National River Health Program

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MONITORING RIVER HEALTH INITIATIVE TECHNICAL REPORT
REPORT NUMBER 23

Australian River Assessment System: AusRivAS Physical and Chemical Assessment Module

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Natural Heritage Trust
Helping Communities Helping Australia
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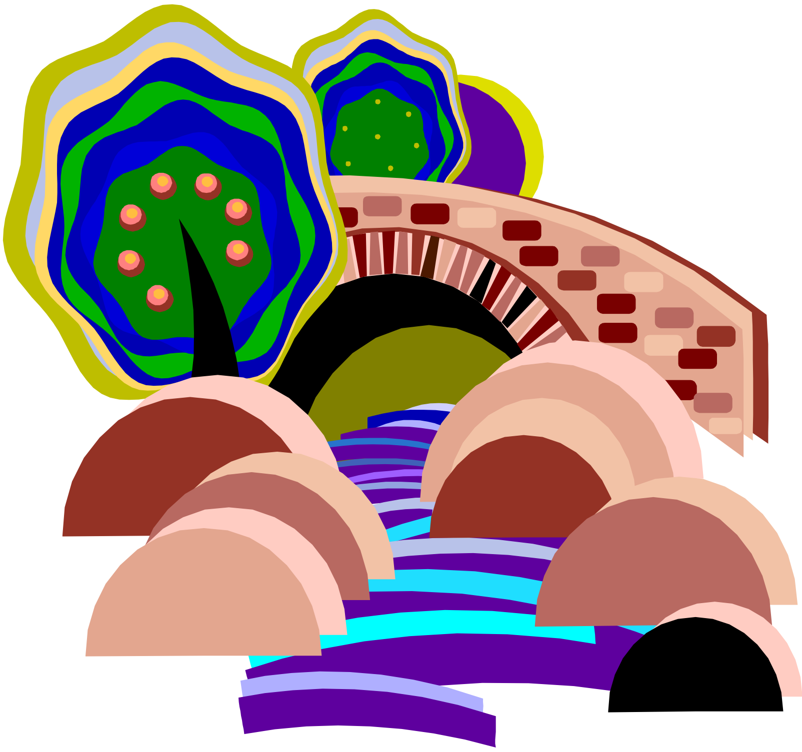
FINAL REPORT

AUSRIVAS PHYSICAL AND CHEMICAL ASSESSMENT MODULE



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23 July 2001

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1 ACHIEVEMENT OF OBJECTIVES

1.1 OBJECTIVE 1

To adopt a standardised protocol within AUSRIVAS for the assessment of river physical and chemical condition incorporating instream physical habitat, catchment geomorphology, riparian condition and water quality.

Status: Achieved

We have produced a comprehensive physical assessment protocol, which details a standardised rapid method for the collection of geomorphological, physical habitat, riparian and basic water quality data. It is intended that after the collection of data from reference sites, AUSRIVAS-style predictive models can be constructed. Subsequently, these models can then be used to assess the physical condition of test sites, and will be able to predict the local scale physical and habitat features that should occur at a test site.

The physical assessment protocol document is comprised of three main components:

Theoretical background

Sets out the philosophies underlying this approach to stream assessment, including predictive capability, hierarchical approach, use of rapid survey techniques and the reference condition concept.

Reference site selection procedure

Details a method for the selection of reference sites, based on the stratification of sampling sites across functional process zones.

Instructions for the collection of each variable

Gives instructions for the collection of each office and field based physical variable. The variables included in the protocol are generally derived from existing stream assessment methods. Variables were chosen to represent a range of physical factors, including planform channel features, catchment character, landuse, hydrology, physical morphology and bedform, substrate, bank character, riparian vegetation, instream habitat and floodplain character. Although water quality is included in the protocol, this aspect of the project was reduced because of concerns about the value of instantaneous chemical measurements and it was decided to concentrate on aspects of water quality that are directly related to geomorphology. To reflect the reduced focus on water chemistry, the name of the protocol was changed from "physical and chemical assessment" to "physical assessment".

1.2 OBJECTIVE 2

To build software to incorporate the physical and chemical assessment module into the AUSRIVAS software platform, with relevant text resources and diagnostic outputs, integrated with the results of bioassessment.

Status: Achieved

We have produced software that reports test site physical data in relation to the physical character of AUSRIVAS reference sites. The user enters test site physical information into the package, and this information is compared against reference site information. The user can then examine whether the physical character of the test site lies outside the range of physical character that occurs at corresponding reference sites. The software was designed to utilise existing AUSRIVAS physical data and as such, it does not support the format of the physical assessment protocol (see Section 1.3 for a description of the recommendations made by the steering committee).

The software is available via the existing AUSRIVAS website and is accessed in the same manner as AUSRIVAS. Users download the software from the website and install the software onto their computer. Test site data is entered via the user's terminal, and is submitted for comparison against reference site data that are stored centrally on the AUSRIVAS server. The user receives graphical and categorical information that summarises the test site value in relation to reference sites. This summary information can be saved in a number of output formats. Access to the program is password controlled. The physical and chemical reporting software is also accompanied by a manual that gives detailed instructions on the use of the program.

1.3 RELATIONSHIP BETWEEN THE PROTOCOL AND THE SOFTWARE

The steering committee meeting of 22 March 2000 resolved that the overall aim of the project was not to construct predictive models from the existing AUSRIVAS data. Discussions at the Habitat Assessment Workshop (2-3 May 2000) and examination of existing data revealed that physical data collected for the AUSRIVAS biological models did not include the full array of geomorphological variables necessary to construct comprehensive and robust physical predictive models. Thus, the project proceeded to develop the physical assessment protocol, which is a 'ready to implement' method for the collection of data appropriate for the construction of AUSRIVAS-style models. Once data are collected and models constructed, it will be possible to predict the occurrence of physical features and assess the physical condition of test sites. Implementation of the physical assessment protocol is discussed further in Section 3.1.

The steering committee meeting of 22 March 2000 also resolved that it would be necessary for this project to develop software to report the existing AUSRIVAS physical and chemical data. Thus, the AUSRIVAS physical and chemical reporting software utilises existing AUSRIVAS data and reports the physical character of test sites, in relation to the physical character of reference sites. The software does not provide any quantitative assessment of 'condition', because it was not considered valid to assign ratings of condition to individual variables (e.g. what percentage of riparian vegetation cover is good and what percentage is bad?), or to sets of variables that contained different arrays of physical components.

Further, the software was designed to utilise existing AUSRIVAS physical data and subsequently, it does not support the format of the physical assessment protocol. That is, it is not software to construct and display physical predictive models. Instead, the software utilises existing AUSRIVAS data by reporting the physical character of test sites, in relation to the physical character of reference sites. Implementation of the software is discussed further in Section 3.2.

2 PRODUCTS

The AUSRIVAS Physical and Chemical Assessment Module project has produced five products. These are:

1. AUSRIVAS physical assessment protocol (separate document, 173 pages).
2. Software to report existing AUSRIVAS habitat data (software package and software manual).
3. Review of physical river assessment methods (separate document, 59 pages).
4. Habitat assessment workshop (held 2-3 May 2000, report on workshop is Appendix 1 of this final report document).
5. Evaluation of aspects of existing river assessment methods to include in the final protocol (Appendix 2 of this final report document).

Further information on the purpose, development and content of each product is provided in the following sections.

2.1 AUSRIVAS PHYSICAL ASSESSMENT PROTOCOL

As mentioned in Section 1.1, the document titled **"AUSRIVAS Physical Assessment Protocol"** details a standardised rapid method for the collection of geomorphological, physical habitat, riparian and basic water quality data. The protocol incorporates aspects of several existing physical assessment methods into a method that can be implemented to construct AUSRIVAS-style predictive models. The process used to evaluate existing methods as candidates for inclusion in the protocol is detailed in Sections 2.3 and 2.5. Production of the protocol document satisfies Task 4, as outlined in paragraph in Paragraph B.3 of the contract schedule.

The AUSRIVAS Physical Assessment Protocol was reviewed by Wayne Erskine (State Forests of NSW), Peter Davies (Freshwater Systems, Tasmania) and Leon Metzeling (VIC EPA) in January 2001. Several aspects of the protocol were modified as a result of review comments, including division of streams into functional process zones, sampling site dimensions, and collection methods and category descriptions for several variables. Additionally, the protocol was discussed at a meeting held on 7 February

2001 (Bruce Gray, Lisa Evans, Allan Thomas (EA), Melissa Parsons, Martin Thoms). Several other aspects of the protocol were modified as the result of review comments from Bruce and Lisa, and included the addition of a note about non-applicability of the protocol in estuarine environments, justification of the scales chosen for use and inclusion of notes about sampling time and training needs.

The protocol was tested in a range of large and small streams on 30-31 January 2001. Several modifications were made to the protocol and field data sheets as a result of field-testing. These modifications included reduction in the sampling site dimensions from 10x bankfull width to 500m, changes to the measurement of cross-sectional profiles and rearrangement of the field data sheets to match the order of work at a sampling site.

2.2 AUSRIVAS PHYSICAL AND CHEMICAL REPORTING SOFTWARE

As discussed in Section 1.2, the **AUSRIVAS Physical and Chemical Reporting software** utilises the existing AUSRIVAS data and reports the status of a test site in relation to reference sites. The Physical and Chemical Reporting software is not a tool for quantifying the physical condition of a test site, because this would require construction of predictive models. Instead, the software allows the user to flag test sites that have physical and chemical characteristics that sit outside the range of characteristics found at corresponding reference sites. These physical and chemical characteristics can then be examined alongside the AUSRIVAS O/E scores to provide insight into the causes of biological degradation at a test site. Production of the software and software manual satisfies Task 5, as outlined in paragraph B.3 of the contract schedule.

Data for the software component were received from each State and Territory. The types of variables included were generally those representing geographical position, riparian vegetation, stream morphology, habitat assessment, water chemistry and organic and inorganic substratum. While used extensively for building AUSRIVAS models, several of the variables give little information about physical stream condition (e.g. latitude, longitude, stream order) and it is anticipated that users will wish to add variables to the reference data-base. In addition, reference site data will need to be updated to coincide with any changes made to the AUSRIVAS predictive models. Thus, the software manual includes detailed instructions for preparing a reference site data set and the programming of the software is set up to facilitate easy insertion of new reference site information as part of routine maintenance.

2.3 REVIEW OF PHYSICAL RIVER ASSESSMENT METHODS

The review document, titled **"Review of physical river assessment methods: a biological perspective"** examines seven methods of stream assessment that are potential candidates for inclusion in a nationally standardised physical and chemical assessment protocol. These methods are: AUSRIVAS, HABSCORE, Index of Stream Condition, River Styles, State of the Rivers Survey (a.k.a River Habitat Audit Procedure), Habitat Predictive Modelling and River Habitat Survey. For each of these methods, four questions were asked and answered:

1. How did the method come about?
2. How does the method work?
3. How does the method assess stream condition?
4. How does the method link physical and chemical features with the biota?

The review document satisfies Tasks 1 and 3, as outlined in paragraph B.3 of the contract schedule. As per the email correspondence of Bruce Gray on 23 May 2000, it is recommended that a slightly modified form of this document be formally published as an EA report.

2.4 HABITAT ASSESSMENT WORKSHOP

A workshop titled **"Stream Habitat Assessment: Integrating Physical and Biological Approaches"** was held at the University of Canberra on May 2-3, 2000. Twenty-two leading geomorphologists, hydrologists and ecologists attended the workshop to discuss approaches that may be useful for inclusion in a nationally standardised physical stream assessment protocol. A report on the habitat assessment workshop is provided in Appendix 1. The habitat assessment workshop satisfies Task 2, as outlined in paragraph B.3 of the contract schedule.

2.5 EVALUATION OF ASPECTS OF EXISTING RIVER ASSESSMENT METHODS TO INCLUDE IN THE FINAL PROTOCOL

Following production of the review document and completion of the habitat assessment workshop, it was necessary to decide on the desired philosophy and content of a standardised physical assessment protocol. This was done in a systematic manner using a four-step process:

1. set desired criteria for the physical assessment protocol;
2. evaluate existing stream assessment methods against these criteria;
3. on the basis of this evaluation, make recommendations about the major aspects of existing stream assessment methods useful for inclusion in the physical assessment protocol; and,
4. make final recommendations about the content and philosophy of the physical assessment protocol.

These final recommendations were then used to guide the development of the AUSRIVAS physical assessment protocol document. Full details of the four-step evaluation process are provided in Appendix 2. The evaluation of existing methods for inclusion into the physical assessment protocol satisfies Tasks 1 and 3, as outlined in paragraph B.3 of the contract schedule.

3 IMPLEMENTATION OF THE PRODUCTS

3.1 AUSRIVAS PHYSICAL ASSESSMENT PROTOCOL

The physical assessment protocol is a 'ready to use' method for collection of the information necessary to construct physical predictive models. Essentially, the protocol is equivalent to the River Bioassessment Manual (Peter Davies, 1994) that was used to direct sampling for the Monitoring River Health Initiative. Full implementation of the protocol will require further steps that progress in the same manner as the development of AUSRIVAS. Further steps for implementation of the physical assessment protocol are as follows:

1. Selection of reference sites in various functional process zones.
2. Collection of physical information from reference sites, and collection of office-based data.
3. Construction of predictive models.
4. Slight modification to the AUSRIVAS software and posting of new models. These models are then available to assess the physical condition of any new test site.

It is recommended that these steps are trialed in one State or region before being implemented on a National basis. Physical predictive models have been constructed successfully in the ACT using a limited set of AUSRIVAS physical data (Davies *et al.*, 2001). However, the ACT is a relatively small area with a limited range of functional process zone types and it would be useful to trial the method on a scale that sits 'in between' the local ACT area and the whole nation. In addition, new analytical techniques for model building have recently emerged (e.g. E-ball) and it would be useful to investigate the ability of these techniques to enhance the robustness and outputs of physical predictive models.

Once fully implemented the physical predictive models will allow ongoing assessment of the physical condition of any test site and will confer the same advantages as the AUSRIVAS biological predictive models. That is, the models can be used for a wide variety of purposes including State and national reporting and monitoring programs, community monitoring, research and teaching in Universities and commercial consulting. However, even though the physical assessment protocol is similar in philosophy to AUSRIVAS and complements biological assessments of river health, it should not be seen purely as an 'attachment' to biological methods. Rather, physical assessment warrants treatment as a separate discipline within river health. This is because physical character and geomorphological process exist independently of biological response and will indicate different aspects of river condition. Assessment of river condition using physical parameters will provide quantitative information on the physical health of rivers, and can be used to set targets for restoration efforts. Combination of the physical and biological assessment of stream condition can be easily achieved via the use of predictive models with the same types of outputs, and represents a potentially powerful tool for scientists and stream managers.

There will be costs associated with implementation of the physical assessment protocol. In particular it will be necessary to visit reference sites to collect physical information. However, the costs of sampling for the physical assessment protocol are reduced relative to AUSRIVAS, because each reference sites only needs to be visited once, and there is minimal laboratory based processing of field data. There is an office data collection component, and although much of this information can be collected from maps, the costs of maps and GIS access must be incorporated. Additionally, there are costs associated with the construction of predictive models, but it is expected that the existing AUSRIVAS algorithms could be used to develop and display the models. However, as mentioned above, several new predictive techniques have recently emerged and these should be tested to ensure production of robust physical models. It is expected that in the best case scenario, each State or regional physical predictive model would be available within 6-8 months of the completion of data collection.

The physical variables used in the protocol include many items that are not commonly used in biological assessment protocols (see Part 5 of the protocol document). Given experiences on training and quality control generated from the National River Health Program, it will be necessary to conduct a training program prior to commencement of any sampling program, where sampling teams standardise the collection of local scale data. This training exercise will be critical to the overall quality and success of predictive models, because the collection of local physical information is analogous to the collection of macroinvertebrate samples. In addition, it will also be necessary to provide training in the delineation of functional process zones, because this procedure requires the input of geomorphological expertise. However, many rivers in the Murray Darling Basin have already been characterised into Functional Process Zones. Further recommendations on training are provided in Appendix 1 of the protocol document.

3.2 AUSRIVAS PHYSICAL AND CHEMICAL REPORTING SOFTWARE

The States and Territories will be able to use the AUSRIVAS physical and chemical reporting software to evaluate the physical and chemical characteristics of a test site in relation to corresponding reference sites. The AUSRIVAS physical and chemical reporting software does not provide a quantitative measurement of physical and chemical condition. Rather, the software allows the user to flag test sites where the measured value of a physical or chemical variable sits outside the range of values measured at corresponding reference sites. These physical and chemical variables can then be used alongside the outputs from the AUSRIVAS biological models to indicate factors that may be contributing to biological degradation at a test site.

The physical and chemical reporting software currently operates using reference data supplied by each State and Territory. However, as discussed in Section 2.2, individual States and Territories may wish to update the variables included in the reference site data, and reference data sets will need to be updated when there is a change in an AUSRIVAS predictive model. Updating of reference site data and the accompanying reference variable information sheet will require individual States and Territories to set up new data sets, or to make modifications to the existing data sets. Detailed instructions for updating a reference data set or reference variables information sheet are provided in the User Manual. The updated reference data sets will then need to be forwarded to the software administrator, for insertion into the program.

As detailed in Section 1.2, the software is accessed via the existing AUSRIVAS website. The user manual that accompanies the software is also available via the same website. Once assigned a password, users will be able to begin using the software to examine the physical and chemical character of test sites. However, there are several aspects that need to be considered for ongoing use and maintenance of the software. These are:

- password allocation and administration;
- maintenance of the server (e.g. bringing it back up if it crashes);
- backing up data and programs stored on the server;
- responding to technical queries from users;
- maintenance of the web site; and,
- insertion of updated or modified reference data files provided by the States.

Thus, there will be a requirement for some ongoing funding associated with the implementation, administration and maintenance of the software.

4 APPENDICES

4.1 APPENDIX 1 HABITAT REPORTING WORKSHOP REPORT

4.1.1 Introduction

Twenty-two leading ecologists, geomorphologists and hydrologists attended a workshop titled "Stream Habitat Assessment: Integrating Physical and Biological Approaches", that was held at the University of Canberra on May 2-3, 2000 (Table 4.1). Broadly, the workshop was designed to provide the rationale and background information upon which to build the physical assessment protocol. The specific aims of the workshop were to:

1. examine physical and biological approaches to the assessment of stream condition currently in use in Australia;
2. determine the critical parameters required for assessment of stream condition from both a geomorphological and a biological perspective; and,
3. determine variables that are easily measured in the field and which represent critical parameters.

There were many tangible and some less tangible outcomes of the habitat assessment workshop. The less tangible outcomes generally related to the formation of interdisciplinary approaches to stream assessment and are summarised as follows:

- the workshop bought together geomorphologists, ecologists and hydrologists to seek an interdisciplinary approach to physical assessment of stream condition. As such, the workshop fostered dialogue that may result in advances in both disciplines; and,
- the workshop highlighted that the topic of physical and chemical stream assessment is complex and multifaceted, particularly when overlain with a prerequisite of biological relevance.

The tangible outcomes of the workshop relate directly to the development of a standardised physical and chemical assessment protocol. Three main topics of concern arose from general discussion sessions and workshop presentations on five existing stream assessment methods (River Habitat Audit Procedure, River Styles, Index of Stream Condition, AUSRIVAS and Habitat Predictive Modelling). These topics of concern were: study design issues, appropriate scale of focus and identification of physical and chemical variables to use in the protocol. A fourth issue that will need to be addressed is the overall choice of method used to determine stream condition. These topics of concern are discussed individually in the following sections.

Table 4.1 List of participants in the Habitat Assessment Workshop

John Anderson[1]	Judy Faulks	Richard Norris[5]
Rebecca Bartley	Brian Finlayson	Melissa Parsons
Andrew Boulton	Kirstie Fryirs	Mike Stewardson
Gary Brierley[2]	Chris Gippell	Mark Taylor
Nerida Davies[3]	Bruce Gray	Jim Thompson
Jenny Davis	Kathryn Jerie	Martin Thoms
Barbara Downes	Tony Ladson[4]	Simon Townsend
Fiona Dyer	Richard Marchant	John Whittington
Wayne Erskine	Leon Metzeling	

1. Presented an overview of the River Habitat Audit Procedure
2. Presented an overview of River Styles
3. Presented an overview of Habitat Predictive Modelling
4. Presented an overview of the Index of Stream Condition
5. Presented an overview of AUSRIVAS

4.1.2 Key issues arising from the workshop

4.1.2.1 Study design issues

Some study design issues that need to be considered in developing a protocol are:

- Comparisons between similar types of rivers will be an important aspect of the physical and chemical assessment protocol. Thus, the protocol should include an explicit method for dividing streams into homogeneous stream sections. The River Habitat Audit Procedure (Anderson, 1993) and River Styles (Brierley *et al.*, 1996) are potential candidates for achieving this on a medium to large-scale. However, if the Habitat Predictive Modelling approach (Davies *et al.*, 2000) is to be used in the standardised protocol, consideration must also be given to the grouping of similar sites using small-scale physical features. It may be possible to use the homogeneous stream section identification techniques of the River

Habitat Audit Procedure and River Styles to enhance the formation of groups in Habitat Predictive Modelling.

- The geomorphological reference condition needs to be defined for a standardised protocol. The definition of reference condition is particularly important if Habitat Predictive Modelling is used, because this approach requires a reference site database on which to build the model. The River Habitat Audit Procedure, River Styles and the Index of Stream Condition are less reliant on pre-defined reference conditions, and use post-sampling condition ratings derived from knowledge of the 'best available' stream condition. Similarly, the approach of the United Kingdom's River Habitat Survey was to identify reference sites post-sampling, on the basis of criteria such as the occurrence of rare or outstanding habitat features or a habitat quality assessment score (Raven *et al.*, 1998). Delineation of physical reference condition needs to be examined in detail for the protocol, because this step is critical to the process of assessing stream condition, as separate from merely describing the physical characteristics of streams.

4.1.2.2 Appropriate scale of focus

Some scale issues that need to be incorporated into the standardised physical and chemical assessment protocol are:

- The design of the standardised physical and chemical assessment protocol should pay close attention to both grain and extent. Extent is the overall area encompassed by a study, and grain is the individual unit of observation (Wiens, 1989). AUSRIVAS has a large extent (sites spread across States) but a small grain (10m sweep net samples collected from habitats within reaches). As a group, macroinvertebrates integrate a whole range of impacts occurring over a range of temporal and spatial scales and thus, the grain size used in AUSRIVAS is adequate for assessing the biological condition of individual sites spread across the landscape. However, physical and chemical aspects of stream condition have different properties to the biota and thus, the use of the same grain and extent as AUSRIVAS may not be adequate for assessments of physical and chemical condition.
- In addition to the scale of focus of the study design, the scale of focus of measurement variables needs to be resolved. It is well accepted that there is a

hierarchical arrangement of physical features within river systems and that processes operating on higher scales act to constrain processes operating on lower scales (Schumm and Lichty, 1965; Schumm, 1977; Frissell *et al.*, 1986). Thus, physical features could be measured on a number of scales ranging from catchments, to sections, zones, reaches, individual habitat units and microhabitats. It may be best to match the scale of focus of the measurement variables with the grain and extent of the study design. However, the arrangement of river systems in a hierarchical formation suggests that factors operating at scales 'in-between' the grain and extent may also be important for determining physical and chemical stream condition. If the Habitat Predictive Modelling approach is to be adopted as the overall method of assessment, it will be necessary to measure a large number of large and local-scale physical features, although other variables measured at other scales may also be incorporated into the model. Conversely, the collection of variables at 'too many' scales may complicate interpretations, add to field collection times and add little to assessment of stream condition. Perhaps the best way forward would be to examine the grain and extent of existing physical and chemical assessment methods and then investigate the deviation of these scales from the ones currently used in AUSRIVAS.

4.1.2.3 Identification of physical and chemical variables to use in the protocol

Considerations for selecting the variables to include in the protocol are:

- Scale of focus of the variables, as discussed in Section 4.1.2.2
- When selecting potential variables for use in the protocol, the ease of field measurement, conformity with rapid philosophies and the expertise required to collect and interpret data will need to be considered. However, in eliminating variables that do not meet these criteria, care needs to be taken that key variables for the assessment of river condition are maintained in the protocol. Additionally, consideration must be given to the practical application of the protocol in the field. If it is to be conducted alongside AUSRIVAS sampling, then realistically it can not take longer than one or two hours in the field to collect data. However, if it is to be conducted as a separate exercise from

AUSRIVAS, then more field time can be incorporated because of the reduced need for laboratory processing time.

- The current set of AUSRIVAS variables does not seem to fully encompass physical influences on stream condition, because AUSRIVAS variables were chosen to represent the physical environment for macroinvertebrates. In the protocol, it will be necessary to include variables that are important to macroinvertebrates, however, there are many additional variables to include that represent important physical and geomorphological aspects of stream condition. A summary of physical and chemical variables discussed at the workshop is given in Table 4.2.

4.1.2.4 Choice of method used to determine stream condition

Each of the methods presented at the workshop (Index of Stream Condition, River Habitat Audit Procedure, River Style and Habitat Predictive Modelling) has the potential to assess different aspects of stream condition. However, no single method seems to fulfil all the requirements for a standardised physical and chemical assessment protocol and as such, the relevant components will need to be extracted from each method and incorporated into a new protocol. The suitability of each method and the relevant components to incorporate into the protocol will be discussed in Appendix 2.

4.1.3 References

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Table 4.2 Potential physical and chemical assessment variables discussed in the habitat assessment workshop. Workshop participants were split into two discussion groups and thus, workshop group recommendation describes the decision made by each group on the usefulness of each variable for physical and chemical assessment of stream condition.

Variable category and description	Source	Workshop group recommendation	Notes
GEOGRAPHICAL POSITION			
Altitude	AUSRIVAS variable	6B2 YES, 6B9 NO	Debate about whether geographic position variables tell you anything about stream condition. However, they may place the site into its catchment context which is important biologically and geomorphologically
Latitude	AUSRIVAS variable	6B2 YES, 6B9 NO	As above
Longitude	AUSRIVAS variable	6B2 YES, 6B9 NO	As above
Catchment area upstream	AUSRIVAS variable	6B2 YES, 6B9 NO	As above, but may be more relevant to geomorphological process
Distance from source	AUSRIVAS variable	6B2 YES, 6B9 NO	As above, but may be more relevant to geomorphological process
Channel slope	AUSRIVAS variable - some States only	6B2 YES, 6B9 YES	Important geomorphological variable. Probably misplaced in geographical position category, should be in channel morphology.
Valley confinement	Suggested in workshop		Useful for indicating differences in stream power between confined, floodplain and broad sections. Misplaced in geographical position category, should probably be in channel morphology category.
RIPARIAN VEGETATION			
Width of riparian zone	AUSRIVAS variable	6B2 YES, 6B9 YES	Riparian vegetation was considered an important aspect both ecologically and geomorphologically
Cover of riparian zone by trees, shrubs, grasses	AUSRIVAS variable	6B2 YES, 6B9 YES	As above
Canopy cover of river	AUSRIVAS variable	6B2 YES, 6B9 YES	As above
Native and exotic vegetation cover	AUSRIVAS variable	6B2 YES, 6B9 YES	As above
Riparian vegetation density	AUSRIVAS variable - some States only	6B2 YES, 6B9 YES	As above

Table 4.2 (cont.)

Riparian Vegetation (cont.)			
Riparian vegetation continuity	AUSRIVAS variable - some States only	6B2 YES, 6B9 YES	As above
Riparian vegetation stability, density, composition, continuity	Suggested at workshop		May need to involve botanist for suggestions on the types of floristic variables that may be relevant.
Evidence of regeneration	Suggested at workshop		This variable is measured in the ISC.
CHANNEL MORPHOLOGY			
Stream width	AUSRIVAS variable	6B2 YES, 6B9 YES	More important for ecology than for geomorphology
Stream depth	AUSRIVAS variable	6B2 YES, 6B9 YES	More important for ecology than for geomorphology
Bank width	AUSRIVAS variable	6B2 YES, 6B9 YES	Important geomorphologically
Bank height	AUSRIVAS variable	6B2 YES, 6B9 YES	Important geomorphologically
Width:depth ratio	Suggested at workshop		May be an indicator of incision. If relating to catchment dimensions, width and depth measurements need to be taken at many places along a stream reach. Also may need to make these measurements relative to the water mark.
Bed heterogeneity	Suggested at workshop		Scale of focus? Bed heterogeneity can be measured at a small microscale or at a reach scale. May also link to the measure of channel complexity below. Can Mannings *n* be used as a measure of heterogeneity?
Bed form assessment	Suggested at workshop (6B2)		Is a measure of the types of bedfoms (glides, runs, pools etc.) present.
Channel complexity	Suggested at workshop		Not sure exactly what this would comprise, or at which scale. Perhaps a measure of wetted channel complexity or an index of channel shape. Rebecca Bartley may be a good contact for this.
Erosion (local and catchment)	Suggested at workshop (6B2)		Would be a measure of the extent of local and catchment erosion. Perhaps covered by bed and bank stability measures?
ISC measurements, especially physical form sub-indices of bed stability, bank stability and instream physical habitat	Suggested at workshop		Represents geomorphological processes. Field interpretation may need to be aided by photographs (see ISC field manual).

Table 4.2 (cont.)

<u>Channel Morphology (cont.)</u>			
River braiding and bars	Suggested at workshop although is included in AUSRIVAS observations – some States only		Unclear about what this indicates about stream morphology.
Bank shape	Suggested at workshop		To indicate undercutting etc. This variable is measured in the River Habitat Audit Procedure
Longitudinal variability	Suggested at workshop		Probably measured within the sampling reach. See Rebecca Bartley for more details.
WATER CHEMISTRY			
Temperature	AUSRIVAS variable	6B2 YES, 6B9 YES	Should also record time of day. Temperature probably not useful in itself but may be needed to calibrate other measurements
Conductivity	AUSRIVAS variable	6B2 YES, 6B9 YES	Reflects catchment geology
pH	AUSRIVAS variable	6B2 YES, 6B9 YES	
Dissolved oxygen	AUSRIVAS variable	6B2 YES, 6B9 YES	
Turbidity	AUSRIVAS variable	6B2 YES, 6B9 YES	
Alkalinity	AUSRIVAS variable	6B2 YES, 6B9 YES	Reflects catchment geology
Nutrients	AUSRIVAS variable	6B2 NO, 6B9 YES	Debate about usefulness of instantaneous measurements. Probably not worth collecting as spot measures. Other indicators (e.g. algae) may provide an integrated assessment of nutrient levels.
Ammonium	AUSRIVAS variable – some States only	6B2 NO, 6B9 YES	Again, debate about usefulness of instantaneous measurements.
Air temperature	AUSRIVAS variable – some States only	6B2 NO, 6B9 NO	Can be discarded
Stratification	Suggested at workshop (6B2)		May be useful in lowland rivers, especially in deep pools.
HABITAT COMPOSITION			
Large woody debris	Suggested in workshop (6B2)		Important variable ecologically and geomorphologically. Not covered well in AUSRIVAS.

Table 4.2 (cont.)

<u>**Habitat Composition (cont.)**</u>			
Percent riffle, edge, pool, macrophytes, run, snags and or dry bed in sampling area	AUSRIVAS variables	Mixed support. Important as a measure of macroinvertebrate habitat availability, but may not be the most geomorphologically relevant 'units' to measure.	Perhaps better covered in a bedform assessment (see channel morphology section) with units that are important geomorphologically. However, the current units are important because they (runs, pools, riffles etc.) represent the availability of the habitat types sampled for macroinvertebrates.
HYDROLOGY			
Mean annual discharge	AUSRIVAS variable	6B2 MIXED SUPPORT, 6B9 YES	Generally useful ecologically (i.e. how big is the stream) but not useful geomorphologically
CV of variation of mean annual discharge	AUSRIVAS variable	6B2 YES, 6B9 YES	Useful as a measure of variability over time
Stream power	Suggested in workshop (6B2)		Not discussed in detail, Chris Gippel may provide some insight
Time since last flood	Suggested in workshop (6B2)		This is the Thoms silt trembler and gooley shaker idea! The time since the last flood with a force that moved silt or larger particles along the streambed
Measure of ephemerality	Suggested in workshop (6B2)		Represents the ephemerality of flow and should indicate the difference between permanent and temporary streams. Is probably not the same thing as seasonal variation in flow?
Hydraulic variability	Suggested in workshop (6B2)		Is a measure of the different hydraulic 'types' present in a reach. When considered alongside substratum, hydraulic variability may provide a rough measure of channel hydraulic complexity.
Cease to flow	Suggested in workshop (6B2 and 6B9)		Probably obtained off flow duration curves.
Overbank flows	Suggested in workshop		Related to floodplain processes
Flow seasonality	Suggested in workshop		Is a measure of seasonal variation in flows. Represents differences in summer and winter rainfall areas?

Table 4.2 (cont.)

Hydrology (cont.)			
Change in flood frequency	Suggested in workshop		Would need to be compared to natural conditions?

Note on hydrology:

There are hundreds of hydrological measurements that could be included in the protocol, including those from the ISC (see back pages of ISC reference manual). There needs to be a closer consideration of the information that is required from the hydrological measurements, so that the appropriate measures can be collected. Concern was also raised about the difficulty of obtaining hydrological data and also about the lack of relationships that hydrological data generally has with macroinvertebrate data. However, hydrological data was considered to be critical to the assessment protocol because geomorphological changes tend to occur under high flow events.

INORGANIC SUBSTRATUM			
Bedrock	AUSRIVAS variable	6B2 YES, 6B9 NO	Both groups agreed that substratum was important geomorphologically and ecologically. However, group 6B9 did not think that it could tell us something about condition relative to pristine. Substratum process measurements may be more important geomorphologically whereas substrate composition may be important ecologically. It was agreed that the small fractions should be included because they were important ecologically and geomorphologically. It may also be relevant to take surface and sub-surface measurements because biota use both layers of substratum.
Boulder	AUSRIVAS variable	6B2 YES, 6B9 NO	As above
Cobble	AUSRIVAS variable	6B2 YES, 6B9 NO	As above
Pebble	AUSRIVAS variable	6B2 YES, 6B9 NO	As above
Gravel	AUSRIVAS variable	6B2 YES, 6B9 NO	As above
Sand	AUSRIVAS variable	6B2 YES, 6B9 NO	As above
Silt/Clay	AUSRIVAS variable	6B2 YES, 6B9 NO	As above
Substratum heterogeneity	AUSRIVAS variable - some States only	6B2 YES, 6B9 NO	Integrates the composition of each substrate component into an overall measure of heterogeneity?
Armouring	Suggested in workshop (6B2)		Is a measure of the potential for the stream bed to move under high flow conditions.
Matrix characteristics	Suggested in workshop (6B2)		Measures the matrix sediment and the fines component (Martin's idea). Is based in sediment theory.

Table 4.2 (cont.)

ORGANIC SUBSTRATUM			
Detritus cover (CPOM and FPOM)	AUSRIVAS variable	YES 6B2, NO 6B8	Group 6B9 thought that this was unable to indicate condition relative to pristine. But 6B9 thought that it was important to indicate condition. Unclear of the geomorphological relevance of detritus cover, except perhaps as an indicator of bed stability.
Moss cover	AUSRIVAS variable	YES 6B2, NO 6B9	Group 6B9 thought that moss was unable to indicate condition relative to pristine. The ecologists in group 6B2 couldn't work out why moss was important ecologically. However, the geomorphologists thought that moss was important because it could indicate the time since the last stream bed disturbance event that moved particles along the bed.
Filamentous algae cover	AUSRIVAS variable	YES 6B2, NO 6B10	Group 6B9 thought that this was unable to indicate condition relative to pristine. But 6B9 thought that it was an important variable for indicating condition.
Macrophyte cover	AUSRIVAS variable	YES 6B2, NO 6B11	Group 6B9 thought that this was unable to indicate condition relative to pristine. But 6B9 thought that it was important to indicate condition. Unclear of geomorphological relevance, except perhaps as an indicator of bed stability.
Periphyton cover	AUSRIVAS variable	YES 6B2, NO 6B12	Group 6B9 thought that this was unable to indicate condition relative to pristine. But 6B9 thought that it was important to indicate condition. Unclear of geomorphological relevance, except perhaps as an indicator of bed stability.
Macrophyte architecture	Suggested in workshop (6B2)		Indicates macrophytes as a habitat for macroinvertebrates. The complexity of macrophyte architecture may be related to species diversity.
Large woody debris	Suggested in workshop (6B2)		See notes in habitat composition section above
USEPA HABITAT ASSESSMENT			
Bottom substrate / available cover	AUSRIVAS variable	6B9 not considered, 6B2 unresolved	Unclear as to whether habitat assessment variables are important geomorphologically. Ecologically, they are important because they place a condition rating on whether each habitat parameter is able to support biological communities.

Table 4.2 (cont.)

USEPA Habtiat Assessment (cont.)			
Embeddedness	AUSRIVAS variable	6B9 not considered, 6B2 unresolved	As above
Velocity / depth category	AUSRIVAS variable	6B9 not considered, 6B2 unresolved	As above
Channel alteration	AUSRIVAS variable	6B9 not considered, 6B2 unresolved	As above
Bottom scouring and deposition	AUSRIVAS variable	6B9 not considered, 6B2 YES	As above. However, bottom scouring and deposition score is probably misplaced here and should be with channel morphology variables.
Pool/riffle, run/bend ratio	AUSRIVAS variable	6B9 not considered, 6B2 YES	As above. However, pool/riffle ratio score is probably misplaced here and should be with channel morphology variables.
Bank stability	AUSRIVAS variable	6B9 not considered, 6B2 YES	As above. However, bank stability score is probably misplaced here and should be with channel morphology variables.
Bank vegetative stability	AUSRIVAS variable	6B9 not considered, 6B2 unresolved	As above
Streamside cover	AUSRIVAS variable	6B9 not considered, 6B2 unresolved	As above
Total habitat score	AUSRIVAS variable	6B9 not considered, 6B2 unresolved	As above
SITE OBSERVATIONS			
Water and sediment odours and oils	AUSRIVAS variable	6B9 not considered, 6B2 unresolved	May be important biologically, but what can it tell us geomorphologically? Might be an important indicator of severe pollution.
Flow level and restrictions	AUSRIVAS variable	6B9 not considered, 6B2 NO	A coarse measurement that may only be applicable locally. May be better measured on a larger scale using hydrological data.
Kicknetting plume	AUSRIVAS variable	6B9 not considered, 6B2 NO	Relevance is limited to macroinvertebrate collection. This variable indicates the amount of fines, which would be picked up by other substratum variables. Thus, kicknetting plume can be discarded.
Local bank and catchment erosion	AUSRIVAS variable	6B9 not considered, 6B2 YES	Important geomorphological variable. Included in channel morphology section above.

Table 4.2 (cont.)

Site Observations (cont.)			
Landuse	AUSRIVAS variable	6B9 not considered, 6B2 NO	Not sure about this one. Landuse is probably a large-scale factor that influences a range of smaller scale factors. Thus, landuse can be measured on a catchment wide or local reach scale. Landuse would need to be included in a predictive modelling approach. This variable also gives scope to include man in the landscape and move away from notions of pristine condition.
Valley topography	AUSRIVAS variable	6B9 not considered, 6B2 YES	Should be changed slightly to valley confinement. Valley confinement is included in geographical position section above.
River braiding and bars	AUSRIVAS variable	6B9 not considered, 6B2 YES	Important geomorphological variable. Included in channel morphology section above.
Local point source and non-point source pollution	AUSRIVAS variable	6B9 not considered, 6B2 NO	Probably more important biologically, but still only used for interpretation. Can be discarded.
OTHER VARIABLES			
Overhanging vegetation	AUSRIVAS edge habitat variable	6B9 not considered, 6B2 not considered	Probably doesn't need to be measured because it is specific to the edge habitat. However, a measure of the degree of trailing bank vegetation in slow flowing areas might be included under the riparian vegetation category.
Water velocity	AUSRIVAS variable	No real conclusions reached	Probably important information for distinguishing between habitats and between different stream gradients for macroinvertebrates. However, it is probably of limited use geomorphologically, because geomorphology is concerned with high flow events and whole stream discharges. Also, 3 or 4 replicate velocity measurements may not be adequate to characterise hydraulic conditions.
Floodplain characteristics such as condition, erosion, sedimentation, connectivity to main channel, frequency of innundation	Suggested at workshop (6B2)		Not so important for AUSRIVAS but important geomorphologically.
Catchment geology	Suggested at workshop (6B2)		Important geomorphologically, at a large-scale. There may also be other large-scale 'control' type variables that can be measured. See Nerida's study for ideas.

4.2 APPENDIX 2
EVALUATION OF EXISTING RIVER ASSESSMENT METHODS FOR INCLUSION IN THE PHYSICAL ASSESSMENT PROTOCOL

Assessment of stream condition using physical and chemical parameters will provide information on the physical and chemical health of streams, as well as providing information that is complementary to the AUSRIVAS biological assessments of stream condition. Thus, the development of a standardised physical and chemical assessment protocol will need to merge aspects of physical assessment with aspects of biological assessment. The following sections expand on the work included in the review of physical stream assessment methods (Parsons *et al.*, 2000; and see Section 2.3) and **describe the process used to derive the philosophy and content of the physical assessment protocol**. Section 4.2.1 examines the criteria required for the physical and chemical assessment protocol. Section 4.2.2 then evaluates the performance of four existing methods of stream condition against these criteria. Section 4.2.3 makes recommendations about the inclusion of existing river assessment methods into the protocol and Section 4.2.4 outlines the major components that are to be included in the protocol, in light of the evaluation of existing methods. The methods of physical stream assessment included in the evaluation (River Habitat Audit Procedure, Index of Stream Condition, Habitat Predictive Modelling and River Styles) correspond with the methods presented at the Habitat Assessment Workshop. Each method is also examined in detail in the review document of Parsons *et al.* (2000).

4.2.1 Criteria for the physical and chemical assessment protocol

Ideally, a standardised physical and chemical assessment protocol will:

- have an ability to predict the physical features that should occur in disturbed rivers and streams;
- have an ability to assess stream condition relative to a desirable reference state;
- utilise a 'rapid' data collection philosophy;
- use physical and chemical variables that do not require a high level of expertise to measure and interpret;

- use variables that represent the fluvial processes that influence physical stream condition;
- have outputs that are easily interpreted by a range of users; and,
- be applicable to all stream types within Australia.

In addition, compatibility of the protocol with AUSRIVAS will require:

- incorporation of a scale of focus that matches the scale of biological collection within AUSRIVAS;
- collection of physical parameters that are relevant to macroinvertebrates; and,
- outputs of physical condition that are comparable to AUSRIVAS outputs of biological condition.

The representation of these criteria within the five stream assessment methods examined at the habitat assessment workshop is summarised in Table 4.3. The relationship between each stream assessment method and each desired protocol criteria is discussed in Section 4.2.2.

4.2.2 Performance of existing methods against criteria for the physical and chemical assessment protocol

4.2.2.1 Ability to predict the physical features that should occur in disturbed rivers and streams

Habitat Predictive Modelling (Davies *et al.*, 2000) is clearly the most advanced method in this category. Habitat Predictive Modelling has the ability to predict the occurrence of local stream features from larger scale catchment characteristics. River Styles (Brierley *et al.*, 1996) is the only other method with predictive capability. However, the predictions made in River Styles are based upon expert geomorphological interpretation of the behaviour of river systems and this knowledge is not easily transferable to a standardised physical and chemical assessment protocol. The Index of Stream Condition (Ladson and White, 1999) and the River Habitat Audit Procedure (Anderson, 1993) were not designed to have predictive ability.

Table 4.3 Evaluation of river assessment methods against desired criteria of the physical and chemical assessment protocol. The representation of each of the criteria by the methods is designated as yes (Y), no (N) or potentially (P).

Criteria required for the physical and chemical assessment protocol	**Existing physical assessment methods**			
	River Habitat Audit Procedure	Index of Stream Condition	River Styles	Habitat Predictive Modelling
Ability to predict the physical features that should occur in disturbed rivers and streams	**N**	**N**	**P**[1]	**Y**
Ability to assess stream condition relative to a desirable reference state	**Y**	**Y**	**Y**	**Y**
Use of a 'rapid' data collection philosophy	**Y**	**Y**	**N**	**Y**
Use of physical and chemical variables that do not require a high level of expertise to measure and interpret	**Y**	**Y**	**P**[2]	**Y**
Use of variables that represent the fluvial processes that influence physical stream condition	**Y**	**Y**	**Y**	**P**[3]
Outputs that are easily interpreted by a range of users	**Y**	**Y**	**N**	**Y**
Applicability to all stream types within Australia	**P**[4]	**P**[4]	**P**[4]	**P**[4]
Incorporation of a scale of focus that matches the scale of biological collection within AUSRIVAS	**Y**	**Y**	**P**[5]	**Y**
Collection of physical parameters that are relevant to macroinvertebrates	**P**	**P**	**P**	**Y**
Outputs of physical condition that are comparable to AUSRIVAS outputs of biological condition	**N**	**N**	**N**	**Y**

1. Predictive ability relies on expert knowledge of the geomorphological behaviour of river systems.
2. Variables may not require a high level of expertise to measure, but a high level of expertise to interpret.
3. Currently uses physical and chemical data collected in AUSRIVAS, but can be modified to incorporate other types of variables.
4. There is no existing Australia wide system for assessing the physical and chemical condition of rivers. All methods are potentially modifiable for use in different river types across Australia.
5. River Styles uses a multi-scale approach to characterise and assess river systems.

4.2.2.2 *Ability to assess stream condition relative to a desirable reference state*

All of the stream assessment methods have the capacity to assess stream condition against a reference state. However, each method differs in its delineation of that reference state. The River Habitat Audit Procedure (Anderson, 1993) uses a rating system where the condition of a site is expressed as a percentage of the original pristine values, functions or utilities that are retained. However, the designation of pristine values for each data component is somewhat subjective. For example, a riparian width of 50m is designated as pristine. Local reference sites can be used to re-scale the condition ratings to reflect inherent local or regional features, although this re-scaling process is still dependent on the original designation of pristine. The Index of Stream Condition (Ladson and White, 1999) also uses a rating system to assess stream condition. Reference values or ranges are defined for each indicator and allocated rating scores. For each site, the rating scores for each indicator are summed to produce an overall index. The rating scores reflect coarse differences between excellent, moderate and poor stream condition, however, it may not provide the resolution to reflect a continuum of stream condition with many states.

Delineation of the reference condition in River Styles (Brierley *et al.*, 1996) is descriptive only. It is based on expert geomorphological knowledge of a river system in relation to its historical and catchment context. Reliance on expert geomorphological knowledge to determine reference condition is not conducive to a standardised physical and chemical assessment protocol. However, the placement of a river into its historical and catchment context may be an aspect of reference condition that is important when examining physical stream condition, and which is not addressed in detail by other methods.

Habitat Predictive Modelling (Davies *et al.*, 2000) uses the same regional reference approach as AUSRIVAS. Reference sites are chosen to represent minimally disturbed conditions, on the basis of criteria such as land-use, absence of point source pollution, riparian vegetation, geomorphology and general catchment condition. These reference sites form the basis of the predictive model. The advantage of the regional reference site approach is that assessment of condition at a test site is derived from comparison with a group of reference sites with similar environmental conditions (Norris, 1994; Reynoldson *et al.*, 1997). However, the Habitat Predictive Modelling study used the

AUSRIVAS reference sites, which were originally chosen on the basis of characteristics related to biota. Habitat Predictive Modelling may be improved by selecting reference sites on the basis of characteristics that are related to physical stream condition.

4.2.2.3 Use of a 'rapid' data collection philosophy

The River Habitat Audit Procedure (Anderson, 1993) and Habitat Predictive Modelling (Davies *et al.,* 2000) are designed specifically to use rapid data collection methods. The River Habitat Audit Procedure collects a comprehensive set of physical measurements and Habitat Predictive Modelling measures the physical parameters chosen for use in AUSRIVAS. For both methods, the amount of time spent at a sampling site is approximately one hour, although there is also an office data collection component. The Index of Stream Condition (Ladson and White, 1999) is also a rapid method and field information can be collected in approximately two hours. However, the collection of hydrology and biological data adds a substantial office component to this time. River Styles (Brierley *et al.,* 1996) was not designed to fit rapid a sampling philosophy. However, many of the physical and geomorphological variables collected in River Styles have potential for adoption into a standardised physical and chemical assessment protocol (see Section 4.2.2.4).

4.2.2.4 Use of physical and chemical variables that do not require a high level of expertise to measure and interpret

The River Habitat Audit Procedure (Anderson, 1993) and the Index of Stream Condition (Ladson and White, 1999) are designed for use by a range of operators. As such, the physical and chemical variables are collected using standard and rapid techniques. For example, the River Habitat Audit Procedure includes variables such as bank condition and riparian vegetation characteristics, and the Index of Stream Condition includes sub-indices such as bed and bank stability and longitudinal connectivity of riparian vegetation. In the Index of Stream Condition, consistency of interpretation and measurement is achieved through the provision of reference photographs and in the River Habitat Audit Procedure, consistency is achieved through a two-day training program. Likewise, Habitat Predictive Modelling (Davies *et al.,* 2000) was developed using the AUSRIVAS data, which included physical and chemical variables that could be easily measured and interpreted by a range of users.

River Styles (Brierley *et al.*, 1996) aims to assess the geomorphological character of a river and thus, it includes specialised geomorphological measurements. Different sets of variables are measured at the catchment, reach and geomorphic unit scales, however, many of these variables correspond to those used in other methods. For example catchment area, reach vegetation cover, stream order and landuse are measured using standard techniques. The more specialised variables measured in River Styles include catchment elongation ratio, meander wavelength, planform geometry, width to depth ratio, stream power, bankfull discharge and sediment grain size distribution, among others. With appropriate operator training, most of these variables could be collected in the field by agency staff, using rapid data collection techniques. However, it is unclear whether these variables require specialised field measurement equipment.

4.2.2.5 Use of variables that represent the fluvial processes that influence physical stream condition

The River Habitat Audit Procedure (Anderson, 1993) measures variables that essentially 'summarise' fluvial processes. Features such as channel shape, sediment particle size, aggradation and degradation of the bed, sediment compaction and instream bars are visually assessed. Thus, many of the River Habitat Audit Procedure variables represent important fluvial processes and utilise rapid collection methods. River Styles (Brierley *et al.*, 1996) also measures fluvial process variables, but in a more specialised manner. As mentioned in the preceding section, the more specialised variables measured in River Styles include catchment elongation ratio, meander wavelength, planform geometry, width to depth ratio, stream power, bankfull discharge and sediment grain size distribution, among others. The direct process based nature of these variables suggests that they may be important inclusions in the physical and chemical assessment protocol.

The Index of Stream Condition (Ladson and White, 1999) is designed to be a holistic assessment of stream condition, on a scale that is commensurate with management concerns. The sub-indices used in the method represent the broad influences on stream condition and indicators within these sub-indices measure specialised aspects of condition. The hydrology, physical form and streamside zone sub-indices are the most relevant to fluvial processes. As with the River Habitat Audit Procedure these sub-indices are 'summary' rather than 'direct' measures of fluvial processes. Conversely, Habitat Predictive Modelling (Davies *et al.*, 2000) was developed using the physical and chemical variables collected in AUSRIVAS, and thus, these variables predominantly reflect fluvial factors that are related directly to macroinvertebrates. However, Habitat Predictive Modelling contains scope to incorporate different types of variables and it is potentially possible to develop a model that contains fluvial process variables (e.g. River Styles), fluvial ‘summary’ variables (e.g. River Habitat Audit Procedure and Index of Stream Condition) and biologically relevant variables (e.g. AUSRIVAS).

4.2.2.6 Outputs that are easily interpreted by a range of users

The outputs of the River Habitat Audit Procedure (Anderson, 1993) can be simplified into a skeleton map or pie chart that shows the condition of river sections within a catchment. Likewise, the sub-indices of the Index of Stream Condition (Ladson and White, 1999) are added together to form an overall index score that represents a continuum of excellent to poor stream condition. Habitat Predictive Modelling (Davies *et al.*, 2000) produces AUSRIVAS-style observed:expected ratios, however, the designation of these ratios into bands representing different levels of impairment has yet to be investigated for physical features. River Styles makes a detailed assessment of the geomorphological character and behaviour of a river within its catchment and historical context and thus, outputs are not summarised into an index or score. Maps of channel character under pre and post-disturbance conditions can be constructed for different rivers, although in comparison to the outputs of the other methods, these maps provide a more indirect, expert interpretation based assessment of stream condition.

4.2.2.7 Applicability to all stream types within Australia

Of the four stream assessment methods considered in this document, none are presently being applied Australia wide. Each method has potential applicability to a range of stream types, however, modifications to the variables collected and the delineation of reference condition may be required to reflect inherent local or regional variability in stream types.

4.2.2.8 Incorporation of a scale of focus that matches the scale of biological collection within AUSRIVAS

The focus of the AUSRIVAS study design is on the reach scale. At each site, the length of the sampling reach is defined as 10 times the mean stream width. Macroinvertebrates are collected from different habitats (riffle, main channel, edge, macrophyte or sandbeds) within this reach. It is assumed that a macroinvertebrate sample collected from a 10m transect in each habitat will be representative of the fauna present in that habitat along the entire reach. In addition to macroinvertebrates, physical, chemical and habitat features are measured within the whole reach (e.g. riparian vegetation, substratum, water chemistry, HABSCORE) or within individual habitats (e.g. water velocity, substratum, FPOM, CPOM). A set of large-scale map measurements is also collected (e.g. landuse), along with a set of measurements that indicate geographic position of the sampling site (e.g. altitude, latitude, longitude, distance from source). Thus, the main scale of focus of AUSRIVAS is the reach scale, although macroinvertebrates are collected on a smaller scale within this reach, and physical, chemical and biological variables are collected across different scales. In addition, the statistics used to derive the AUSRIVAS predictive models are based on differences in the spread of riffle samples across the landscape.

The sampling focus of the River Habitat Audit Procedure (Anderson, 1993), Index of Stream Condition (Ladson and White, 1999) and Habitat Predictive Modelling (Davies *et al.*, 2000) is also predominantly at the reach scale. The River Habitat Audit Procedure divides streams into homogeneous stream sections then samples representative reaches within each section. The Index of Stream Condition divides streams into reaches and then samples at three measuring sites within each reach. Habitat Predictive Modelling is based on the AUSRIVAS data and uses large-scale catchment characteristics to predict reach or individual habitat scale physical features. However, each method uses a different definition of a reach. Reaches within the River Habitat Audit Procedure are equivalent to two meander wavelengths or pool/riffle/run sequences. Reaches within the Index of Stream Condition are usually 10-30km long, and measuring sites within these reaches are 430m long. Habitat Predictive Modelling reaches are the same as AUSRIVAS reaches and are equivalent to 10 times the mean stream width. Despite differences in the definitions of a reach, the scale of measurement for these physical assessment methods is generally at a local-scale, in comparison to some larger scale context. This is commensurate with the scale of focus of AUSRIVAS.

River Styles (Brierley *et al.*, 1996) has a multi-scale focus that is designed to encompass hierarchical controls on the behaviour of river systems. Catchment scale boundary conditions dictate the range of behaviour within sub-catchments, planform attributes describe river behaviour at the reach scale and structural attributes describe river character at a geomorphic unit scale. The multi-scale approach used in River Styles facilitates examination of geomorphological character and behaviour, and interpretation of stream condition in different sized 'pieces' of river systems. Although not commensurate with the scale of focus of AUSRIVAS, the multi-scale approach of River Styles may be a useful addition to the standardised physical and chemical assessment protocol because it encompasses the geomorphological processes that influence channel features at different hierarchical levels.

4.2.2.9 Collection of physical parameters that are relevant to macroinvertebrates

AUSRIVAS uses macroinvertebrates to assess stream condition. As such, the physical, chemical and habitat variables that are collected in AUSRIVAS are specifically related to the distribution and ecology of the fauna. While these variables may reflect the environmental requirements of macroinvertebrates, it is unclear whether they cover the full spectrum of factors that may indicate the condition of the stream from a physical perspective.

The relevance of the AUSRIVAS physical and chemical variables to physical stream assessment was examined at the habitat assessment workshop (see Appendix 1). Generally, some of the current AUSRIVAS variables are able to indicate aspects of physical stream condition. These include factors such as riparian vegetation, water chemistry and inorganic substratum. However, there are also other variables not collected in AUSRIVAS that are important for assessing physical stream condition. These include factors such as hydrology, channel complexity, channel morphology, valley characteristics and floodplain characteristics, among others. These factors are also important biologically, because they indirectly influence ecological processes or the provision of instream habitat. Thus, a standardised physical and chemical assessment module should include variables other than those collected in AUSRIVAS.

A comprehensive spectrum of variables that indicate physical stream condition are encompassed by the River Habitat Audit Procedure (Anderson, 1993), the Index of Stream Condition (Ladson and White, 1999), Habitat Predictive Modelling (Davies *et al.,* 2000) and River Styles (Brierley *et al.,* 1996). However, no one method contains all the variables relevant to physical stream assessment. Habitat Predictive Modelling is based primarily on the physical and chemical features important to macroinvertebrates, but also includes a set of larger scale predictor variables that are related to catchment scale morphology and processes. The Index of Stream Condition collects a range of physical and hydrological indicators that are related to physical stream condition and the River Habitat Audit Procedure collects a comprehensive set of physical stream features. River Styles measures variables related to geomorphological structure and process. Thus, the variables included in a standardised physical and chemical assessment protocol could be drawn from the different methods, to represent both biologically relevant and geomorphologically relevant factors.

4.2.2.10 Outputs of physical condition that are comparable to AUSRIVAS outputs of biological condition

The main output of the AUSRIVAS predictive models is an observed:expected taxa ratio. The deviation between the number of taxa expected to occur and the number of taxa that were actually observed at a test site is a measure of stream condition. Other outputs from the AUSRIVAS predictive models include the probability of occurrence of individual taxa at a test site, the impairment band of the observed:expected ratio and an observed:expected ratio for the SIGNAL index. Habitat Predictive Modelling (Davies *et al.,* 2000) is the only stream assessment method that matches AUSRIVAS outputs, because it can produce an observed:expected ratio that compares the local habitat features expected to occur at a site against the local habitat features that were actually observed at a site. Despite its demonstrated ability to predict habitat features, Habitat Predictive Modelling adapts a biological monitoring technique to the assessment of physical condition and thus, there are several analytical limitations associated with this method. In particular, Habitat Predictive Modelling currently predicts categories of habitat features, rather than continuous data. Investigations into new analytical techniques that can predict continuous data are currently under way. In addition, the relationship between actual instream condition and the observed:expected ratio needs to be investigated for physical data.

4.2.3 Recommendations for the inclusion of existing river assessment methods in the physical and chemical assessment protocol

The River Habitat Audit Procedure, Index of Stream Condition, River Styles and Habitat Predictive Modelling were designed for slightly different purposes. Subsequently, each method differs in its compatibility with the requirements of a standardised physical and chemical assessment protocol (Table 4.3). Each method performs equally well against criteria such as 'ability to assess stream condition against a desirable reference state', and 'applicability to all stream types within Australia'. However, only one or two methods perform well against criteria such as 'ability to predict physical stream features that should occur in disturbed rivers and streams' and 'outputs of physical condition that are comparable to AUSRIVAS outputs of biological condition' (Table 4.3). Overall, no one method meets all the requirements for a stand-alone stream assessment protocol. However, each method contains important individual components that can be combined into a comprehensive protocol for assessing stream physical and chemical condition. The components of each method that will be incorporated into the physical and chemical assessment protocol are outlined below:

- **River Habitat Audit Procedure** – this method has an excellent general approach to data collection. The river habitat audit procedure collects a comprehensive set of physical attributes that represent a range of indicators of stream condition. This method also uses rapid data collection methods in the field, and has easily understood data sheets. Additionally, the River Habitat Audit Procedure divides the study area into homogeneous stream sections to facilitate comparisons of similar stream types. These four aspects will be incorporated into the physical and chemical assessment module.
- **River Styles** – this method uses geomorphological theory to divide river systems into hierarchical units and is most useful for distinguishing homogeneous stream sections of similar river styles. River Styles also measures specialised physical variables that represent geomorphological processes, and these will be incorporated into the protocol at the appropriate spatial scale.

- **<u>Index of Stream Condition</u> –** this method includes indicators of stream condition such as bank stability, bed stability, streamside zone and hydrology that will be incorporated into the protocol.
- **<u>Habitat Predictive Modelling</u> –** predictive ability is the most inviting aspect of this method. Habitat Predictive Modelling has the ability to incorporate a range of physical and chemical variables collected at different scales, as well as variables that are specifically important to macroinvertebrates. This method also has outputs (observed:expected ratios) that are directly comparable to the outputs of the AUSRIVAS predictive models.

As mentioned in Appendix 1, three major considerations in the design of the physical and chemical assessment protocol will be scale of focus, determination of reference condition and comparisons of similar stream types. The River Habitat Audit Procedure, Index of Stream Condition, River Styles and Habitat Predictive Modelling methods adopt broadly similar approaches to these three aspects. For example, each method samples at a reach scale, each assesses condition against some desirable reference state, and each contains a mechanism for delineating stream types with similar physical features. However, there are also several differences between methods that may influence the incorporation of these aspects into the physical and chemical assessment protocol. For example, Habitat Predictive Modelling uses classification analysis to group similar stream types, whereas the River Habitat Audit Procedure uses a combination of map examination and field reconnaissance to determine homogeneous stream sections.

4.2.4 Recommendations for major components of the physical assessment protocol

The Habitat Assessment Workshop (Appendix 1) identified areas of concern for the development of a standardised physical and chemical assessment protocol. Evaluation of four existing stream assessment methods against specific criteria (Section 4.2.2) then identified the aspects of each method that should be included in the protocol (Section 4.2.3). The following sections bring together the habitat assessment workshop and method evaluation outcomes, to make recommendations about the major components that will be included in a standardised physical assessment protocol.

4.2.4.1 Habitat Predictive Modelling will be the overall approach used in the protocol

The overall approach of the physical and chemical assessment protocol will be based on Habitat Predictive Modelling (Davies *et al.,* 2000). Habitat Predictive Modelling confers four main advantages in the assessment of stream condition. Firstly, it is the only existing method that is able to predict the local-scale habitat features that would be expected to occur at a site in the absence of degradation. These features can then be compared against the features that were actually observed at that site, with the deviation between the two being an indication of physical stream condition. Secondly, Habitat Predictive Modelling uses multivariate data analysis, which allows simultaneous consideration of multiple physical factors. Thirdly, Habitat Predictive Modelling can be easily modified to incorporate aspects of other stream assessment methods and in fact, is strengthened by the addition of components from other methods (see Section 4.2.4.2).

The fourth advantage of using Habitat Predictive Modelling as the basis for the physical and chemical assessment protocol is its compatibility with AUSRIVAS. In the data collection phase, many of the current AUSRIVAS variables that are deemed relevant to physical assessment will be included in the protocol (see Section 4.2.4.5). Habitat Predictive Modelling also uses the same model building technique as AUSRIVAS and thus, the outputs of physical stream condition from Habitat Predictive Modelling (observed:expected ratios and probabilities of occurrence) are identical to those of AUSRIVAS. In addition, it is envisaged that once physical and chemical data is collected and models constructed, the existing AUSRIVAS predictive model software would require only minor modifications to accommodate a fully functioning interface for State agency users.

4.2.4.2 Habitat Predictive Modelling will be augmented with aspects from other physical assessment methods

Although Habitat Predictive Modelling (Davies *et al.*, 2000) forms a sound basis for the physical and chemical assessment module, it can be strengthened considerably with the addition of aspects from other physical assessment methods. In particular, the River Habitat Audit Procedure (Anderson, 1993), River Styles (Brierley *et al.*, 1996) and Index of Stream Condition (Ladson and White, 1999) incorporate aspects of physical assessment that are not included in Habitat Predictive Modelling (see Section 4.2.3). Thus, the Habitat Predictive Modelling approach of Davies *et al.* (2000) will be modified to include sampling design, data collection and analytical components from these other stream assessment methods.

4.2.4.3 A hierarchical approach will be incorporated into the design of the protocol

It is generally accepted that stream systems are arranged hierarchically and that physical processes operating at larger scales constrain the expression of physical processes at successively smaller scales (Schumm and Lichty, 1965; Frissell *et al.*, 1986). Habitat Predictive Modelling uses this relationship to predict the occurrence of local-scale stream features on the basis of large-scale catchment characteristics (Davies *et al.*, 2000). Similarly, River Styles uses a hierarchical approach that measures physical character and geomorphological behaviour at the catchment, reach and geomorphic unit scales (Brierley *et al.*, 1996). Merging the hierarchical approaches of Habitat Predictive Modelling and River Styles has the potential to improve prediction of stream habitat features by encompassing the scales that represent geomorphological processes, as well as the scales that represent aspects of the physical environment that are important for macroinvertebrates.

The use of a hierarchical approach has implications for several areas of the physical and chemical assessment protocol. Firstly, Habitat Predictive Modelling uses large-scale characteristics to predict local-scale stream features. The use of a hierarchical approach will assist in determining the link between the large-scale 'controlling' variables and the local-scale features that can be predicted using these larger scale variables. Secondly, physical and chemical variables will be measured across the range of scales that represent geomorphological processes, and across the range of scales that represent the physical environment for macroinvertebrates. This will ensure that the factors influencing physical stream condition and the factors important for macroinvertebrates are included in the predictive model. Lastly, the delineation of groups of reference sites with similar local-scale features is a pivotal step in Habitat Predictive Modelling. Given that river systems are organised hierarchically, meaningful grouping of reference sites on the basis of local-scale features requires some knowledge of the characteristics of the constraining levels of the hierarchy within which these local-scale features sit.

4.2.4.4 Definition of geomorphological reference condition will be critical to Habitat Predictive Modelling

A recent development in river assessment has been the use of reference conditions, rather than reliance on single sites as controls. These reference conditions then serve as the control against which test site conditions are compared. Given the caveat that man is part of the landscape, the determination of reference condition is essentially one of best available condition (Norris and Thoms, 1999). The AUSRIVAS predictive models incorporate the concept of reference condition in two ways. Firstly, sampling sites are selected to represent least impaired biological reference conditions. The characteristics used to discriminate least impaired reference sites include: the degree of urbanisation, forestry and agriculture in the catchment; the influence of major impoundments, extractions or diversions; the influence of point sources of pollution; the degree of channel modification; and, the degree of bank degradation (Davies, 1994). It is assumed that reference sites with minimally disturbed physical characteristics will contain unimpaired macroinvertebrate communities. Secondly, the physical and biological information collected from these reference sites is used to build the predictive models and thus, this information becomes the template against which test sites are compared to assess their ecological condition. Procedures exist to 'weed out' reference sites that do not represent least impaired conditions (Coysh *et al.*, 2000) but ultimately, the definition of reference condition is critical to the biological assessments of stream condition that are made by the AUSRIVAS predictive models.

Habitat Predictive Modelling uses the same reference condition approach and modelling techniques as AUSRIVAS (Davies *et al.*, 2000). As with AUSRIVAS, the definition of geomorphological or physical reference condition will be critical to the assessments of physical stream condition that are made using Habitat Predictive Modelling. However, the geomorphological reference condition used in Habitat Predictive Modelling has different properties from the biological reference condition used in AUSRIVAS. Thus, it will be necessary to determine the characteristics that represent least impaired physical and geomorphological condition. The Habitat Assessment Workshop (see Section 4) identified several parameters that could be used to guide the selection of appropriate reference sites for geomorphological or physical assessment of stream condition. These were:

- riparian zone condition and characteristics

- influence of river regulation - regulated catchments should be avoided but where regulation is unavoidable, the percentage of flow contributed by the regulated and unregulated portions of the catchment should be examined.
- history of mining activity within the catchment
- density of tracks and roads
- catchment landuse
- catchment geology
- influence of non-native vegetation that changes channel morphology
- historical incision of channels
- de-snagging and instream vegetation removal
- flood regime
- valley configuration, as an indicator of stream power

Additionally, the Index of Stream Condition (Ladson and White, 1999) and River Habitat Audit Procedure (Anderson, 1993) each compare sampling sites against some type of reference state, and these reference states may be incorporated into the identification of geomorphological or physical reference condition for Habitat Predictive Modelling. For example, the rating scores used for each indicator in the Index of Stream Condition are derived from knowledge of a continuum of good to poor condition. Similarly, the condition ratings used in the River Habitat Audit Procedure express condition as a percentage of the original values, functions or utilities that are retained at a sampling site. Subsequently, the threshold reference values for individual data components that are used in both of these rating processes can be used to aid the identification of characteristics that represent geomorphological or physical reference condition.

The development of a standardised physical and chemical protocol that is complementary to AUSRIVAS biological assessments may also require consideration of biological reference condition. Macroinvertebrates are inextricably linked to their physical surroundings (Southwood, 1988; Townsend and Hildrew, 1994) and as a result, the condition of the macroinvertebrate community is directly related to the condition of the physical habitat (Barbour, 1991; Rankin, 1995). However, it is possible for sites that are physically degraded to contain a relatively healthy fauna or conversely, it is possible for sites in good physical or geomorphological condition to contain a degraded fauna, because of water quality influences. Merging an assessment of the ability of the physical habitat to support biota into the determination of geomorphological reference condition may allow distinction between the effects of habitat impairment and the effects of water quality degradation.

4.2.4.5 The choice of measurement variables will be critical to assessment of stream condition

The River Habitat Audit Procedure, Index of Stream Condition, River Styles and AUSRIVAS stream assessment methods measure a range of physical, chemical and habitat variables. The types of variables measured in these methods correspond to the purpose and context of each method. The variables collected in River Styles (Brierley *et al.*, 1996) are important for the geomorphological characterisation of stream systems at the catchment, reach and geomorphic unit scales. The River Habitat Audit Procedure (Anderson, 1993) measures a comprehensive set of physical variables that describe structural components of streams and which indirectly 'summarise' fluvial processes. The Index of Stream Condition (Ladson and White, 1999) incorporates indicator variables that encompass the important influences on stream condition, and which are able to detect changes in stream condition over a 5 year assessment interval. AUSRIVAS (Coysh *et al.*, 2000) and Habitat Predictive Modelling (Davies *et al.*, 2000) measure physical variables that are important for macroinvertebrates. As such, there are many variables that can potentially be measured in the physical and chemical assessment protocol.

The robustness and power of a predictive model based solely on physical characteristics is directly dependent on the variables that are available to construct the models, and on the physical processes that these variables indicate. Habitat Predictive Modelling uses large-scale characteristics to predict local-scale stream habitat features and is based on the paradigm that large-scale features constrain the expression of small-scale features (see Section 4.2.4.3). Thus, successful prediction of small-scale features from large-scale characteristics relies on the collection of a range of variables that can be linked hierarchically. Similarly, Habitat Predictive Modelling uses the deviation between the predicted occurrence and observed occurrence of small-scale features as a measure of physical stream condition. Thus, the determination of stream condition using Habitat Predictive Modelling relies on the inclusion of small-scale features that represent a range of fluvial processes, and which may indicate the impacts of stream degradation.

To encompass both the hierarchical linkages and the indicators of degradation within a standardised assessment protocol, it will be necessary to incorporate variables from the Index of Stream Condition, River Habitat Audit Procedure and River Styles. However, variables chosen for inclusion in a standardised protocol must conform to the overriding criteria of being rapid and easy to measure, and must also provide information about physical aspects of stream condition (see Section 4.2.2.5). Additionally, the assessment protocol must have biological relevance and thus, AUSRIVAS variables that represent the environmental requirements of macroinvertebrates will also be included.

4.2.5 References

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