the pro-formas by regular mail or fax were accommodated. The reference group considered the Australian Society for Limnology the key professional association, with no equivalent association representing geomorphological research.

Survey strategy

Email address lists were compiled and the survey mailed as an attachment using an Excel spreadsheet. A covering letter explained the purposes of the survey, instructions for completion of the survey pro-forma and a brief outline of the project. The Excel spreadsheet was designed to fit on two pages so that it could be printed if required and fitted within the width of a computer screen for ease of reading. It was set up in colour codes: only sections in grey could be accessed by respondents. Areas of background (pale yellow) and the questions, highlighted in green, were protected by a password. Plans were made to directly transfer the data into a SPSS software program to undertake the comparison between researchers and managers. A macro would allow all survey forms to be compiled into a single spreadsheet and results analysed using Excel or, if necessary for other statistical operation, the SPSS package.

A database of potential respondents was created using Access software. Records of distribution of surveys, reminders, receipt of completed questionnaires, and the allocation of a sequential and individual survey number to each completed survey were kept on this master file. The Access database automatically generates an identification number for the survey respondent which was transferred to the completed form by the researcher on receipt. This enabled survey data to be identified with the respondent. As emails are returned, the mail

software (Eudora) labels the attached file with an individual suffix number, enabling each returned survey to be identified with the sender.

Recipients of the email request could forward the letter and attachment to others they thought could be interested or to a more appropriate individual in the case of the government agencies. Most respondents correctly completed the whole survey aided by the on-screen design and colour coding. Approximately 100 initial email requests were distributed. A further couple of dozen people indicated interest via the Australian Society for Limnology listserv, though not all eventually responded. An unknown number of messages were forwarded or distributed by recipients.

A reminder email, together with the attached survey file, was sent out to those who did not respond by the initial closing date. The electronic strategy allowed for such targeted follow-up at no cost.

A total of 74 people completed the survey. One received from overseas was not included in the numerical analysis. Several others made written comments without completing the survey or indicated that, while interested, they were too busy. Comments tended to come from those who believed their views were incompatible with what they interpreted to be the general direction of the project. Notably, several had (incorrectly) interpreted the criteria as implying that

only rivers in natural or undisturbed condition could be considered of high ecological value. Where the comments extended or enhanced the attributes or their interpretation, these were incorporated into the final framework. An estimated 90 individuals either completed the survey or made comments on the project. The survey generated a considerable amount of interest among the limnological research community and river managers.

Respondent profile

Responses included in the analysis ($n = 73$) came from all States, the Australian Capital Territory and the Northern Territory. People from 15 universities and 21 different government agencies or river management authorities contributed. Other contributors came from CSIRO, the Murray-Darling Freshwater Research Centre and five different private consultancies. Table 13 shows the distribution of responses by State and categorisation by their key roles in relation to rivers. Note that many university researchers were also lecturers. Some researchers were employed in government agencies, and some consultants classed their role as researcher.

Fields of expertise of the respondents are summarised in table 14.

Table13: Respondent profile by state and key role

State/Territory	Researcher	Manager	Other	Total
ACT	6	0	0	6
NSW	7	6	4	17
NT	3	1	0	4
Queensland	9	9	1	19
SA	2	3	1	6
Tasmania	2	1	0	3
Victoria	9	4	0	13
WA	2	3	0	5
Total	40	26	6	73

Table 14: Expertise of survey respondents

Area of expertise	Frequency
Hydrology, environmental flows, modelling	6
Geomorphology	5
Aquatic ecology, limnology	18
Macroinvertebrates	14
Fish	7
Ecosystem processes	3
Floodplains/lowland rivers	6
Instream/riparian flora	5
Water quality, monitoring	9
Water/environmental management	8

Results: Attributes of rivers of high ecological value

Support for attributes

The question posed to survey respondents was as follows:

The following attributes could be used to define or describe a river of 'high ecological value'. How important do you consider each of these attributes in assessing the ecological value of a river?

Mean ratings (n = 73) of importance suggested for each attribute are shown in table 15. The highest possible rating is 10.

All the attributes suggested in the survey form were supported as important aspects of ecological value. Additional attributes were suggested by 14 respondents. These suggested additional attributes included:

- maintenance of natural variation;
- associated, dependent aquatic habitats, for example, backswamp lakes;

Table 15: Mean ratings of possible attributes for rivers of high ecological value

Criterion	Rating	Attribute
1 Naturalness	8.12	1.1 undisturbed catchment
Overall rating: 7.86	8.11	1.2 unregulated flow
	7.90	1.3 unmodified river/channel features
	7.49	1.4 natural water chemistry
	7.10	1.5 absence of interbasin water transfer
	7.84	1.6 intact and interconnected river elements
	7.58	1.7 natural temperature regimes
	8.01	1.8 natural processing of organic matter
	8.04	1.9 natural nutrient cycling process
	8.58	1.10 intact native riparian vegetation
	7.47	1.11 absence of exotic flora or fauna
	6.93	1.12 habitat corridor
	8.28	1.13 natural in-stream faunal community composition
	8.60	1.14 natural ecological processes, including energy base and energy flow through food webs
2 Representativeness	6.76	2.1 representative river system or section
Overall rating: 6.74	6.13	2.2 representative river features
	6.80	2.3 representative river processes
	7.46	2.4 representative aquatic or riparian communities

continued

Table 15: Mean ratings of possible attributes for rivers of high ecological value (continued)

Criterion	Rating	Attribute
3 Diversity and richness	5.68	3.1 diversity of rock types or substrate size classes
Overall rating: 6.79	7.42	3.2 diversity of in-stream habitats eg pools, riffles, meanders, rapids
	7.33	3.3 diversity of channel, floodplain (including wetland) morphologies
	7.36	3.4 diversity of native flora or fauna species
	7.15	3.5 diversity of in-stream or riparian communities
	7.18	3.6 diversity of floodplain and wetland communities
	7.66	3.7 diversity of endemic flora or fauna species
	5.92	3.8 important bird habitat
	7.22	3.9 high diversity of ecological processes
4 Rarity	7.26	4.1 rare or threatened geomorphological features
Overall rating: 7.83	7.90	4.2 rare or threatened ecological processes
	7.63	4.3 rare or threatened hydrological regimes
	7.49	4.4 rare or threatened in-stream hydrological processes
	7.58	4.5 rare or threatened invertebrate fauna
	7.89	4.6 rare or threatened fish or other vertebrates
	8.27	4.7 rare or threatened habitats
	7.79	4.8 rare or threatened flora
	8.63	4.9 rare or threatened communities or ecosystems
5 Special features	6.36	5.1 karst, including surface features
Overall rating: 7.40	7.93	5.2 significant ephemeral floodplain wetlands
	6.30	5.3 rivers with unusual water chemistry
	6.71	5.4 dryland rivers with no opening to ocean
	8.15	5.5 important for the maintenance of downstream or adjacent habitats such as floodplain/estuary
	6.45	5.6 important for the maintenance of karst system or features
	7.61	5.7 important for migratory species or dispersal of terrestrial species
	7.88	5.8 drought refuge for terrestrial or migratory species
	7.23	5.9 habitat for important indicator or keystone taxa

- connectivity to floodplain;
- dry season refugia for aquatic species;
- size (area or length), absence of artificial barriers (weirs, causeways and so on) which block fish migration, natural stream morphology (lack of erosion, widening and so on) and natural sediment composition (absence of siltation);
- uniqueness or 'representativeness' of this type of river system (geological, faunal, floral);
- resilience to disturbance (natural and anthropogenic);
- high scientific value, for example, lots of research into natural functions of rivers;
- high genetic diversity;
- heritage values;
- combination of highly significant ecosystem function within landscape, distinctive flow regime types and/or flow needs and existence of habitat for rare and/or threatened plants and/or animals;
- cultural significance to Australians;
- high habitat diversity at the meso or micro scale; and
- permanent springs in intermittent streams.

Box 12: Rivers nominated by survey respondents as examples of rivers of high ecological value

Sandon River	Upper Brogers Creek	Paroo River
Mitta Mitta	Tully River	Upper Noosa River
Arthur River	Goyder River	Broken River
Upper Colo River	Franklin River	Jardine River
Daly River	Hawkesbury-Nepean	Nymboida River
Upper Coomera River	Lower Ovens River	Gregory River
Tookayerta Creek	King George River	Mueller River
Acheron River	Thurra River	Daintree River
Rocky River	Baffle Creek	Gordon River
Upper Murrumbidgee	Kowmung River	Olga River
Lower Murray River	Alligator Creek	Never-Never River
Murray-Darling system	Sth Alligator River	Mulgrave/Russell
Carbo Creek	St Mary's River	O'Shannassy River
Stoney Creek	Macquarie River	Deep River
Sybella Creek	Upper Yarra River	King Edward River
Denison River	Clyde River	Lamington NP
Snowy River	Warrell Creek	
Cooper Creek	Magela Creek	

These suggestions were reviewed with reference to the distributed list and to comments provided elsewhere. Most are considered to be incorporated under, or to be specific examples of, the attributes as listed. Following the survey and review of the attributes, an amended list is provided in the final report (table 4). This list of attributes will require further evaluation and refinement based in practical assessment activities by river managers.

Suggestions for Australian rivers of high ecological value

Respondents were asked to nominate a single river which they considered to be of high ecological value. A total of 53 different rivers or river sections were suggested. These are listed in box 12.

The scale of rivers nominated ranged from upstream sections or tributaries to large rivers and even the entire Murray-Darling system. Several rivers were nominated independently by three or more individuals. These rivers include the Paroo River, Cooper Creek, Baffle Creek and sections of the Murray and Ovens Rivers. Rivers nominated by two people include the Franklin River,

Tully River, Upper Yarra, Jardine River, Thurra River, Upper Nepean and Daly Rivers. Only four respondents did not offer a river known to them and seen as of high ecological value.

Using the list of attributes, the values perceived or known for the nominated river were listed by the respondents. The most frequently mentioned attributes for all rivers put together are shown in table 16. Attributes which were less often mentioned as being important for the particular rivers nominated are shown in table 17.

A low frequency of citation does not necessarily indicate that these values are relatively less important. In fact it might be argued that they are more important because they are mentioned less frequently. Other explanations are also possible: it may reflect the tendency towards selection of the least disturbed rivers, the particular areas of knowledge of respondents, state of knowledge of some river values by respondents, or lack of information about some values generally or about some rivers. Equally, it may suggest that some discrimination between rivers is possible even from

collecting the accumulated knowledge of people who know that river well.

Eighteen respondents nominated a river but did not suggest attributes for which they considered it to be of value. This may have been as much owing to the nature of the effort required to complete this part of the survey and not necessarily indicate ignorance of values.

Results: Protecting rivers of high ecological value

Respondents were asked to indicate which of a list of possible measures might be appropriate to protect the values of the chosen river. In a number of cases, the rivers were located within a national park or other protected area and therefore alternative types of protection were not seen as necessary.

The question of protection was directed to a particular river to provide a profile of those measures which were likely to be most important across all river

types. A score was given indicating the importance of each selected protection measure. Table 18 shows the results displayed by total of all scores, ranks, average scores and numbers of high scores.

The proposed protection measures fall into four broad groups. These groupings remain generally together based on total, average or numbers of high scores. Column D shows the average score. A maximum figure would be a score of 10, meaning that every river nominated required such protection. Note that some rivers would already have the protection of, for example, legislated protection if they lay within the boundaries of a national park. Protection measures in the highest scoring group are all broadscale and require a national or coordinated approach for implementation.

The second most important group of measures must be addressed at least at regional and catchment level. In some cases, collaboration between States would be required. The third group of strategies for protection with an average score close to 6 were, perhaps,

Table 16: Attributes most commonly mentioned for nominated rivers of high ecological value (maximum possible = 73)

No.	Attribute	No. of times recorded
1.2	unregulated flow	42
1.1	undisturbed catchment	33
1.6	intact and interconnected river elements	30
1.10	intact native riparian vegetation	30
1.13	natural in-stream faunal community composition	30
1.3	unmodified river/channel features	29
1.14	natural ecological processes, including energy base and energy flow through food webs	28
1.4	natural water chemistry	27
1.7	natural temperature regimes	27
1.5	absence of interbasin water transfer	25
1.8	natural processing of organic matter	23
1.12	habitat corridor	23
1.9	natural nutrient cycling process	22
3.2	diversity of in-stream habitats eg. pools, riffles, meanders, rapids	22
3.4	high diversity of native flora or fauna species	22
2.1	representative river system or section	20
1.11	absence of exotic flora or fauna	17
3.7	high diversity of endemic flora or fauna species	17
3.3	diversity of channel, floodplain (including wetland) morphologies	16

Table 17: Attributes least commonly mentioned for nominated rivers of high ecological value

No.	Attribute	No. of times recorded
5.4	Dryland rivers with no opening to the ocean	1
3.1	Diversity of rock types or substrate size classes	4
5.1	Karst, including surface features	4
5.3	Rivers with unusual natural water chemistry	4
5.6	Importance for the maintainence of karst systems or features	4
5.7	Important for migratory species or dispersal of terrestrial species	5
3.8	Important bird habitat	6
4.2	Rare or threatened ecological processes	6
5.2	Significant ephemeral floodplain wetlands	6
5.8	Drought refuge for terrestrial or migratory species	6
2.2	Representative river features	7
2.3	Representative river processes	8
3.6	High diversity of floodplain and wetland communities	8
4.8	Rare or threatened flora	8
5.9	Habitat for important indicator or keystone taxa	8

important for particular rivers as they are mentioned relatively more often with scores of 9 or 10 compared with other measures lower in the rank order by total. The last group of measures generally focus on restoration rather than primary protection and therefore are less likely to be significant for the nominated rivers of high ecological value which were, by and large, at the less disturbed end of the range.

It is interesting to note that exercises such as restoration of riparian vegetation, which forms a substantial focus of community group activities in river management, are considered to have relatively less importance as a measures of protection of high ecological value.

The protection measures are related specifically to individual nominated rivers and therefore any deductions must be treated with caution. The rating of the importance of the measures which address the needs

of some 52 different high ecological value rivers nevertheless provides general directions for protection of riverine values.

Some 26 of the nominated rivers were already protected in some way; 40 were not protected; and a further 4 were partly protected.

Results: A desktop validation of the attributes

A follow-up survey was distributed to make some assessment of the utility of the list of attributes and the consistency with which they might be used. This offered the opportunity of rating attributes for one of six particular rivers. Rivers were selected from those which were mentioned by more than one person in the original survey. As a consequence they tended towards those rivers in more natural condition. The rivers offered were:

Table 18: Evaluation of the importance of various protection measures for nominated rivers of high ecological value

A	B	C	D	E	F	
Protection measure		Rank by total	Total	Average score	Rank by average score	No. of high scores (9 or 10)
	legislated protection of rivers	1	539	8.0	3	41
	protection of natural flow regime of unregulated rivers	2	529	8.4	1	44
	protection of riparian vegetation	3	527	8.1	2	35
	control of land clearance in catchment	4	526	7.9	4	34
	control of feral animals and non-native plant species	5	468	7.0	7	20
	integrated catchment management	6	465	7.4	5	33
	control on level or timing of abstraction of water	7	462	7.1	6	32
	control of grazing	8	457	6.9	8	24
	control of diffuse discharge into rivers	9	421	6.7	9=	20
	establishment of riparian reserves	10	409	6.7	9=	17
	avoidance of interbasin transfer	11	366	5.9	11	22
	control of point source discharge into rivers	12	366	5.7	13=	21
	control on abstraction of materials, sand, gravel	13	351	5.8	12	20
	restoration of riparian vegetation	14	336	5.7	13=	13
	control of recreational activities eg fishing, boating	15	317	4.8	16=	7
	restoration of natural flow regimes	16	288	5.1	15	17
	land buy-back	17	286	4.8	16=	7
	restoration of in-stream coarse woody debris	18	280	4.7	18	6
	removal of infrastructure such as channels, dams	19	234	4.1	19	7

the Paroo, Franklin, Upper Yarra, Cooper Creek, King George River, Upper Colo River.

Three or four responses were received for each river offered. In summary, the attributes selected by the different respondents were generally consistent. Scores for important attributes fell within the same range, plus or minus one for the great majority of attributes.

The results of this exercise suggest that the attributes are appropriate, can be applied from basic knowledge of a river system, and are generally applied in a consistent way.

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