Final Report
Project R2004
Development of a Framework for the Sustainable Rivers Audit

Appendix 1

Review of existing programs that measure and report river health in the Murray-Darling Basin

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1 Introduction

The ‘‘Scope of the Sustainable Rivers Audit’’ (Cullen *et al*. 2000) recommended that the development of the Sustainable Rivers Audit (Audit) and Comprehensive Sustainability Assessment (CSA) should be comprehensive, and build on and add value to what is being already collected in State and National programs. Consequently a major challenge in developing the Audit and CSA is the identification of common threads across the range of assessment programs that could contribute to meeting the requirements of the Audit. The purpose of this review is to collate information on existing State, Territory and Commonwealth approaches to assessing river health. This information will be used to guide the development and trial of Audit indicators throughout this project.

The scoping document identified five ecological themes for which indices would be developed to comprise the Audit; fish, macroinvertebrates, hydrology, physical habitat and water quality. In addition the CSA would include further habitat structure and biological measures. Proposed biological themes included measures on aquatic invertebrates and fish communities. Water quality indices might include measures on parameters such as total phosphorus, electrical conductivity, turbidity and pH and other water quality parameters. The habitat structure indices were proposed to include measures on connectivity, riparian conditions, woody debris in streams, geomorphic and wetland elements. Other biological elements notionally identified for inclusion in the CSA were measures on algal growth and blooms, riparian vegetation, aquatic plants, aquatic and riparian weeds, wetland area and condition, and water birds.

In the Audit and CSA scoping document the concept of river health has a specific focus. Although this term has been used to denote attainment of a range of values in relation to rivers, in the Audit and CSA the scoping document identifies river health to be synonymous with ecological integrity. The working definition of river health used in this review is:

> the degree to which aquatic ecosystems support and maintain processes and a community of organisms and habitats relative to the species composition, diversity, and functional organisation of natural habitats within a region.

The initial starting point for this review was the suite of assessment programs identified in the scoping document. Advice was sought from State, Territory and Commonwealth representatives on additional programs that were specifically aimed at assessing “river health” or at the indicators recommended for inclusion in the Audit and CSA (see Table 1). In the course of this review the intention has been to provide an overview of the programs that could potentially contribute elements to the audit. It was not intended to produce an exhaustive review, particularly as recommendations on specific indicators to be used in the audit will come from subsequent tasks under this brief (Tasks 3-7). In particular, it should be noted that monitoring methods reviewed in this document are mainly Federal and State government programs and that considerable data has been collected by local councils and community groups.

Table 1 Programs specifically monitoring "river health"

Jurisdiction	Specific river health programs	Funding Status
Queensland	• Water Allocation Management Planning (WAMP) ecological assessment • State of Rivers approach	To be advised
New South Wales	• Integrated Monitoring of Environmental Flows (IMEF) • Pressure/ Biota/ Habitat Approach (PBH) • NSW Rivers Survey (IMEF rivers only) • Stressed Rivers Assessment • State of Rivers approach	• till June 2001 – likely to be ongoing • till June 2001 (trials only) • till June 2002 • complete – no funds • no funds
ACT	No specific program but data relevant to the Audit and CSA has been collected.	Not applicable
Victoria	• Index of Stream Condition (ISC)	Streamside zone and physical form – ongoing (CMAs) The Water quality and hydrology – ongoing (State agencies) Aquatic life – possibly ongoing (State agencies)
South Australia	No specific program but data relevant to the Audit and CSA has been collected.	Not applicable
Commonwealth	• National State of the Environment Reporting (SOE) • Assessment of River Condition (ARC) • Wild Rivers • National River Health Program (NRHP)[1] • Waterwatch	Note 2 TBA Note 2 Monitoring has ceased. Collation of data continuing under NHT to June 2002 NHT funded to June 2002
Murray-Darling Basin Commission	• MDBC Water Quality Monitoring program[1]	Ongoing

Note 1: These programs are joint State, Territory, Commonwealth initiatives.
Note 2: These programs are not primary sources of data collection. Compiled data from other primary data bases are collated to comply with the requirements of these Programs.

In addition to the programs identified above, there is a range of programs monitoring indicators identified for inclusion in the Audit, particularly hydrological, water quality and fish monitoring. These programs occur in each of the States and Territories in the Murray-Darling Basin and provide a widespread and long-term data set.

2 General description of programs

2.1 Index of Stream Condition (ISC)

Where used: Victoria
Agency responsible: Department of Natural Resources and Environment
When developed: 1995
Principal focus: Measurement of river environmental condition

Principal documentation:

An Index of Stream Condition: Reference Manual (White and Ladson 1999a)
An Index of Stream Condition: Field Manual (White and Ladson 1999b)
An Index of Stream Condition: Catchment Manager's Manual (White and Ladson 1999c)
An Index of Stream Condition: User's Manual (in preparation).

The ISC was developed as a tool to provide a holistic measure of river health that could be used by managers and the community to benchmark river condition, assess the effectiveness of rehabilitation and to set priorities for management action.

The intention of the ISC is to provide measures of the health of both the aquatic biota and the drivers that may impact on the health of the biota.

2.2 Integrated Monitoring of Environmental Flows (IMEF)

Where used: NSW

Agency responsible: Department of Land and Water Conservation (DLWC)

When developed: 1998

Principal focus: Ecological responses to environmental flows in regulated rivers

Principal documentation: Not yet available (Design report awaiting approval to publish; first major technical report in preparation)

The IMEF approach was established as part of the State water reform package to assess the ecological responses to improved flows. A hypothesis driven approach was taken, with ecological responses to environmental flows being predicted in a series of testable hypotheses. Nine priority hypotheses are being tested in one or more river valleys. The intended outcomes of the project are an understanding of the existing state and trends over time in hydrology, morphology and ecology in the major river systems, and evaluation of the likely contributions of environmental flows to these changes through the construction of predictive models.

2.3 Pressure/ Biota/ Habitat Approach (PBH)

Where used: NSW

Agency responsible: Department of Land and Water Conservation

When developed: 1999

Principal focus: Conservation value, ecological health and pressures on ecological health for unregulated rivers

Principal documentation: Not yet available (Report on trial implementation being drafted for review commencing February 2001)

The PBH approach is a general framework that has been tested through a multi-faceted, rapid procedure for the assessment of ecological conservation values and ecosystem stress in small and medium size streams. The PBH approach uses three kinds of variables: human generated pressure on rivers, components of the biota, and aspects of bio-physical habitat. These variables are used to generate indicators of richness, rarity, native abundance, alien biota, sensitivity, physical structure, water extraction and water quality. These indicators are wrapped up into indices of conservation significance, biological stress (or condition) and stressors. It is explicitly designed to provide information for

management prioritisation, for strategic river management by describing the properties of river systems and identifying key issues, and for general performance monitoring/environmental auditing. The PBH approach has been trialled by DLWC and the trial results will be reviewed in early 2001.

2.4 State of Rivers (also called Riverine Habitat Audit Procedures – RHAP)

Where used: Queensland, more recently NSW

Agency responsible: Queensland Department of Primary Industry (now Department of Natural Resources)

When developed: 1993

Principal focus: Assessment of riverine habitat

Principal documentation:

> Anderson, J.R. (1993*) 'State of the Rivers' Project: Report 1. Development and Validation of the Methodology.*
> Anderson, J.R. (1993) *'State of the Rivers' Project: Report 2. Implementation Manual.*

The State of the Rivers assessment procedure was developed to provide the Queensland Department of Primary Industry (DPI) with a tool to assess physical and environmental health of rivers and streams. DPI required objective information on river condition to participate in the integrated catchment management program adopted as a State policy. Although the DPI already had programs for monitoring water quality and stream flow, these were seen as restricted in scope and a wider assessment with an ecosystem focus was required. Data is collected largely by field survey.

This approach focuses on collection of habitat data (geomorphology, and vegetation). There are intentions to integrate hydrology, water quality and biota assessment into this approach.

Although this approach provides a snapshot of riverine condition, repeated sampling could be used to assess trends, e.g. the Maroochy River has been resampled 5 years after the initial sampling.

2.5 MDBC Water Quality Monitoring program

Where used: Murray-Darling Basin

Agency responsible: Murray-Darling Basin Commission

When developed: 1978

Principal focus: Water quality in River Murray

Principal documentation*: The Murray-Darling Basin Commission Water Quality Monitoring Program* (internal document). Three water quality data reports 1988/89; *Physico-chemistry, Macroinvertebrates, Phytoplankton*.

Under its charter the MDBC is required to monitor the water quality of the River Murray and the lower reaches of its tributaries. The MDBC established a monitoring program in 1978 which continues to the present. Three types of data are collected; physico-chemical, phytoplankton and macroinvertebrate data. Actual monitoring is conducted by State agencies; NSW Department of Land and Water Conservation, and SA Water, or by consultants; Australian Water Technologies Victoria.

2.6 National State of the Environment Reporting (SOE)

Where used: Australia

Agency responsible: Environment Australia

When developed: 1996

Principal focus: Physical, chemical, biological and socio-economic condition of rivers

Principal documentation:

Core Environmental Indicators for Reporting on the State of the Environment. ANZECC SOE Reporting Task Force, March 2000.

Environmental Indicators for National State Of The Environment Reporting: Inland waters. State of the Environment Environmental Indicator Report. Peter G. Fairweather and Gillian M. Napier, CSIRO Land and Water

National SOE reporting is undertaken to provide information on the environment as a foundation for ecologically sustainable development. It allows regular reports on indicators of changes in environmental condition and provides a means of monitoring the performance of government policies against actual outcomes.

National SOE reporting is conducted approximately every five years. An initial assessment was conducted in 1996, and the second report is planned for completion in 2001. Reports are largely compiled from data collected by other State and Federal agencies.

2.7 Water Allocation Management Planning (WAMP) ecological assessment

Where used: Queensland

Agency responsible: Department of Natural Resources

When developed: Varies with Basin

Principal focus: Ecological condition of rivers in a Basin in relation to flow

Principal documentation: WAMP documentation specific to Basin

The purpose of this process is to provide an ecological baseline for a catchment principally from the perspective of the impacts that flow abstractions or diversions have caused, or future abstractions or diversions may cause. The WAMP covers all streams in a catchment but focuses on the main trunk. Data is normally acquired from other programs though baseline and survey type data may be acquired during the WAMP process to supplement existing data. The WAMP process for each basin is specific to that basin and so the outputs may differ from those of other basins.

2.8 Assessment of River Condition (ARC)

Where used: Australia

Agency responsible: National Land and Water Audit office

When developed: In development

Principal focus: Ecological health of rivers

Principal documentation: Not yet available

The ARC project will provide an overarching view of the quality of rivers across Australia. It will do so by drawing together information from river and catchment attributes. It is intended to be used as both a measure of river condition and as a tool to

identify management options for rivers. Outputs from the project will be a system for assessment of river condition, and, using that system, an Australia-wide assessment of waterway condition.

2.9 NSW Rivers Survey

Where used: NSW

Agency responsible: NSW Fisheries and CRC Freshwater Ecology

Principal focus: Ecological status of fish in NSW rivers

When Developed: 1995-1997, development on-going as part of IMEF (note: not in inter-state catchments)

Principal documentation:

- *Fish and Rivers in Stress. The NSW Rivers Survey*. (1997) Harris JH and Gehrke PC (eds.) NSW fisheries Office of Conservation and the CRC for freshwater Ecology.
- *Large-scale assessments of river health using an Index of Biotic Integrity with low-diversity fish communities* 1999. Harris JH and Silveira R. *Freshwater Biology* **41**, 235–252.
- *Methods manual for IBI* (in preparation)

The NSW Rivers Survey was a collaborative project between NSW fisheries and the CRC for Freshwater Ecology with five specific objectives:

- Study the distribution and abundance of native fish of NSW rivers
- Determine the abundance, distribution and habitat use of carp and other alien species in NSW rivers
- Develop understanding of the ecological effects of river regulation and establish hypotheses for further study of environmental flows
- Establish and test a standardised predictive model for monitoring river health using fish community assessment
- Establish a standardised survey structure for use in other studies.

The NSW River Survey also provided data for an assessment of the performance of the Index of Biotic Integrity (IBI) as a river-health indicator. The IBI analysis produces relative assessments, rather than an evaluation of absolute condition, which can be used to assess spatial and temporal changes in the relative health of rivers within regions and river types. This IBI analysis may provide a baseline for monitoring river health using fish. NSW Fisheries recommends further analysis of IBI as well as other interpretative models of fish survey data before indicator measures for the Audit are endorsed.

2.10 Wild Rivers

Where used: Australia

Agency responsible: Australian Heritage Commission

When developed: 1998

Principal focus: Assessment of ecological and landscape values of rivers

Principal documentation: *The identification of wild rivers: Methodology and database development*. Stein, J.L., Stein, J.A. and Nix, H.A. A report for the Australian Heritage Commission by the Centre for Resource and Environmental Studies, Australian National University.

The Wild Rivers project arose from a commitment by the Commonwealth to assist State and Territory agencies to identify rivers in near pristine condition, to encourage protection and proper management of their catchments. The approach uses data on human disturbances within a catchment and to the river's channel directly, to assess the potential of a river to be a "wild river". Elements chosen for inclusion include both those important to ecosystem functioning, and others of a more visual landscape basis. Although the focus of the project was originally on near pristine rivers, the approach is applicable to rivers across the entire spectrum of degraded to pristine.

The assessment of wild rivers is based on a modelling approach using remotely sensed and cartographic information.

2.11 QLD EPA Guidelines for Waterway Conservation/Ecological Values

Where used: Queensland

Agency responsible: Queensland Environment Protection Agency

When developed: In development

Principal focus: Assessment of ecological values

Principal documentation: *Interim Guideline for: Describing Conservation Values of Waterways*. May 2000. Draft report on testing the methodology in the Burnett River catchment. Scoping Paper on National Ecological Value Guideline (L&WA Project QEH3).

The purpose of the Conservation/Ecological Value Guidelines is to provide a systematic, comprehensive and flexible method to describe the ecological values of waterways and floodplains. The Guideline is designed to support both conservation planning and development assessment. This method has been trialled in the Burnett catchment. with the results of the trial yet to be evaluated.

2.12 National River Health Program (NRHP)

Where used: Australia

Agency responsible: Environment Australia

When developed: 1994 - present

Principal focus: Assessment of the ecological status of streams using in-stream macroinvertebrate fauna

Principal documentation: *River Bioassessment Manual*, February 1994.

The National River Health Program arose to support the environmental component of the COAG Water Reform Framework. The objectives of the program are to:

- Provide a sound information base on which to establish environmental flows
- Undertake a comprehensive assessment of the health of inland waters. Macroinvertebrates were used as the initial main indicator of river health but other potential indicators, e.g. fish and diatoms, were assessed under the NRHP.
- Consolidate and apply techniques for improving the health of inland waters.

As part of this program the first Australia wide assessment of the health of aquatic systems was conducted at approximately 6000 sites across Australia.

2.13 Stressed Rivers Assessment

Where used: NSW

Agency responsible: Department of Land and Water Conservation

When developed: 1997 to 1999

Principal focus: Assessment of hydrologic stress and conservation status

Principal documentation: No general description of methods is available. However, assessments compiled for individual river basins have followed a similar approach and include descriptions of methods.

The Stressed Rivers program arose from the NSW Government Water Reforms, with the intention of providing information on the environmental stress, particularly hydrologic, of unregulated rivers. High priority catchments were identified where demand for water exceeds supply, where the water environment is degraded or the catchments have high conservation value. This information was to be used to guide management priorities and policies. Stressed Rivers Assessment relies on information already collected on hydrology, land use, conservation issues etc, and does not involve field sampling.

2.14 Waterwatch

Where used: Australia

Agency responsible: Coordinated nationally by Environment Australia, with State and Territory Coordinators. On ground activities conducted by an extensive network of community groups.

When developed: 1995 to present

Principal focus: Community assessment of stream ecological and water quality status.

Principal documentation: No general description of methods is available. Individual Waterwatch groups, regional bodies and State/Territory bodies determine their own approaches and produce their own protocols and communication. Nevertheless efforts are made to coordinate between groups so that there is a degree of consistency in the type of data collected and the methods used. State/Territory manuals are available.

The Waterwatch program differs from others in this review in that, although funded to an extent by the Natural Heritage Trust program, it is conducted almost entirely by the community. The Waterwatch program was developed to provide community members interested in the status of their streams with techniques they could use to monitor stream condition. It is recognised that data collected under this program varies in quality and consistency depending on the expertise of the different Waterwatch groups. It is included here because it has been responsible for collection of a vast body of data across the Basin, and demonstrates the level of and location of community interest in stream condition in the Basin. As an indication of the level of sampling effort involved, in 1999 in NSW there were 15,138 people in the Waterwatch program and 981 sites were monitored.

2.15 Other State and Territory water quality, hydrology and fish monitoring programs

Where used: All States and Territories

Agency responsible: Various

When developed: Various

Principal focus: Monitoring of particular variables

Principal documentation: Commonly in-house documentation or undocumented

All States and Territories have monitoring programs directed at measuring particular variables that would contribute to a more comprehensive assessment of river health. In some States monitoring programs provide the information used in more comprehensive "river health" assessments and reports.

3 Cost

At this stage of the development of the Audit and CSA it is not useful to conduct a cost effectiveness assessment of different assessment programs undertaken throughout the Basin. It would also be very difficult to achieve and is likely to provide unreliable information due to issues such as cross-subsidy of indicator measurement in existing programs. The purpose of the development of an audit framework is to identify appropriate elements from different programs that together meet the Audit and CSA requirements. After development of detailed conceptual models, leading to recommendations on appropriate indicators, we may need to consider cost effectiveness of alternative approaches to measuring an indicator; for example, in the situation in which an indicator has not been measured in a particular State. It was not intended that an entire program would be recommended for adoption on the basis of its cost effectiveness.

4 Spatial classification of rivers

The Audit and CSA will be reporting at a "river valley" scale using data acquired at finer spatial scales within each river valley. For the purposes of this study, river valleys were taken to be the AWRC basins that occur in the MDB, slightly modified to remove anomalies such as catchments being divided by State boundaries, e.g. the Warrego. One of the responsibilities of the scoping project is to review and provide recommendations on the spatial distribution of sampling sites. It is important for the Audit and CSA that data collected within a river valley should provide reliable spatial measures of indicators within the valley and perhaps within functional zones in each valley. In consequence, an important component of this process will be identification of functional process zones throughout the Murray-Darling Basin.

In identifying an appropriate sampling framework it is useful to consider the assessing/reporting frameworks used by different programs. This should include consideration of any river classification adopted, and how sampling sites were located within "reaches" or "zones".

In this section the term "reach" is used for the basic component of the river for which data is collected and an assessment made. For some methods of assessment the term "reach" is used for this component. In others, terms such as "segment", "sub-section" or "geomorphic unit" are used, and the term "reach" may be used for a different purpose. Most programs classify rivers into reaches or equivalent for sampling purposes. Additionally, some programs classify rivers into broader categories to assist stratified sampling. Program details are summarised in Table 2.

4.1 ISC

Reaches are defined as sections of river typically 10-30 km long and relatively homogeneous in terms of their hydrology, physical form, streamside vegetation, and water quality or aquatic life.

Initially the ISC proposed that a "representative" measuring site be identified in each reach, and five transects be assessed at that site. Analysis of the representative nature of these assessments led to the evolution of a modified sub-sampling schema in which three measuring sites are randomly identified within each reach, and three transects assessed at each site. This schema was found to be the optimum balance between reliability of results and cost.

4.2 IMEF

The IMEF has an experimental focus with nine priority hypotheses being tested in one or more river valleys. Site selection procedures varied across the different studies, but generally followed stratified random designs. In some cases, sites were selected for strategic reasons (e.g., weir pools where cyanobacterial blooms have been reported). No overarching river classification schema was determined for use by the IMEF program.

4.3 PBH

PBH uses the geomorphic River Styles™ approach to identify reaches for stratified random site selection. The river styles approach is based on the critical role played by fluvial geomorphology, hydrology and vegetation in determining the physical template of rivers. It provides a technique for characterising rivers at three nested spatial scales; catchment, reach and geomorphic unit. The catchment is the largest scale and determines the boundary conditions within which a river operates. The reach is a length of channel within which there is a characteristic channel form. The geomorphic unit, the smallest scale, is the basic building block of a river system and within which basic processes operate to create the channel and floodplain morphology. The identification of the components of a river style requires detailed field mapping. This contrasts with many other approaches used to define sections of river.

4.4 State of Rivers

The State of the Rivers approach identifies units for reporting, called sub-sections, in a two stage process. The first stage is identification of homogeneous "sections" based on sub-catchment structure / stream order, natural and artificial barriers and obstructions, altitude, slope, stream gradient, geology, soils, catchment land use, climate, stream permanence, point sources, diversions and other major discontinuities. Sections could include several tributaries within a catchment. This stage is completed using maps and GIS tools.

The second stage involves identification of "sub-sections", formed by the division of sections at each tributary junction or other discontinuity of land use, stream slope etc.

Once sub-sections have been determined, the river is reconnoitred using maps and on the ground to identify a site that is representative of the habitats and conditions within the sub-section. Initially one site is identified within each sub-section, but if the study design permits, more sites can be allocated.

4.5 MDBC WQ Monitoring program

Reaches are not explicitly defined under this program. Sites have been identified based on areas of particular interest or with perceived problems.

4.6 National SOE

Reaches are not explicitly defined under this program.

4.7 WAMP ecological assessment

Major rivers and streams in the study area are divided into relatively homogeneous river reaches on the basis of their natural characteristics, management regimes, and location of gauging stations in order to provide a spatial reference framework. Reaches appear to range in length from 10 to 80 km.

4.8 ARC

Reaches are defined as sections of river with relatively homogeneous geomorphology. Reach boundaries are determined from a digital elevation model at points where stream power, a major determinant of geomorphology, changes (usually increases) by more than a factor of two. Two other rules are followed; in the extreme part of a catchment a reach does not commence until it has a contributing catchment of at least 50 km^2, and the minimum length for reaches is 5 km.

For most ARC components, assessment is conducted for all 250 m sections of a reach, and aggregated to arrive at a reach assessment.

4.9 NSW River Survey

Reach selection was undertaken as staged process. For the MDB, rivers were firstly classified into one of four main types: unregulated lowland, regulated lowland, slopes (300-700 m altitude) and montane. River reaches were selected from within these river types. The definition of river reach varied between river type; in lowland rivers it was between 20 and 50 km length of river and all slopes and montane reaches were 10km long. Minimum catchment size criteria were set which required a catchment to be larger than 20 km^2 and have a stream order of 3 or greater.

A "constrained random" selection procedure was developed to select river reaches for sampling. To ensure a wide representation of river types, rivers were grouped in to large, medium and small rivers. A constraint on the random selection of reaches was that a maximum of three replicate reaches could be selected in total for each large river, two for each medium river and one for each small river. A second constraint was that a minimum of three reach lengths had to separate selected reaches, except for regulated reaches where a minimum of one reach length was required.

Within each randomly selected reach, a sampling site was chosen on practical reasons, usually access, provided the site appeared representative of that reach. Grossly degraded sites were excluded and another site chosen, however these excluded sites were recorded and assessed independently using a less intensive method.

4.10 Wild Rivers

In this program, each river or stream on the AUSLIG stream coverage is divided into "stream sections" comprising either a first order tributary, or a section of the mainstream

between tributary junctions. Each reach is partitioned into 280 m segments, an assessment is calculated for each segment and aggregated to give the reach assessment.

4.11 QLD EPA Guidelines for Waterway Conservation/Ecological Values

Waterways are classified under this approach using criteria that support the assessment of three of the ecological value criteria; rarity, representativeness and naturalness. Consequently waterway classification is based on biogeography, hydrology, habitat, and aquatic flora and fauna. The classification was trialled in the Burnett River catchment, assessing both intuitive and numerical classifications and adopting the latter.

4.12 NRHP

This program did not explicitly define reaches within which sampling sites should be located. Also, although a site sampled under this program is generally taken to be a measure of the condition of the reach some distance upstream and downstream of the site, the program did not seek to define the length of reach that a site condition represents.

Table 2 Spatial reporting scale of river health approaches

Approach	Basic reporting unit	Size
ISC	No classification of catchment into broad zones. "Reaches" defined as relatively homogeneous river sections in terms of hydrology, physical form, streamside vegetation, and water quality or aquatic life.	10–30 km
IMEF	Fish monitoring, wetland replenishment, river organic matter and biofilm studies: Rivers divided into relatively homogeneous "segments" based on regulation, abstraction and geomorphology. Most other studies: Use key water quality sites; reaches not defined.	Spatial reporting scale not specified.
PBH	Uses River Styles™ approach and other information. Classifies sub-catchments into "zones" primarily on the basis of longitudinal changes in channel and planform geometry, topography, hydrology, land use and vegetation.	Zones approximately 5–20 km, however spatial reporting scale for PBH not specified.
State of Rivers	No classification of catchment into broad zones. "Sub-sections" defined by tributary junctions or discontinuities of land use, stream slope, barriers, point sources, geology, soils etc.	1–3 km
MDBC WQ Monitoring program	Not defined	-
National SOE	Not defined	-
WAMP ecological assessment	"Reaches" defined as relatively homogeneous sections in terms of their natural characteristics and management regimes.	Approximately 10–80 km.
ARC	No classification of catchment into broad zones. "Reaches" - Simple geomorphological approach adopted.	5–100 km
NSW River Survey	Catchments classified into four categories based on altitude (<300, 300-700, >700m) and whether they are regulated. Within the two lowland categories, reaches were determined based on river characteristics. The slopes and montane zones were divided up into 10 km reaches.	Lowland: 20–50 km Slopes and montane : 10 km
Wild Rivers	"Reaches" defined as sections between tributaries	Approximately 10–100 km

QLD EPA Guidelines for Waterway Values	Conservation mapping units (used to assign data to a stream unit)	Distance varies (1–66km for the Burnett trial)
NRHP	Habitats within sites	Approximately 100 m
Stressed Rivers Assessment	Assessments on sub-catchments, not reaches. Sub-catchments defined on a hydrologic basis also considering geology, terrain and jurisdictional boundaries.	100–40,000 km^2
Waterwatch	Sites of interest	Approximately 100 m

4.13 Stressed Rivers Assessment

The scale at which this program produces assessments varies across the MDB. In the northern parts of the Basin assessments are produced for entire AWRC Basins, e.g. Paroo. In the southern parts of the Basin assessments are at a finer spatial scale, with AWRC Basins divided into sub-catchments on the basis of hydrology (primary), land use, government boundaries etc.

4.14 Waterwatch

Reaches are not explicitly defined under this program. Sites have been identified based on areas of particular interest or with perceived problems.

4.15 Other monitoring programs

Usually reaches are not defined under these programs. Sites are commonly located at problem areas or sites of interest.

5 Components measured by river health programs

One of the principles guiding development of the Audit and CSA that emerged from the scoping process was that the audit should build on what is being collected already in State and National programs. The following section describes the data used by different programs with an emphasis on measures identified for inclusion in the Audit and CSA. Until the detailed development of conceptual models is completed and the indicators finalised, it will not be possible to identify exactly what State, Territory and National data already available would form part of the audit.

5.1 ISC

The ISC comprises five sub-indices, each composed of a set of parameters or key indicators.

Hydrology:

- hydrologic deviation (Amended annual proportional flow deviation (AAPFD) – i.e. the sum of the monthly deviation of current from natural, divided by the average monthly flow,
- percentage of the catchment that is urbanised,
- presence of a hydroelectric dam in the catchment.

Physical form:

- Bank stability
- Bed condition
- Presence and influence of artificial barriers
- Instream physical habitat

Streamside zone:

- Width
- Longitudinal continuity of vegetation
- Structural intactness of vegetation
- Cover of exotic vegetation
- Condition of billabongs
- Regeneration of native species

Water quality:

- TP, NTU, EC, pH

Aquatic life:

- SIGNAL macroinvertebrate rating
- AUSRIVAS score

5.2 IMEF

The IMEF is based around a series of experimental studies. It is useful to describe the data collected for the main studies.

Bloom suppression and flushing

- Phytoplankton
- Water quality
- Light regime
- Stratification

Wetland replenishment

- Water quality
- Vegetation
- Macroinvertebrates, fish, frogs, birds

Conditioning Stony Beds

- Biofilm characteristics
- Macroinvertebrates
- Stable isotopes
- Water quality

Wetting of Terrestrial Organic Matter

- Organic carbon characteristics
- Microbial characteristics
- Zooplankton
- Macroinvertebrates

Rehabilitating fish communities

- Fish
- Physical habitat

All studies

- Water regime

5.3 PBH

Full details of this method are not yet available as the approach is still in the review phase. Interim components of the assessment include;

Biota

- Diatoms, macrophytes, riparian vegetation, macroinvertebrates, fish

Water quality measures

Water use data

Physical habitat and structure measures

5.4 State of Rivers

The State of the Rivers approach has been applied to a number of catchments in both Queensland and NSW. The attributes measured in some catchments have differed slightly from those in the original manual (set out below) as regional authorities have adapted the technique to meet their management requirements.

Reach environment condition: Assessment of land adjacent to stream. Includes land use, vegetation, floodplain features, tenure. Also includes a measure of the water level.

Channel habitat diversity: This measure assesses the range of channel habitats such as waterfall, rapid, riffle, glide, run, pool, backwater, etc., in a reach.

Bed, bank and bar condition: Distribution of bars, stability of banks and bed, restriction to fish passage.

Vegetation: Aquatic and riparian vegetation recorded in terms of percentage cover, structure and presence of key species. The riparian zone is defined subjectively on site.

Aquatic habitat: This attribute is assessed in terms of the diversity of in-stream habitat types: logs, branches, leaves etc.

Scenic, recreational and conservation values: This measure includes an assessment of recreational opportunity, scenic quality and conservation status of the stream.

5.5 MDBC Water Quality Monitoring Program

This program has been in operation since 1978. During this time there have been significant changes in the program, e.g. inclusion of a macroinvertebrates measure. The components below are those currently monitored under the program.

- Physical and chemical variables (TP, EC, Turbidity, pH; nitrogen, major anions and cations, trace metals)
- Phytoplankton
- Macroinvertebrates (using an artificial substrate technique)

5.6 National SOE

The National SOE identifies a suite of indicators which meet its assessment requirements (listed below). The majority of the data which comprises the SOE is not collected by Environment Australia, the Commonwealth agency responsible for completion of the National SOE. Nor are the chosen indicators constrained by the existence of data; instead they comprise an ideal for which data may not have been collected.

- The proportion of each catchment under deep-rooted vegetation.
- The ratio of water use to catchment yield.
- The location and number of point source discharges into inland waters, including the type and load of materials discharged.
- Salinity levels in surface waters.
- Exceedences of ANZECC water quality guidelines for a suite of (unspecified) microbiological, bacterial and chemical parameters. (Note: exceedences are assessed against a range of uses, stock watering etc, not solely ecological integrity.)
- Incidence of freshwater algal blooms.
- Percentage of streamlength with riparian vegetation, its width and quality.
- Assemblages of macroinvertebrates as assessed by AUSRIVAS.
- Extent and condition of wetlands.
- Status of freshwater fishes and crustacean stocks.

5.7 WAMP ecological assessment

Although the actual approach taken for the ecological assessment has differed between basins, it is possible to identify elements generally common to WAMP ecological assessments.

Geomorphological assessment: Based on components such as channel morphology (size, shape, substrate), hydraulic habitat and sediment transport processes. A reference approach is used with reference condition being determined from historical photographs, site inspections, hydrological data and inference.

Riparian and aquatic vegetation: Vegetation was assessed on the basis of species richness, total abundance, and presence of weeds. Vegetation assessments were site-specific and were not necessarily applicable over the length of a reach.

Aquatic macroinvertebrates: Condition was determined from data collected as part of the NRHP program. Six indices have been used: taxonomic richness, sensitive (PET) taxa, SIGNAL index, AUSRIVAS scores, functional feeding groups, and flow velocity and substrate preference groups.

Fish communities: Condition was determined from a review of existing data. Criteria used in assessment included the total number of native species present within a reach, the ratio of the number of species observed versus the total number of species expected within a reach (as determined from historical information, comparisons with nearby streams and position in catchment), and proportion of the total number of individuals collected at a given site which are native species.

Water quality: Condition was assessed based on previous reports and existing data.

Hydrological measures (for example):

- Daily Flow
- Annual Flow
- Mean Annual Flow
- Median Annual Flow
- Coefficient of Variation of Mean Annual Flow

- Annual Proportional Flow Deviation (APFD).
- Annual Recurrence Interval (ARI) Flow Event Analysis - a measure of the change in size of floods of a given recurrence interval.
- Maximum Spell Duration - duration of the maximum dry spell
- High Flow Duration – percentage of days with flows above a certain threshold.
- Medium Flow Duration – percentage of days with flows above a certain threshold
- Low Flow Duration – percentage of days with flows above a certain threshold
- No Flow Duration – percentage of days with flows above a certain threshold

Wetlands and Floodplains
- Condition assessment
- Condition assessment under proposed water development scenarios

Integrated Monitoring
This program will look at different indicators, to be first trialled in the Condamine-Balonne Basin starting 2001, in relation to changes in flow regime while accounting for other influences such as land use.

5.8 ARC

Biota assessment:
- Macroinvertebrates - AUSRIVAS score
- Fish (not available in initial assessment)
- Algae (not available in initial assessment)
- Macrophytes (not available in initial assessment)

Hydrological assessment:
- Mean Annual Flow
- Deviation from mean annual flow
- ARI Flow Event Analysis
- Change in seasonal amplitude
- Change in seasonal periodicity

Water quality assessment:
- TP, TN, NTU, toxicants

Physical habitat assessment:
- Riparian vegetation condition
- Geomorphological condition
- Connectivity of reaches

Catchment disturbance index:

Measure of anthropogenic activities with the potential to impact on stream condition; principally land use and catchment infrastructure.

5.9 NSW River Survey

Fish:
- All fish caught counted and identified to species
- Catch or subsample measured for length to nearest mm
- Each fish examined visually for disease, parasites and abnormalities

Habitat Assessment:
- Water Quality - dissolved oxygen, pH, conductivity, turbidity and temperature

- Subjective grading system for flow, depth, width, substrate, vegetation cover, level and turbidity

5.10 Wild Rivers

Catchment characteristics:

- Land use
- Point sources
- Settlements (a measure of the extent of urbanisation of the catchment)
- Infrastructure

In stream characteristics:

- Impoundments
- Flow diversions
- Levees

5.11 QLD EPA Guidelines for Waterway Values

Naturalness: An assessment of the natural State of the river in terms of its biota, habitat, water quality, riparian zone, hydrology, catchment condition, and ecological processes.

Representativeness: As assessment of how representative the reach is in terms of its geomorphology, hydrology, riparian zone and biota.

Diversity: An assessment of the diversity of the river in terms of its biota, geomorphic and habitat components.

Rarity: Presence of rare or threatened biota, habitats or geomorphological features.

Special features: Special features that distinguish the river.

5.12 NRHP

Biota: AUSRIVAS score and SIGNAL score

Habitat: Varies between States and Territories

Queensland — Riparian vegetation, geomorphological condition
NSW — Not assessed
ACT — Riparian vegetation, geomorphological condition
Victoria — Riparian vegetation, geomorphological condition
SA — Riparian vegetation, geomorphological condition

Water quality: Range of variables including TP, TN, EC, NTU

Hydrology: Basic measures of flow, e.g. velocity

5.13 Stressed Rivers Assessment

Indicators common across the unregulated sections of the Basin (not including the Barwon Darling River) were:

Proportion of water extracted
Band, bed, bar stability
Riparian and aquatic vegetation
Structures in the channel

Note: this program was a desktop collation and interpretation of existing information.

5.14 Waterwatch

Parameters measured vary from region to region and with the expertise of the group. However, the following variables are measured in most programs:

- Habitat

- Macroinvertebrates
- pH, nitrate, phosphate, temperature, turbidity, dissolved oxygen, conductivity

5.15 Other monitoring programs

There are a number of other programs that measure water characteristics in streams across the Basin. They range in scale from samples collected at a few sites for a specific purpose, to multiple site monitoring programs that have been operating over a considerable period. The parameters measured also range enormously. In addition to this level of complexity, most water monitoring programs undergo more or less continual change in response to our understanding of processes, resources available, new analytical procedures and changes in agency responsibilities. Here we focus on three groups of measures identified as part of the Audit or CSA: water quality, fish, hydrology.

5.15.1 Water quality

Water quality measurements comprise one of the most complex suites of data in the Basin. The data presented here are intended to provide only an indication of the extent of water quality data across the Basin. There is a wide range of other data collected by State and Territory agencies across the Basin which may potentially be of use in the Audit or CSA. However, it is not useful to explore these extensive data coverages until we have a better idea of the water quality indicators that will be included.

The data presented here have been taken from the suite of water quality sites identified by the National Land and Water Audit as suitable for assessing water quality. In this process the Audit adopted stringent criteria to identify those water quality monitoring sites at which the data records were complete enough, and methods used robust enough to warrant inclusion in a national water quality database:

- There should be data for one or more of the parameters EC, pH, TP, TN, NTU or faecal coliforms.
- Standardised and recognised sampling, preservation and storage techniques were used.
- Laboratories undertaking the chemical analyses were NATA registered for that analysis (Waterwatch data was not included).
- Data was verified to ensure that transcription errors and database errors were removed before processing.
- A minimum of three years data with a monthly sampling interval is required.

The above requirements provide a rigorous though realistic filter with which to view the plethora of water quality data that has been collected in the Basin. We should not overlook the fact that it produces a subset of the highest quality data from a much larger data set.

5.15.2 Hydrology

Hydrological records have been kept by all States and the ACT at a number of gauging stations in the Basin. As with water quality monitoring, records for different stations are of different length and have been captured using different methods. This review uses the Bureau of Meteorology (BOM) database of Australian hydrological stations to provide an indication of the extent of hydrological data available for the Basin. The BOM database is compiled from information provided by the States and Territories and has been updated in 2000.

5.15.3 Fish

There has been considerable monitoring of fish populations in the Basin, but many surveys have focussed on particular species or groups of species; for example carp or major angling species. Such surveys are much less useful for an assessment of the ecological status of fish communities than the more comprehensive surveys in which all fish species are surveyed. The most comprehensive fish survey of this latter "biodiversity" type conducted in the Basin is the NSW River Survey, described separately, which is now being incorporated into the fish sampling that forms part of the IMEF program. In addition to this work there has been fish monitoring in Queensland, ACT, Victoria and South Australia.

In Queensland the Department of Primary Industries has only this year initiated a long-term fisheries monitoring program. Although the program will focus on species of particular interest to anglers, abundance data on all other species will be recorded. Sites will be re-sampled on a yearly interval. Only selected river catchments will be sampled, five in the north and five in the south of the State. The Condamine-Balonne is the only catchment in the Basin that will be sampled under this program. DNR also has a program looking at fish fauna in relation to fishways.

In the ACT fish populations have been monitored at a number of sites at irregular intervals. Originally the program focussed on larger fish species targeted by anglers, but since 1994 the program has been modified to include all fish species. A variety of sampling techniques are used, including electrofishing. The last survey was conducted in 1998 with six sites intended to continue to be monitored biennially.

In Victoria there is no State-wide survey program for fish biodiversity. There have been a series of fish monitoring programs extending back to the 1960s, but commonly these surveys were for particular fish species or groups and not fish biodiversity. Examples of the sort of programs for which there is data include the relatively intense sampling programs in the 1970s focussing on recreational fisheries, and the 600 sites surveyed for fish biodiversity for the RFA process. Only during the last ten years have data on full fish biodiversity been collected by the Arthur Rylah Institute, and these data have come from a range of programs, many of them single snapshots of a particular area. Data from the majority of these fish survey programs has been collated into a database managed by the Department of Natural Resources and Environment at the Arthur Rylah Institute and could be made available to the Audit project.

In South Australia catch and effort information has been collected for all commercial fishing in the State, extending back to the beginning of the 20th century. This information provides basic biological information on size structure of populations of commercial species. Currently there is a survey of recreational fishing which will provide a 'snap-shot' of the existing fishery. In addition, there have been a number of *ad hoc* surveys of native and exotic fish including work on threatened and endangered species.

6 Data documentation and level of expertise required

Programs differ in the extent to which the procedures used have been codified. They also differ in the degree of and ranges of expertise required to complete an assessment. These two elements are both important considerations if a particular technique were to be recommended for use in the Audit or CSA.

This comes as a clear message from other areas of monitoring, particularly water quality monitoring, with much data now regarded as virtually useless as a result of poor procedures or poor documentation of procedures. Clearly documented procedures are critical to ensure that data collected over time is consistent, and that it is comparable with the same indicator measured elsewhere in the State or in another State. The level of expertise required should be considered here, as ongoing monitoring as part of the Audit or CSA may need to be conducted by regional staff who have a range of other responsibilities. In this review the expertise required to conduct a program has been assigned to one of three classes: low = able to be conducted by staff with a minimum of experience in stream condition assessment, medium = requiring staff skilled in a range of techniques, high = requiring specialist skills.

6.1 ISC

The ISC program is well documented, including background to the development of indicators, management issues and a detailed users manual (yet to be finalised). Much of the data used in the ISC is sourced from other programs. That acquired during the ISC process requires a medium level of expertise.

6.2 IMEF

A Design Report (intended for publication in early 2001) sets out the rationale for and development of the IMEF approach. Seven Operations Manuals (one for each participating valley) and a Methods Manual (200 page set of field and laboratory procedures) are working documents for staff involved in the program. A Statistical Analysis Manual and initial Technical Report are in preparation. The IMEF program requires medium to high levels of expertise, depending on the study.

6.3 PBH

Documentation is unavailable for the PBH program as yet, as the report on the field trials (and a separate consultant report on desktop application of the framework) are currently in preparation. It is not possible to determine what expertise would be required for a routine PBH program until the approach is finalised; however, existing requirements are for a mix of general and specialised expertise (the latter mainly in fish and vegetation).

6.4 State of Rivers

The State of the Rivers approach was originally documented in the two reports referred to in Section 2.4. However since then the approach appears to have undergone undocumented refinement by both the originator of the approach and by agencies implementing the approach. The program was intentionally designed to be conducted by regional technical officers after a brief training period. Consequently it can be conducted by people with a low level of expertise.

6.5 MDBC WQ Monitoring program

Data for this program is collected by States and by private laboratories under contract. Prescription of measures and expertise required is detailed in those programs, but generally requires medium to high expertise.

6.6 National SOE

Data for this program is collected by States and Territories under a range of programs. Prescription of measures and expertise required is detailed in those programs.

6.7 WAMP ecological assessment

Techniques are not prescribed for the WAMP process in general. A Technical Advisory Panel (TAP) is set up for each basin, and this TAP determines how the environmental conditions within a basin will be assessed. Procedures adopted by each TAP to assess environmental conditions are set out in detail in the WAMP supporting documents. Despite the independence of the process there appears to be a good deal of consistency between basins in the indicators chosen and techniques adopted. A very high level of expertise in a range of disciplines is required, particularly in assessing the condition in relation to water resource development.

6.8 ARC

This is an approach used to provide a national snapshot of river health, and not a generic technique intended to be adopted for application elsewhere.

6.9 NSW River Survey

This fish survey program was designed by senior ecologists within NSW Fisheries and required sampling using five different gear types (boat electrofishing, backpack electrofishing, fyke nets, multimesh gill nets and small bait traps). During this survey all participants, NSW Fisheries scientific and technical staff, attended a three day sampling methods workshop to ensure a suitable level of consistency in the application of sampling methods. Medium to high level of expertise required.

6.10 Wild Rivers

Essentially, use of this technique only involves retrieval of existing river condition data using the established Wild Rivers approach. The technique does not involve processing newly collected data to recalculate a Wild Rivers measure. The procedure initially used to collect and process the data, and those required to access the data are described in detail. A high degree of expertise is required to access the Wild Rivers data.

6.11 QLD EPA Guidelines for Waterway Values

Techniques are not prescribed in detail in this Guideline document. The definition of ecological values and their measurement is deliberately left to the group involved. Consequently the level of expertise required may vary. This approach has been applied to only one catchment as a trial and so the comparability of results between areas assessed by different groups is not known.

6.12 NRHP

Strenuous attempts have been made in this program to standardise techniques for site selection, data collection, laboratory procedures and analysis so that results are

comparable between operators and regions. These procedures are well documented. A medium level of expertise is required.

6.13 Stressed Rivers Assessment

Techniques have not been formally prescribed, but enough detail of the approach is given in each report to enable a consistent application of the model. A medium level of expertise is required.

6.14 Waterwatch

This program is developing standard methods for use across regions and nationally. As a result of the different skill levels available, methods with different degrees of scientific rigour are used. Low to medium expertise required.

6.15 Other monitoring programs

Other monitoring programs, e.g. water quality and hydrological monitoring, are usually highly prescriptive. Generally they require a medium level of expertise in the field and a high level of expertise in the laboratory, and in the analysis and interpretation of the data.

7 Spatial and temporal variability

A natural characteristic of the measures used to assess river health is their variability over space and time. Spatial variability needs to be considered to assess the value of the data. The extent of variability within the basic spatial unit used in an assessment (reach, sub-catchment etc), will determine the representativeness of any individual measurement. If the intention of a sampling program is to provide a measure that represents the state of that reach or sub-catchment, knowledge of the spatial variability should inform the sampling design.

Common approaches taken to ensure that the data collected represent the status of the reach or sub-catchment of interest include:

- a stratified sampling approach, with sampling effort spread across regions.
- collection of data at scales appropriate to the data type, e.g. in-stream habitat data would be collected at a finer spatial scale than catchment land use data.

In a similar fashion, all river health measures vary over time, with time scales ranging from the geological to the very rapid. If measures are to be an accurate reflection of reach / sub-catchment condition such variability must be accommodated. Approaches taken include:

- using measures that integrate effects over time (e.g. fish)
- taking multiple samples over time (e.g. event based monitoring)
- modelling data based on a system understanding (e.g. hydrology)

The Audit and CSA should be capable of providing a reliable measure of river health. With the State and Territory programs comprising the building blocks of the audit, it is important to be aware of how these programs have dealt with spatial and temporal variability. The following section reviews how programs have dealt with spatial and temporal variability.

Another issue that needs to be addressed in tasks 3–7 is how data collected at non-randomly located sites, sampled at irregular or regular intervals, can be used to generate an unbiased estimate of river health in a catchment or river valley. Several of the assessment procedures discussed here provide a measure of river health for a catchment (e.g. ISC, ARC) by aggregating data from different sites and over time. If a sampling program were designed a priori to provide an accurate measure of the river condition in the catchment, sites could be chosen that were known to be representative of the river condition, or sampling locations could be chosen using a random or stratified random design. In addition repeat sampling should be conducted over timescales appropriate to the processes operating.

The approach most commonly adopted is to stratify the catchment into "homogeneous" units, and then conduct a comprehensive sampling of each or many of these units (e.g. ISC, State of the Rivers). Synthesis of these measurements into a single catchment measure is taken as an acceptable representation of the overall condition of the river within that catchment. In the course of synthesis the measurements may be weighted, e.g. on the length of "homogeneous" section from which they come, or not weighted at all. Weighting is based on the (often implicit) reasoning that an overall measure of condition should represent the status of a river wherever it is encountered in the catchment.

In this vein, an interesting component in the development of the ISC program was an investigation of how representative their overall measures of river condition were. This study led to a modified sampling design which improved the representativeness of their measures.

7.1 ISC

The ISC explicitly acknowledges the significance of natural spatial and temporal variability; indicators and sampling sites were chosen with this consideration in mind. As the ISC was planned to be a 5 yearly snapshot, the natural temporal variability of indicators was important when selecting measures that would provide a measure of trend. Spatial variability of indicators was accommodated both by choosing robust measures and by regionalisation to partition natural variability.

7.2 IMEF

Both spatial and temporal variability are considered in the different studies that comprise the IMEF. The approaches taken differ between studies. For example the wetland replenishment study uses spatially random sites, but with a sampling frequency and timing determined by the occurrence of unpredictable flow events. This enables species succession following flooding to be tracked. In contrast bloom flushing studies use a group of strategic sites sampled at fixed intervals dependent on the seasonal likelihood of blooms and the expected response time of phytoplankton populations.

7.3 PBH

PBH uses a stratified random approach to deal with spatial variability. The question of temporal variability has not been addressed at this stage of development (although time series data on many PBH variables are available from other studies).

7.4 State of Rivers

In order to accommodate spatial variability sampling sites are densely located, for example 48 sites were sampled in the Abercrombie River catchment (100km long). This strategy appears possible as a result of the relatively rapid techniques employed, but may still be extremely resource intensive.

Temporal variability is not explicitly addressed in the State of the Rivers approach as is intended to provide a snapshot of catchment condition. Even so, many of the measures chosen are relatively time invariant and so would provide a robust measure over time.

7.5 MDBC WQ Monitoring program

Spatial variability is explicitly addressed in this program which was designed to provide information at particular points along the river. The location of sampling sites was not originally designed to provide statistically reliable measures of water quality parameters for the river as a whole or for sections of the river.

This program was designed to detect temporal changes in the parameters measured. The sampling interval for different parameters was designed to be consistent with the time scales over which different parameters change. Sampling under this program has continued for a sufficient time to enable longer term trends to be elucidated.

7.6 National SOE

A review of indicators of the condition of inland waters for national SOE reporting acknowledges the importance of spatial variability, and recommends that ecologically based regionalisation be used to partition such variation (Fairweather and Napier 1998). Regions suggested are the AWRC drainage divisions and basins.

Temporal variability is not dealt with explicitly.

7.7 WAMP ecological assessment

Temporal variability of the different indices is considered a key factor in understanding ecosystem status and potential impacts. The difference in the response times of different ecosystem components (e.g. geomorphology, riparian vegetation) to flow is also recognised.

7.8 ARC

Spatial variability of stream condition is accommodated to an extent by using an approach based on remote sensed data that allows condition assessment at a fine spatial scale.

The ARC is a single snapshot and potentially temporal variability of data could reduce the accuracy of the assessment. Where possible, indicators were chosen that change slowly over time and with minimal seasonal variability.

7.9 NSW River Survey

A stratified random sampling approach was used to accommodate spatial variability in fish communities. Two ecoregions were identified within the MDB - the Darling Region and the Murray Region. Within each region four river types were identified. Comparisons were then made within river type and within ecoregion.

Temporal variation was addressed by sampling at standard times of the day relative to sunset and twice per year, in summer and winter. It was concluded that a single summer sampling was appropriate.

7.10 Wild Rivers

Spatial and temporal variability are not explicitly discussed in the Wild Rivers methods. Spatial variability, both natural and anthropogenic, would be accommodated to some extent by the remote sensing approach with its data coverage of the entire Australian continent at a fine spatial scale. A negative aspect of this approach may have been that key ecosystem data was not available at the national scale and so such factors would not have been used.

The Wild Rivers assessment is a single snapshot and temporal variability of data is not discussed. Nevertheless, the assessment would probably not be significantly compromised by temporal changes to data as most of the data upon which the assessment is based changes over time-scales of years.

7.11 QLD EPA Guidelines for Waterway Values

The Guidelines acknowledge the significance of natural spatial and temporal variability, and the importance of designing a sampling regime that will produce a reliable measure of ecological value in the face of such variability. They suggest a series of ways in which the problems of spatial and temporal variability can be addressed in indicator and sampling design. The Guidelines do not prescribe how a sampling program should be designed, intentionally leaving that to the group implementing the assessment.

7.12 NRHP

Spatial variability is not explicitly addressed. Sites were located on the basis of a range of factors including known problems, point sources and to represent different catchment land uses.

The NRHP program deliberately chose the aquatic macroinvertebrate fauna as a means of integrating the temporal variability of conditions in streams. This group was chosen because taxa have generation times long enough to span and react to episodic water quality changes, but no so long that the biotic response to changed conditions is too subtle to detect.

7.13 Stressed Rivers Assessment

A consideration of spatial and temporal variability is not directly applicable to this program which is focussed on stress, not condition.

7.14 Waterwatch

Spatial variability tends not to be addressed under this program with sites located in areas of interest or concern. Temporal variability is better accommodated, as community groups sometimes have the capacity to undertake very frequent sampling.

7.15 Other monitoring programs

Spatial variability is often not explicitly addressed. Temporal variability is a major consideration in collection of hydrological data and to a lesser extent water quality data. It is widely recognised that water quality programs based on sampling at regular intervals will

tend to underestimate annual loads as a large proportion of the load may be transmitted during short duration, intermittent flood events. Some programs attempt to address this issue though it does raise resourcing issues. For example the ISC water quality index is explicitly based on measurements of baseflow concentrations as it was determined that sampling of flood flows would be too difficult.

8 Sampling conducted in the MDB

Data that may be relevant to Audit and CSA has been collected in the MDB at a range of sites for different indicators over different periods and under an array of programs. This section details the broad sweep of such programs where they could be relevant to the Audit. There was no intention of providing a comprehensive review of all data collected in the MDB, an enormous task, particularly in the area of water quality monitoring programs. What is intended is that the data included in this review would be comprehensive for the completion of the project tasks that follow.

In this section data is ascribed to a program only if it is collected by the program. Where a program sources data from another program that data will only be reported against the latter program. For example, the ISC acquires habitat data but relies on other State programs for water quality and hydrology data.

8.1 ISC

Table 3 River valleys for which there is ISC data relevant to the Audit or CSA

River valley	State	Data collected	No. of reaches assessed	Sampling interval
Condamine-Balonne*	QLD	Channel physical form Streamside zone condition	16	Snapshot
Kiewa	VIC	"	19	5 yearly
Ovens	VIC	"	47	"
Goulburn	VIC	"	75	"
Broken	VIC	"	35	"
Campaspe	VIC	"	24	"
Loddon	VIC	"	47	"
Avoca	VIC	"	20	"
Wimmera	VIC	"	72	"
Murray – Above Hume Dam	VIC section	"	44	"

* modified form of ISC (water quality parameters vary slightly)

8.2 IMEF

Table 4 River valleys for which there is IMEF data relevant to the Audit or CSA

River valley	State	Data collected	No. of sites assessed	Sampling interval
Border Rivers/ Moonie	NSW section	Fish	2	2 occasions
Gwydir	NSW	Fish Wetland flora and fauna	16 5	2 occasions Event driven
Namoi	NSW	Fish Wetland flora and fauna Organic carbon processing Phytoplankton	7 5 3 8	2 occasions Event driven NA Weekly to monthly
Macquarie	NSW	Fish Wetland flora and fauna	8 12	2 occasions Event driven
Lachlan	NSW	Fish Wetland flora and fauna Phytoplankton	10 12 4	2 occasions Event driven Weekly to monthly
Murrumbidgee	NSW	Fish Wetland flora and fauna Macroinvertebrates/ biofilm Phytoplankton	9 18 8 4	2 occasions Event driven Event driven Fortnightly
The Barwon/Upper Darling	NSW	Fish Phytoplankton Low-flow habitat	9 13 4+	2 occasions Weekly to monthly

NA = Not available

8.3 PBH

Murrumbidgee - approximately 70 sites sampled
Lachlan - 20 sites sampled. This program is currently under review as to whether and in what form it will/can be applied more widely to unregulated rivers in NSW.

8.4 State of Rivers

Table 5 River valleys for which there is State of the Rivers data relevant to the Audit or CSA

River valley	State	Type of assessment and components measured	Number of sites assessed	Sampling interval
Condamine/Balonne/ Culgoa	QLD section	Channel habitat diversity Riparian and aquatic vegetation Bank, bed and bar stability Aquatic habitats	750	Snapshot
Border Rivers / Moonie	QLD section	As above	367	"
Macquarie	NSW	As above	NA	"
Lachlan	NSW	As above	550	"

NA = Not available

8.5 MDBC WQ Monitoring program

Total number of sites: 35
Number of sites on the Murray: 19
With the exception of the macroinvertebrate sampling, data for this program was collected by NSW, Victorian and SA State agencies on behalf of the MDBC, and will be listed with other State agency water quality monitoring. The macroinvertebrate sampling was conducted twice yearly at two sites on the Murray; above Hume Reservoir and downstream of Lock 5 in SA.

8.6 National SOE

No primary data collected under this program

8.7 WAMP ecological assessment

Table 6 River valleys for which there is WAMP data relevant to the Audit or CSA

River valley	State	Data collected	No. of reaches assessed	Sampling interval
Condamine/Balonne/ Culgoa	QLD section	Streamside zone (as per ISC) Physical form (as per ISC) Fish Macroinvertebrates Hydrology	16	Snapshot
Border Rivers	QLD section	"	NA	Snapshot
Warrego	QLD section	"	NA	Snapshot
Paroo	QLD section	"	NA	Snapshot

NA = Not available

8.8 ARC

Table 7 River valleys for which there is ARC data relevant to the Audit or CSA

River valley	State	Data collected	No. of reaches assessed	Sampling interval
All river valleys	QLD, NSW, ACT, VIC, SA	Macroinvertebrate condition Hydrological condition Nutrient status Physical habitat status Catchment disturbance measure	Approx. 5000 in MDB	Snapshot

8.9 NSW Rivers Survey

The Survey assessed fish communities at a number of sites across the Basin (Table 8). Sites were surveyed four times over two years. There is no commitment for on-going sampling.

Table 8 River valleys for which there is NSW Rivers Survey data relevant to the Audit or CSA

River valley	State	Data collected	No. of sites assessed	Sampling interval
Gwydir*	NSW	Fish abundance and community structure	3	4 occasions over 2 years
Namoi*	NSW		3	"
Macquarie*	NSW		10	"
Lachlan*	NSW		5	"
Murrumbidgee*	NSW		8	"
The Barwon/Upper Darling*	NSW		1	"
Murray – Hume Dam to Tocumwal	NSW	"	1	"
Murray – Tocumwal to Murrumbidgee catchment	NSW	"	1	"

* Currently part of IMEF.

8.10 Wild Rivers

Table 9 River valleys for which there is Wild Rivers data relevant to the Audit or CSA

River valley	State	Data collected	No. of reaches assessed	Sampling interval
All river valleys	QLD, NSW, ACT, VIC, SA	Catchment disturbance index Flow regime disturbance index River disturbance index	NA	Snapshot

8.11 QLD EPA Guidelines for Waterway Values

Not yet applied to any catchments in the Murray-Darling Basin.

8.12 NRHP

Table 10 River valleys for which there is NRHP data relevant to the Audit or CSA

River valley	State	Data collected	No. of sites assessed	Sampling interval
Condamine/Balonne	NSW / QLD	AUSRIVAS score SIGNAL score Nutrient data Riparian condition (some States) Geomorphological condition (some States)	20 + 56[1]	Snapshot involving 2 or more samples
Border Rivers/ Moonie	NSW / QLD	"	40 + 18	"
Warrego River	NSW / QLD	"	6 + 8	"
Paroo	NSW / QLD	"	6 + 4	"
Gwydir	NSW	"	27	"
Namoi	NSW	"	26	"
Macquarie	NSW	"	59	"
Castlereagh	NSW	"	9	"
Lachlan	NSW	"	59	"
Murrumbidgee	NSW / ACT	"	75 + 287	"
The Barwon/Upper Darling	NSW	"	19	"
Lower Darling: Menindee to Wentworth	NSW	"	5	"
Kiewa	VIC	"	21	"
Ovens	VIC	"	58	"
Goulburn	VIC	"	74	"
Broken	VIC	"	23	"
Campaspe	VIC	"	18	"
Loddon	VIC	"	26	"
Avoca	VIC	"	20	"
Wimmera	VIC	"	44	"
Murray – Above Hume Dam	NSW / VIC	"	33 + 6	"
Murray – Hume Dam to Tocumwal	NSW	"	4	"
Murray – Tocumwal to Murrumbidgee catchment	NSW	"	27	"
Murray – Murrumbidgee catchment to Wentworth	NSW	"	3	"
Murray – Wentworth to Wellington	NSW / SA	"	1 + NYA	"

Note 1: Represents 20 NSW and 56 QLD sites.
NYA = Not yet available

8.13 Stressed Rivers Assessment

Table 11 River valleys for which there is Stressed Rivers data relevant to the Audit or CSA (note: unregulated river sections only)

River valley	State	Data collected	No. of sites assessed	Sampling interval
Condamine/Balonne	NSW section	Proportion of water extracted Band, bed, bar stability Riparian and aquatic vegetation Structures in the channel	2	Snapshot
Border Rivers/ Moonie	NSW	"	22	"
Warrego River	NSW / QLD	"	1	"
Paroo	NSW / QLD	"	1	"
Gwydir	NSW	"	32	"
Namoi	NSW	"	40	"
Macquarie / Castlereagh	NSW	"	37	"
	NSW	"		"
Lachlan	NSW	"	24	"
Murrumbidgee	NSW / ACT	"	25	"
Murray	NSW	"	19	"

8.14 Waterwatch

A breakdown on the Waterwatch data across the Basin is not available at this stage.

8.15 Other monitoring programs

Table 12 River valleys for which there is data from other monitoring programs relevant to the Audit or CSA

River valley	State	Components measured / agency	Number of sites	Sampling interval
Condamine/Balonne/ Culgoa	NSW / QLD	Hydrology – DNR, DLWC Water quality – DNR, DLWC Fish – DPI, NSW Fisheries	14 + 86 0 + 13 QLD - NA NSW - See Note 3	See Note 1 See Note 2 Annually
Border Rivers/ Moonie	NSW / QLD	Hydrology – DNR, DLWC Water quality – DNR, DLWC Fish – DPI, NSW Fisheries	64 + 50 4 + 3 QLD: 0	See Note 1 See Note 2
Warrego River	NSW / QLD	Hydrology – DNR, DLWC Water quality – DNR, DLWC Fish – DPI, NSW Fisheries	2 + 5 0 + 0 QLD: 0	See Note 1 See Note 2
Paroo	NSW / QLD	Hydrology – DNR, DLWC Water quality – DNR, DLWC Fish – DPI, NSW Fisheries	3 + 2 0 + 0 QLD: 0	See Note 1 See Note 2
Gwydir	NSW	Hydrology – DLWC Water quality – DLWC Fish – NSW Fisheries	80 9 See Note 3	See Note 1 See Note 2
Namoi	NSW	Hydrology – DLWC Water quality – DLWC Fish – NSW Fisheries	92 8 See Note 3	See Note 1 See Note 2
Macquarie	NSW	Hydrology – DLWC Water quality – DLWC Fish – NSW Fisheries	169 6 See Note 3	See Note 1 See Note 2

Castlereagh	NSW	Hydrology – DLWC Water quality – DLWC Fish – NSW Fisheries	20 1 See Note 3	See Note 1 See Note 2
Lachlan	NSW	Hydrology – DLWC Water quality – DLWC Fish – NSW Fisheries	163 11 See Note 3	See Note 1 See Note 2
Murrumbidgee	NSW / ACT	Hydrology – DLWC, ACTEW Water quality – DLWC, EA Fish – NSW Fisheries, EA	254 10 ACT: 6	See Note 1 See Note 2 Biennially
The Barwon/Upper Darling (Menindee to Border R. junction)	NSW	Hydrology – DLWC Water quality – DLWC Fish – NSW Fisheries	26 5 See Note 3	See Note 1 See Note 2
Lower Darling: Menindee Lakes to the Wentworth Weir Pool	NSW	Hydrology – DLWC Water quality – DLWC Fish – NSW Fisheries	13 2 See Note 3	See Note 1 See Note 2
Kiewa	VIC	Hydrology – NRE Water quality – NRE Fish – NRE	23 3 See Note 4	See Note 1 See Note 2
Ovens	VIC	Hydrology – NRE Water quality – NRE Fish – NRE	30 9 See Note 4	See Note 1 See Note 2
Goulburn	VIC	Hydrology – NRE Water quality – NRE Fish – NRE	33 28 See Note 4	See Note 1 See Note 2
Broken	VIC	Hydrology – NRE Water quality – NRE Fish – NRE	88 6 See Note 4	See Note 1 See Note 2
Campaspe	VIC	Hydrology – NRE Water quality – NRE Fish – NRE	28 6 See Note 4	See Note 1 See Note 2
Loddon	VIC	Hydrology – NRE Water quality – NRE Fish – NRE	105 17 See Note 4	See Note 1 See Note 2
Avoca	VIC	Hydrology – NRE Water quality – NRE Fish – NRE	10 5 See Note 4	See Note 1 See Note 2
Wimmera	VIC	Hydrology – NRE Water quality – NRE Fish – NRE	55 14 See Note 4	See Note 1 See Note 2
Murray – Above Hume Dam	NSW / VIC	Hydrology – DLWC, NRE Water quality – DLWC, NRE Fish – NSW Fisheries, NRE	15 +25 1 + 8 See Note 4	See Note 1 See Note 2
Murray – Hume Dam to Tocumwal (main stem + NSW catchment)	NSW	Hydrology – DLWC Water quality – DLWC Fish – NSW Fisheries	25 1 See Note 3	See Note 1 See Note 2
Murray – Tocumwal to Murrumbidgee catchment (main stem + NSW catchment)	NSW	Hydrology Water quality Fish	86 2 See Note 3	See Note 1 See Note 2
Murray – Murrumbidgee catchment to Wentworth (main stem only)	NSW	Hydrology Water quality Fish	14 - See Note 3	See Note 1
Murray – Wentworth to Wellington	NSW / SA	Hydrology – DWR Water quality – SA Water Fish - PIRSA	17 + 65 11 See Note 4	See Note 1 See Note 2

NA = Not yet available, DNR = Department of Natural Resources, CBWC = Condamine Balonne Water Committee, DPI = Department of Primary Industries, DLWC = Department of Land and Water Conservation, ACTEW = ACT Electricity and Water, EA = Environment ACT, NRE = Department of

Natural Resources and Environment, DWR = Department of Water Resources, PIRSA = Department of Primary Industries and Resources SA, EPA = Environment Protection Agency
Note 1: Most sites sampled continuously, some discontinuous regular or irregular. Hydrology sites include all gauging stations within the river valley, not just those on the main stem of the river.
Note 2: Sampled at least monthly (DLWC program under review).
Note 3: NSW fish survey information described in sections on NSW River Survey and IMEF.
Note 4: Fish data for individual Victorian and South Australian river valleys not available at this stage.

9 Reference Condition

The principles outlined in the scoping document for the Audit and CSA identified the importance of indicators clearly establishing the condition of rivers. Stream condition is most commonly established by comparing the condition in a stream with a set of generic reference conditions, e.g. ANZECC water quality guidelines, or by comparison with conditions at a reference site. Where ecological integrity is the criterion for river health, reference conditions are usually defined as the presumed natural state of a site, determined by comparison with similar undisturbed sites. Typically, it is impossible to find completely undisturbed sites with which to compare test sites, in which case minimally disturbed or best available sites are often used to define reference conditions (Wright *et al.* 1983, Simpson *et al.* 1996, Reynoldson *et al.* 1997). Finding pristine reference sites in the lower parts of the Basin is particularly difficult.

Here this review looks at the approaches adopted by different programs to determining condition with particular reference to the choice of reference condition.

9.1 ISC

The ISC is designed to provide a measure of condition compared with natural or ideal condition. It consists of a number of key indicators amalgamated to produce five sub-indices, and these in turn are amalgamated through an inverse ranking or weighting to produce an overall score, the ISC.

9.2 IMEF

The IMEF program has established hypotheses concerning ecological processes in rivers and is in the process of collecting data to test these hypotheses. It does not attempt to measure condition, but unregulated sites are used as a reference for some studies.

9.3 PBH

At the present stage of development, PBH is a comparative assessment (against the average of the assessed sub-catchments). It is intended that reference levels (thresholds of significance and thresholds of concern) will be incorporated at a later stage.

9.4 State of Rivers

Conditions are assessed relative to natural or near natural, though there is not a formalised process to identify natural conditions. Overall condition of a reach is assessed by first standardising the seven components used so that they each contribute equally. Sites are then forced into one of 7 groups using cluster analysis and conditions assigned to each of the clusters (very good to highly degraded). Later documentation suggests that this approach may have been modified to one in which overall rating is a simple average of the component ratings.

Weighting is applied when combining the sub-components of bank condition and riparian vegetation, but is not applied when spatially aggregating data to create an index for a sub-catchment.

9.5 MDBC WQ Monitoring program

There is no formalised reporting procedure for the data acquired under this program. Data is made available on request and is used for a variety of research and community purposes. Where the MDBC uses this data to provide a measure of condition, data is generally assessed by comparison with ANZECC water quality guidelines or in house benchmarks.

9.6 National SOE

Data in the initial National SOE (1996) were provided as a mixture of raw data and as a measure of condition; generally assessed by comparison with ANZECC water quality guidelines. The 2001 SOE includes more habitat and biotic elements which do not have an ANZECC guideline value. It is anticipated that some indicators used, e.g. AUSRIVAS scores, will use a reference site approach.

9.7 WAMP ecological assessment

Conditions are assessed relative to natural or near natural conditions.

9.8 ARC

Conditions are assessed relative to natural or near natural conditions. For most of the indices in the ARC, e.g. hydrology, pristine conditions are used as the reference condition. Other indices, notably the biota index, accept modified natural conditions as a reference point due to the difficulty of identifying pristine conditions in some of our heavily modified landscapes.

9.9 NSW River Survey

The NSW River Survey incorporates four independent sources of data, as well as other non-independent sources. Twelve metrics are calculated from the fish catch data with the scores for each metric summed to give an overall score at each site. Condition (poor – best) is assessed from individual scores by reference to the best examples from the data set. Therefore, reference condition represents the best condition for that metric for the rivers sampled. This means that the IBI score is not an absolute measure of river condition. Rather it is a score relative to other rivers in the sample data set.

9.10 Wild Rivers

The Wild Rivers Index produces a measure of a river's "wildness" with pre-1750 conditions as the benchmark. A series of metrics are calculated:

- Sub-catchment disturbance index (calculated for just the catchment local to the reach)
- Sub-catchment flow regime disturbance index
- Catchment disturbance index (calculated for the entire catchment of a reach)
- Flow regime disturbance index
- River disturbance index (overall measure of river condition)

A complex series of weightings is applied during the calculation of these indices.

9.11 QLD EPA Guidelines for Waterway Values

An assessment using these Guidelines is designed to produce a measure of river condition relative to a range of benchmarks. Complete details are not provided on the benchmarks used to allow catchment authorities the opportunity to establish locally relevant approaches. As a guide, reference conditions are used for some of the criteria, e.g. naturalness and representativeness, and absolute benchmarks may be used for others, e.g. rarity.

9.12 NRHP

This program uses a reference condition approach to produce an assessment of river health. Condition of a test site is assessed by comparing the biota that are found at the site with those expected at the site with no or minimal disturbance. To assess a test site there needs to be a group of reference sites with similar basic characteristics but without the catchment or in-stream disturbance that the test site is subject to. Consequently, pristine reference sites are difficult to find in lowland rivers and the minimally modified reference sites are used.

9.13 Stressed Rivers Assessment

The Stressed Rivers reports do not include an explicit discussion of the reference conditions used to assess environmental stress. Advice from DLWC is that thresholds for individual indicators falling into Low, Medium or High classification were set by consensus of expert opinion, and that natural conditions (low level or no stressors) were used as a benchmark.

9.14 Waterwatch

The Waterwatch program focusses on measurement of water quality variables and the macroinvertebrate community. Water quality condition is measured with the ANZECC water quality guidelines as reference points, and the macroinvertebrate community is compared to the AUSRIVAS reference of natural or near natural sites.

10 Programs monitoring specific Audit components

This section draws together the information from different programs to provide an integrated picture of the potential sources of data for the nominated Audit and CSA components. Indicators of habitat condition nominated for inclusion in the Audit were macroinvertebrates, fish, hydrology and water quality. Indicators nominated for inclusion in the CSA were connectivity, riparian condition, woody debris in streams, geomorphic condition and wetlands.

Table 13 Macroinvertebrate monitoring

Approach	Monitoring procedure	Where applied in Basin
ISC	SIGNAL rating AUSRIVAS score	Entire Victorian section of Basin
IMEF	Wetland replenishment study: sweep-net sampling; species level identification Conditioning stony beds: sampling of individual stones; genus level identification Wetting of Terr. Org. matter: sampling of inundated leaf litter; species level identification	Gwydir, Macquarie, Lachlan, Murrumbidgee Barwon-Darling Namoi
PBH	Sweep and kick net sampling of riffle or similar, edge-alcove and dominant habitat; family richness and SIGNAL	Murrumbidgee, Lachlan; Castlereagh
State of Rivers	Not measured	-
MDBC WQ Monitoring program	Artificial substrate	Murray: Above Hume reservoir and below Wellington
National SOE	AUSRIVAS score	Sourced from NRHP and State programs
WAMP ecological assessment	Taxonomic richness PET taxa SIGNAL index, AUSRIVAS score Functional feeding groups Flow velocity and substrate preference groups	QLD section of Condamine/ Balonne/ Culgoa, Border Rivers, Warrego and Paroo
ARC	AUSRIVAS score	Entire Basin
NSW River Survey	Not measured	-
Wild Rivers	Not measured	-
QLD EPA Guidelines for Waterway Values	Not specified	Not applied yet
NRHP	SIGNAL score AUSRIVAS score	Entire Basin
Waterwatch	SIGNAL score AUSRIVAS score	Sites throughout Basin

Table 14 Fish monitoring

Approach	Monitoring procedure	Where applied in Basin
ISC	Not measured	-
IMEF (now includes NSW Fish Survey)	Electrofishing	Border Rivers, Gwydir, Namoi, Macquarie, Lachlan, Murrumbidgee, Barwon/Darling
PBH	Electrofishing	Murrumbidgee; Lachlan; Castlereagh
State of Rivers	Not measured	-
MDBC WQ Monitoring program	Not measured	-
National SOE	Uses data from State programs	See State programs
WAMP ecological assessment	Uses data from other State programs	Condamine-Balonne, Border Rivers, Warrego, Paroo
ARC	Not measured	-
NSW River Survey (original survey)	Range of techniques used	Gwydir, Namoi, Macquarie, Lachlan, Murrumbidgee, Barwon/Darling, Murray

Wild Rivers	Not measured	-
QLD EPA Guidelines for Waterway Values	Not specified	Not yet applied in Basin
NRHP	Not measured	-
Waterwatch	netting	Toowoomba area of Condamine-Balonne

Table 15 Hydrological measures

Approach	Indicators used
ISC	• Amended annual proportional flow deviation • Percentage of catchment urbanised • Presence of hydroelectric dams
IMEF	Various, depending on study
PBH	As for Stressed River program; also hydraulic diversity, depth, width, discharge
State of Rivers	• modification of natural flow regime • high flow events • low flow events • changes to seasonal pattern
MDBC WQ Monitoring program	Not measured
National SOE	The ratio of water use compared to catchment yield.
WAMP ecological assessment	• Daily Flow • Annual Flow • Mean Annual Flow • Median Annual Flow • CV of Mean Annual Flow • APFD • ARI Flow Event Analysis • Maximum dry spell • High Flow Duration • Medium Flow Duration • Low Flow Duration • No Flow Duration
ARC	• Mean Annual Flow • Deviation from mean annual flow • ARI Flow Event Analysis • Change in seasonal amplitude • Change in seasonal periodicity
NSW River Survey	Subjective grading of flow
Wild Rivers	• Presence of impoundments • Occurrence of flow diversions • Presence of levees
QLD EPA Guidelines for Waterway Values	Not specified
NRHP	Varies between States and ACT, and over time
Waterwatch	Not measured

CV = Coefficient of Variation, APFD = Annual Proportional Flow Deviation, ARI = Annual Recurrence Interval

Table 16 Water quality

Approach	Nominated Audit water quality variables measured (TP, EC, NTU and pH)
ISC	Sourced from other State programs
IMEF	Measured in some studies
PBH	Temperature, EC, turbidity, DO, pH, filterable NOx, NHx & P
State of Rivers	No
MDBC WQ Monitoring program	Yes
National SOE	Not specified
WAMP ecological assessment	Yes
ARC	TP only
NSW River Survey	EC, NTU, pH
Wild Rivers	No
QLD EPA Guidelines for Waterway Values	Not specified
NRHP	Yes
Waterwatch	Yes

Table 17 CSA components currently assessed in the Murray-Darling Basin

River valley	State	Type of assessment and components measured	Number of sites	Sampling interval
Condamine/ Balonne/ Culgoa	QLD section	SOR: See Note 1	750	Snapshot
		NRHP: See Note 2	51	Snapshot
		ARC: See Note 3	All reaches	Snapshot
	NSW section	Wild Rivers: See Note 4	All reaches	Snapshot
		NRHP:	10	Snapshot
		ARC:	All reaches	Snapshot
		Wild Rivers:	All reaches	Snapshot
Border Rivers / Moonie	QLD section	SOR:	367	Snapshot
		NRHP:	18	Snapshot
		ARC:	All reaches	Snapshot
	NSW section	Wild Rivers:	All reaches	Snapshot
		NRHP:	40	Snapshot
		ARC:	All reaches	Snapshot
		Wild Rivers:	All reaches	Snapshot
Warrego River	QLD section	NRHP:	8	Snapshot
		ARC:	All reaches	Snapshot
		Wild Rivers:	All reaches	Snapshot
	NSW section	NRHP:	6	Snapshot
		ARC:	All reaches	Snapshot
		Wild Rivers:	All reaches	Snapshot
Paroo	QLD section	NRHP:	4	Snapshot
		ARC:	All reaches	Snapshot
		Wild Rivers:	All reaches	Snapshot
	NSW section	NRHP:	6	Snapshot
		ARC:	All reaches	Snapshot
		Wild Rivers:	All reaches	Snapshot
Gwydir	NSW	IMEF: Wetland condition	5	1-3 months
		NRHP:	27	Snapshot
		ARC:	All reaches	Snapshot
		Wild Rivers:	All reaches	Snapshot
Namoi	NSW	IMEF: Wetland condition, phytoplankton	5, 8	1-3 months, 0.25-1 month
		NRHP:	26	Snapshot
		ARC:	All reaches	Snapshot
		Wild Rivers:	All reaches	Snapshot

Macquarie	NSW	IMEF: Wetland condition SOR: NRHP: ARC: Wild Rivers:	12 Not available 59 All reaches All reaches	1-3 months Snapshot Snapshot Snapshot Snapshot
Castlereagh	NSW	NRHP: ARC: Wild Rivers:	9 All reaches All reaches	Snapshot Snapshot Snapshot
Lachlan	NSW	IMEF: Wetland condition, phytoplankton SOR: NRHP: ARC: Wild Rivers:	12, 4 550 59 All reaches All reaches	1-3 months, 0.25-1 month Snapshot Snapshot Snapshot Snapshot
Murrumbidgee	NSW section ACT section	IMEF: Wetland condition, phytoplankton NRHP: ARC: Wild Rivers: NRHP: ARC: Wild Rivers:	18, 4 75 All reaches All reaches 287 All reaches All reaches	1-3 months, 2 weeks Snapshot Snapshot Snapshot Snapshot Snapshot Snapshot
The Barwon/Upper Darling (Menindee to Border R. junction)	NSW	IMEF: Phytoplankton, low-flow habitat NRHP: ARC: Wild Rivers:	13, 4+ 19 All reaches All reaches	Snapshot Snapshot Snapshot
Lower Darling: Menindee Lakes to the Wentworth Weir Pool	NSW	NRHP: ARC: Wild Rivers:	5 All reaches All reaches	Snapshot Snapshot Snapshot
Kiewa	VIC	ISC: NRHP: ARC: Wild Rivers:	19 21 All reaches All reaches	5 yearly Snapshot Snapshot Snapshot
Ovens	VIC	ISC: NRHP: ARC: Wild Rivers:	47 58 All reaches All reaches	5 yearly Snapshot Snapshot Snapshot
Goulburn	VIC	ISC: NRHP: ARC: Wild Rivers:	75 74 All reaches All reaches	5 yearly Snapshot Snapshot Snapshot
Broken	VIC	ISC: NRHP: ARC: Wild Rivers:	35 23 All reaches All reaches	5 yearly Snapshot Snapshot Snapshot
Campaspe	VIC	ISC: NRHP: ARC: Wild Rivers:	24 18 All reaches All reaches	5 yearly Snapshot Snapshot Snapshot
Loddon	VIC	ISC: NRHP: ARC: Wild Rivers:	47 26 All reaches All reaches	5 yearly Snapshot Snapshot Snapshot
Avoca	VIC	ISC: NRHP: ARC: Wild Rivers:	20 20 All reaches All reaches	5 yearly Snapshot Snapshot Snapshot

Wimmera	VIC	ISC: NRHP: ARC: Wild Rivers:	72 44 All reaches All reaches	5 yearly Snapshot Snapshot Snapshot
Murray – Above Hume Dam	NSW section VIC section	NRHP: ARC: Wild Rivers: ISC: NRHP: ARC: Wild Rivers:	33 All reaches All reaches 44 6 All reaches All reaches	Snapshot Snapshot Snapshot 5 yearly Snapshot Snapshot Snapshot
Murray – Hume Dam to Tocumwal (main stem + NSW catchment)	NSW	NRHP: ARC: Wild Rivers:	4 All reaches All reaches	Snapshot Snapshot Snapshot
Murray – Tocumwal to Murrumbidgee catchment (main stem + NSW catchment)	NSW	NRHP: ARC: Wild Rivers:	 All reaches All reaches	Snapshot Snapshot Snapshot
Murray – Murrumbidgee catchment to Wentworth	NSW	NRHP: ARC: Wild Rivers:	3 All reaches All reaches	Snapshot Snapshot Snapshot
Murray – Wentworth to Wellington	NSW section SA section	NRHP: ARC: Wild Rivers: NRHP: ARC: Wild Rivers:	1 All reaches All reaches NYA All reaches All reaches	Snapshot Snapshot Snapshot Snapshot Snapshot Snapshot

SOR = State of the Rivers type approach, NYA = Not yet available
Note 1: Includes measures of channel habitat and catchment land use
Note 2: NRHP habitat assessment commonly includes USEPA measures, but varies between States and over time within some States.
Note 3: Includes measures of riparian and geomorphological condition
Note 4: Includes measures of connectivity and catchment land use
Note 5: Includes measures of physical form and streamside zone condition

11 Summary of approaches

This section provides a brief overview of each of the river health programs reviewed. It covers such aspects as the purpose for which the program was designed, what sort of data has been collected and where sampling has occurred in the Murray-Darling Basin. Where appropriate it also touches on the spatial reporting scale, how reporting units (reaches) have been defined and the reference condition used.

11.1 ISC

The ISC was developed as a measure of river health that could be used by managers and the community to benchmark river condition, assess the effectiveness of rehabilitation and to set priorities for management action. It takes an ecological focus on river health and went through an extensive development phase to identify appropriate indicators. The ISC is reported at a reach scale, with reaches defined as sections of river typically 10-30 km long and relatively homogeneous in terms of their hydrology, physical form, streamside vegetation, and water quality or aquatic life.

Within each reach three measuring sites are randomly identified, with three transects assessed at each site. The ISC indicators have many elements in common with the components identified for inclusion in the Audit and CSA: hydrological, physical form, streamside zone, water quality and aquatic life measures. All river valleys within the Victorian part of the Basin have had reaches defined and all components of the ISC assessed. It should be noted that for some reaches data on aquatic life and water quality were not available and have been assessed on a pro rata basis from other sub-indices in the reach.

11.2 IMEF

The IMEF is a part of a State approach to assess ecological responses to improved flows. It relies on a hypothesis driven approach, with ecological responses to environmental flows being assessed in spatially and temporally replicated studies and through the construction and testing of predictive models. Nine priority hypotheses have been generated for different biota and processes, and are being tested in one or more valleys. The intended outcomes of the project are an understanding of the existing state and trends over time in hydrology, morphology and ecology in the major river systems, and evaluation of the likely contributions of environmental flows to these changes.

Site selection procedures differed between the studies that make up the IMEF program. As the program relies on data from other sampling programs in some instances, sites from those primary sampling programs were used. In other studies sites were randomly located to provide a spatially unbiased estimate of the indicators used, or placed at sites of specific concern. As a result of the different natures of the studies that IMEF program comprises, no overarching river classification schema was applied.

The different studies in the program have specific data requirements, and are applied to specific catchments. Consequently, the data collected under the IMEF program varies considerably between catchments. This is to be expected in a program the primary intention of which is system understanding not monitoring. Some of the data used in the studies are derived from other NSW monitoring programs, e.g. water quality and hydrological data. Data collected in the studies of particular relevance to the Audit will be data on biota (phytoplankton, fish, macroinvertebrates and birds, etc.) and on habitat (wetland condition, river biofilms). In addition to the data that is already available from the IMEF program, the system understanding from this approach will be valuable for future refinement of Audit and CSA indicators.

11.3 PBH

The PBH approach is a general framework for integrated conservation and stress assessment, which is being tested via a desktop review and via a multi-faceted, rapid procedure for small and medium size streams. The PBH approach uses three kinds of variables; human generated pressure on rivers, components of the biota, and aspects of bio-physical habitat. These variables are used to generate indicators of richness, rarity, native abundance, alien biota, sensitivity, physical structure, water extraction and water quality. These indicators are wrapped up into indices of conservation significance, biological stress (or condition) and stressors. It is explicitly designed to provide information for management prioritisation, for strategic river management by describing the properties of river systems and identifying key issues, and for general performance monitoring/environmental auditing. The PBH approach has been trialled by DLWC and the trial results will be reviewed in early 2001.

In the initial trials of the PBH approach, sampling sites were selected randomly within River Styles™. The PBH approach has been applied to two sub-catchments in the Murray-Darling Basin, with application to another 3 sub-catchments in the basin partly completed. Data from the first two trials in the basin are currently being compiled with other data into a draft report.

11.4 State of Rivers

The State of the Rivers assessment procedure was originally developed in Queensland as a way of assessing the physical and environmental health of rivers and streams. It has subsequently been adapted and used in NSW.

Reporting units, called sub-sections, are identified in a two stage process. Firstly homogeneous "sections" are identified based on a series of map based characteristics. Secondly sub-sections are identified by the division of sections at each tributary junction or other discontinuity. Each sub-section is sampled at least once, leading to an extremely dense array of sites. The State of the Rivers approach focusses on habitat assessment; catchment condition, channel habitat diversity, bank, bed and bar condition, vegetation and aquatic habitat. It does not measure water quality, biota or flow as these components were assessed as too technically difficult or required specialised equipment. Data is collected largely by field survey.

A manual for the State of the Rivers approach was produced in 1993 as part of the methods development process. Since that time the approach has been applied to a number of catchments in Queensland and at least two in NSW. It appears that during this period the methods used have been refined, both by the original developer of the method, and by regional agencies implementing the approach. If this method or components from it were to be used in the Audit or CSA it would be important that a standardised method be applied to ensure data from different regions were compatible.

11.5 MDBC WQ Monitoring program

The MDBC established a monitoring program in 1978 to monitor the water quality of the River Murray and of tributaries close to their confluence with the Murray. There is no explicit identification of river regions or reaches under this program.

Three types of data are collected; physico-chemical (35 sites), phytoplankton (12 sites) and macroinvertebrate data (7 sites). Actual monitoring is conducted by NSW Department of Land and Water Conservation, SA Water, Australian Water Technologies Victoria and Murray-Darling Freshwater Research Centre.

11.6 National SOE

National SOE reporting is undertaken to provide information on the environment as a foundation for ecologically sustainable development. It allows regular reports on indicators of changes in environmental condition and provides a means of monitoring the performance of government policies against actual outcomes. National SOE reporting is conducted approximately every five years, with the first assessment conducted in 1996, and the second report is planned for completion in 2001.

Reports are largely compiled from data collected by other State and Federal agencies and consequently any regionalisation, reach definition or site location in the Murray-Darling

Basin reported on in the National SOE will arise from other programs. The Commonwealth has undertaken an extensive investigation of the most appropriate indicators for the SOE. For the section of the SOE dealing with river health the nominated indicators include exceedences of ANZECC water quality guidelines, algal blooms, riparian vegetation, wetland condition and macroinvertebrates. The SOE program does not collect data, it uses data collected by State and Territory programs. So this suite of indicators represents an ideal for which data may not have been collected.

11.7 WAMP ecological assessment

The WAMP process is intended to provide an ecological baseline, for a catchment, of the effects of flow abstractions or diversions as an input to catchment and water allocation planning. Within a catchment the WAMP process tends to focus on the main river, though not to the exclusion of other streams. The assessment is made primarily on the existing data and information, although some supplementary surveys may be made in the field. Thus the analytical procedures are not prescribed for the entire WAMP process and assessments may differ from catchment to catchment.

Major rivers and streams in the catchment being assessed are divided into relatively homogeneous river reaches on the basis of their natural characteristics, management regimes, and locations of gauging stations. This results in a considerable variation in reach length, from 10 km to more than 100 km.

As techniques are not prescribed in the WAMP process the components measured differ between catchments. However, it is possible to identify elements generally common to WAMP ecological assessments. They include a geomorphological assessment, riparian vegetation, macroinvertebrates, fish, water quality and hydrology. Most of these measures consist of a number of sub-measures. Much of the data used in the WAMP process is sourced from other programs and the WAMP process is used to draw together a comprehensive picture of river health in relation to flow.

11.8 ARC

The ARC project is intended to provide an overarching view of the quality of rivers across Australia as input to National and State policy development, and as management input. It takes the assessment of ecological integrity as its principal measure of river health. It is intended to be used as both a measure of river condition and as a tool to identify management options for rivers. The reporting scale for this project is the river reach, defined as sections of river with relatively homogeneous geomorphology. Reach boundaries have been determined objectively using a national digital elevation model and a protocol for determining reaches based on river and catchment geomorphology.

The ARC project is developing a set of five indices to report on river health in each reach. Biota (initially using macroinvertebrate data) will be the primary measure of river health. The ARC will also report on the status of four indices measuring driving processes: hydrology, water quality, physical habitat and catchment disturbance. For many ARC components the data used is remote sensed data with an Australia wide coverage. An assessment is conducted for the entire length of each reach, or the entire area of a catchment. The ARC project will provide only a snapshot of river health, like many programs, and would need to be repeated to reveal trends.

11.9 NSW River Survey

The NSW Rivers Survey had a series of objectives including assessing the distribution and abundance of native fish of NSW rivers, developing an understanding of the ecological effects of river regulation, and establishing standardised fish survey methods for use in other studies. The survey approach classified rivers into four main types: unregulated lowland, regulated lowland, slopes (300-700m altitude) and montane. River reaches were selected from within these river types and samples taken at a number of reaches based on a random selection process.

Fish were sampled at selected reaches using a range of techniques to ensure that all species were sampled. Habitat measures were also taken. A series of metrics based on the Index of Biological Integrity were calculated from the fish data to generate a series of condition indices. The NSW River Survey was a snapshot of fish community status and has not been repeated. Note this has now been incorporated into IMEF.

11.10 Wild Rivers

The Wild Rivers project arose from a commitment by the Commonwealth to assist State and Territory agencies to identify rivers in near pristine condition and to encourage protection and proper management of their catchments. The approach uses data on human disturbances within a catchment and to the river's channel directly, to assess the potential of a river to be a "wild river". Elements chosen for inclusion include both those important to ecosystem functioning, and others of a more visual landscape basis. Although the focus of the project was originally on near pristine rivers, the approach is applicable to rivers across the entire spectrum of degraded to pristine.

The Wild Rivers spatial framework is a set of reaches determined on the stream network at a relatively fine scale across the Murray-Darling Basin. Each reach is assessed. However, there are details in this approach which detract from its usefulness as a sampling template for the Audit and CSA, and as a source of data. The reach delineation method uses the morphology of the stream network. It is not a geomorphologically defined approach and consequently changes in ecological functioning that reflect the geomorphological template may not be well represented. Also, the AUSLIG streamline database has been used to define streams. Stream density on this database varies geographically depending on the scale of maps available, and in consequence the density of Wild Rivers reaches varies geographically.

The indicators used in Wild Rivers were largely intended to measure "wildness" and reflected scenic or landscape quality to a large extent. Additionally, as Wild Rivers was a desktop study assessing much of the continent, indicators chosen were constrained to existing data sets with national coverage. In summary, the Wild Rivers data will be of limited use in the Audit and CSA process.

11.11 QLD EPA Guidelines for Waterway Conservation/Ecological Values

The purpose of the Conservation/Ecological Value Guidelines is to provide a systematic, comprehensive and flexible method to describe the ecological values of waterways and floodplains. The Guideline is designed to support both conservation planning and development assessment. The framework is centred around five categories of information deemed necessary for assessing the ecological values of streams. The Guidelines intentionally do not specify in detail how these five components should be assessed, how reaches should be determined, or how the information should be compiled and presented.

The intention of the Guidelines appears to be to provide a flexible framework so that a group assessing a particular basin can tailor the approach to their individual information needs and expertise. A negative aspect of this flexibility is that it could result in assessments that differed markedly in methodology between catchments, potentially producing assessments that would not be comparable.

11.12 NRHP

The National River Health Program was developed in a joint State–Commonwealth partnership to support the environmental component of the COAG Water Reform Framework. It has progressed through a development and trialling phase to a snapshot of river health. The objectives of the program are to:

- Provide a sound information base on which to establish environmental flows
- Undertake a comprehensive assessment of the health of inland waters
- Consolidate and apply techniques for improving the health of inland waters.

As part of this program the first Australia wide assessment of the health of aquatic systems based on macroinvertebrates as indicators was conducted at approximately 6000 sites across Australia. Sites sampled during this program were often places of interest to a management authority or places with potential problems. They were not chosen to provide an unbiased estimate of the status of the macroinvertebrate community in a catchment.

In conjunction with the macroinvertebrate data sampled with this program, a wide range of water quality and habitat variables were also measured at most sites. At present there is no commitment from the Commonwealth to continue the monitoring component of the program, though many States and Territories have adopted this procedure as part of their monitoring program.

11.13 Stressed Rivers Assessment

The Stressed Rivers program was developed by the NSW DLWC to provide information on the environmental stress, particularly hydrologic, of unregulated rivers. It was a desktop type study, drawing on data from previous studies and from in-house expertise. The program produced a series of reports on catchments in the Murray-Darling Basin and elsewhere in NSW in which high priority catchments were identified where there was a high level of water extraction during low flow periods (80^{th} percentile flow), during the driest month of high irrigation demand, or catchments with high conservation value. This information was to be used to guide management priorities and policies for interim water management rules.

The scale at which this program produced assessments varied across the MDB. In the northern parts of the Basin assessments were produced for entire AWRC Basins, e.g. Paroo. In the southern parts of the Basin assessments are at a finer spatial scale, with AWRC Basins divided into sub-catchments on the basis of land use, government boundaries etc, and an assessment produced for each sub-catchment. Assessments have been completed for all river valleys in the Basin.

11.14 Waterwatch

The Waterwatch program is a community based river health monitoring program developed to provide community members interested in the status of their streams with techniques they could use to monitor stream condition. It has developed a considerable groundswell of active involvement, with the number of people and groups participating

across Australia numbering in the tens of thousands and hundreds respectively. Sites sampled tend to be in those areas in which the group has a particular interest, rather than part of a more representative sampling network.

The data collected under this program varies in quality and consistency depending on the expertise of the different Waterwatch groups. Despite this shortcoming, it is worth consideration in development of the Audit and CSA because it comprises a large body of data across the Basin, and demonstrates the level of and location of community interest in stream condition in the Basin. However the issues of standardised methods and data quality need to be addressed.

12 References

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State contacts for Tasks 1, 3–7

Jurisdiction	Primary contact	Additional contacts	Area
Queensland	Jenny Edwards – DNR John Bennett – EPA	-	
New South Wales	Glenda Orr – DLWC	Bruce Chessman – DLWC Eren Turak – EPA	Aquatic invertebrates
		Peter Gehrke – Fisheries	Fish
		Daren Barma – DLWC	Hydrology
		Helen Daly – DLWC	Water quality
		Richard Denham – DLWC	Habitat
ACT	Peter Donnelly	Greg Keen – Env ACT	Aquatic invertebrates, hydrology
		Mark Lintermans – Env ACT	Fish, habitat
		Bob Neill – Env ACT	Water quality
Victoria	Paul Wilson – DNRE	-	
South Australia	Heather Hill – DWR	Peter Goonan – EPA	Aquatic invertebrates, water quality, habitat
		Ben Loiterton – Inland Fisheries	Fish
		Jim Barratt – DWR Tony Herbert – DWR	Hydrology
Commonwealth	Jean Chesson – AFFA Martin Shafron - EA	-	