

National River Health Program

AusRivAS Quality Assurance and Quality Control Project

Final Report



for

**Australian Government
Department of the Environment and
Heritage**

August 2004

Project Manager:
Ross Bannister
telephone +61 3 9550 1000
email rbannister@wes.com.au

WATER ECOscience Pty Ltd
ACN 064 477 989

Head Office

68 Ricketts Road Mt Waverley Victoria 3149
Australia
Private Bag 1 Mt Waverley Victoria 3149 Australia
telephone +61 3 9550 1000
facsimile +61 3 9543 7372

Wangaratta

1st floor NETC House
90-100 Ovens Street
Wangaratta, Victoria, 3676

Carrum

Eastern Treatment Plant
Thompson Road
Bangholme Victoria 3175

Gippsland

71a Argyle Street
Traralgon Victoria 3844

Geelong

49 Carr Street
Geelong, Victoria 3220

Hobart

20 St Johns Avenue
New Town Tasmania 7008

Werribee

Western Treatment Plant
New Farm Road Werribee Victoria 3030

WATER ECOscience Report Number: 766

August 2004

Foreword

WATER ECOscience (WES) was engaged by the Department of the Environment and Heritage to undertake a comprehensive study of Quality Assurance / Quality Control (QA/QC) issues and procedures associated National River Health Program's Australian River Assessment System (known as AusRivAS).

The project comprises five distinct components:

- i. Literature review of Australian and international rapid bioassessment QA/QC methods;
- ii. Audit of Australian state and territory lead agency habitat assessment methods associated with rapid bioassessment programs;
- iii. Audit of Australian state and territory lead agency internal QA/QC procedures associated with processing of macroinvertebrate samples;
- iv. Audit of 1999 FNRHA macroinvertebrate sample processing results for Australian state and territory lead agencies; and
- v. Recommend changes to lead agency internal and external physical site assessment QA/QC procedures.

The project had a scheduled duration of 18 months (since extended) and has been conducted in a two-stage process. Some project components span both stages, while others are restricted to a single stage. The project commenced in January 2000 and the final report is now scheduled for completion in mid 2004.

Contractual arrangements for the project require the preparation of a summary report at the end of Years 1 and 2 (now referred to as Stages 1 and 2) of the project. These reports are to outline progress towards completing project milestones, summarise the work / activities conducted and present a synopsis of findings and outputs produced during the reporting period.

This document constitutes both the milestone and summary report for Stage 2 of the project as well as the Final report for the project as a whole. It therefore represents completion by WATER ECOscience of contractual obligations associated with both years / stages of the project.

This report outlines the project's objectives, presents work programs associated with each project stage, summarises the project's outputs and reports, and provides an overview of findings and recommendations.

Contents

Foreword	ii
1 Introduction	1
1.1 Rapid Bioassessment	1
1.2 AusRivAS- National Context	2
1.3 Project Outline	3
1.4 Work Program	4
1.5 Project Milestones	7
Completed Activities: <i>Stage 1</i>	7
Completed Activities: <i>Stage 2</i>	8
2 Overview of Project Outputs/Reports	11
2.1 Literature review of national and international QA/QC methods	11
2.2 Physico-chemical and Habitat Audit Plans	11
2.3 Stages 1 and 2 Audits and Data Analysis Physical Habitat Assessment	12
Introduction	12
Approach and methods	13
Audit Results	15
2.4 Stages 1 and 2 Audits and Data Analysis Macroinvertebrate Sample Processing	16
Introduction	16
Approach and Methods	17
Audit Results	17
2.5 Recommendations on changes to QA/QC Procedures arising from both Audits	19
3 References	22

List of Tables

Table 1	Outline of work program indicating project phases and the activities associated with each.	5
Table 2	List of project milestone tasks and status/outputs for Stage 1 of the project.	7
Table 3	List of project milestone tasks and status/outputs for Stage 2 of the project.	10

List of Figures

Figure 1	Schematic flow diagram of the relationship and association between the various project phases. Refer to Table 1 for details of activities associated with each phase.	6
----------	---	---

Appendices

Appendix A	Project Tasks	24
Appendix B	Literature Review: QA/QC Methodology for Rapid Bioassessment Programs	B1
Appendix C	Stage 1 and Stage 2 QA/QC Field Audit Plans	C1
Appendix D	Stages 1 and 2 Physico-Chemical and Habitat Audit Error Report	D1
Appendix E	Macroinvertebrate Sample Processing Audit Report	E1

Executive Summary

This study has examined Quality Assurance / Quality Control (QA/QC) issues and procedures associated with the National River Health Program's Australian River Assessment System (known as "AusRivAS"). As the first component of the project, a literature review was undertaken to examine QA/QC methods used overseas and their applicability to AusRivAS. The review concluded that AusRivAS QA/QC is comparable with, or better than, overseas practices; but the level of documentation and application of QA/QC practices need to be more consistent for a national program such as AusRivAS.

The other components of the project were audits of data collection for physico-chemical and habitat variables, and macroinvertebrate sample processing associated with AusRivAS. The value of an external auditing process was previously demonstrated by the initial audit of AusRivAS live-sort procedures undertaken by Humphrey and Thurtell (1996).

This second national audit by WATER ECOscience confirms that each agency's procedures incorporated some elements of good QA/QC practice but there is a need for a more consistent national approach. This would draw on the best of individual practices to provide a comprehensive QA/QC program including training and auditing to ensure that the program is applied across all jurisdictions.

The following are suggestions for the consideration of the Australian Government and the state / territory agencies.

General recommendations:

- consistent documentation should be established for procedures associated with field work, desk-based assessments, laboratory work and QA/QC;
- standard formats should be applied for entry of field data, desk assessments and laboratory work, to ensure that all required data is obtained and calculated correctly;
- labelling of samples should be adequate for correct identification, processing and storage;
- calibration and maintenance of field equipment should be undertaken to meet accepted practices;
- data entry and validation should be included in documented QA/QC procedures and should include scanning for extreme or outlier values;
- targets for acceptable error limits should be set for, at a minimum, AusRivAS predictor variables; and internal and external monitoring undertaken to determine compliance with these targets;
- additional QA/QC training, and assessment of operator competencies, should be incorporated at agency level to mirror existing AusRivAS training and accreditation processes; and

- national QA/QC performance targets should be established against which external auditing can be undertaken to review and assess the effectiveness of state / territory programs.

Habitat and map variables

- more objective procedures should be developed for stream width and substrate size ranges, these would provide more accurate data than the current visual estimation practiced;
- map variables were also found to be subject to operator error, improved techniques and training would improve the accuracy of these variables.

Live-sort Procedures

The substantial improvements in live-sort performance observed in this study underscore the value of external auditing, nevertheless some areas for improvement were highlighted, including:

- improvements to live-sorting of edge samples to reduce the level of bias;
- extensive study of the poor performance of the live-sort protocol in turbid habitats.

Whilst it may be concluded that live-sort sampling bias is probably inherent to the method there is a need to better understand the biases and their implications for AusRivAS assessments.

1 Introduction

1.1 Rapid Bioassessment

Rapid biological assessment (ie. rapid bioassessment - RBA) can be used to describe two very different types of biological monitoring (Norris and Norris 1995). The first is a continual monitoring situation to detect trigger or alarm levels of organisms or toxicants. The second, and the subject of this review, refers to expeditious sampling of biota with rapid delivery of assessment results (Norris and Norris 1995). Benthic macroinvertebrate rapid bioassessment techniques and procedures were developed in 1977 in conjunction with the commencement of the RIVPACS program in October of the same year (Wright 2000, Davies 2001 *pers comm*). The United States Environmental Protection Authority further developed and expanded the RBA techniques to include fish and the work of Platkin *et al.* (1989) was later used by several other countries (eg. Australia and Canada) to develop their own rapid bioassessment procedures (Norris and Norris 1995).

Rapid bioassessment offers several advantages over the more traditional macroinvertebrate sampling methods, which involve a relatively large expenditure of time to collect, process and identify biological samples (Lenat & Eaton 1991). Rapid bioassessment reduces sampling effort, and therefore cost, by taking a relatively large sample instead of several individual replicates and reduces the number of organisms that must be processed by using a standardised sub-sampling procedure. In addition, rapid bioassessment programs often employ more efficient methods of data analysis than traditional biological assessment programs and produce results that are presented and summarised in a manner readily understood by non-specialists (Resh *et al.* 1995).

Although rapid bioassessment of freshwater systems is now used in a number of different countries, only the United States, the United Kingdom, Canada and Australia conduct integrated, large-scale programs using comprehensive models that integrate macroinvertebrate and physico-chemical data to compare test sites to a benchmark or reference condition.

The bioassessment programs used by these four countries vary in the extent to which they are applied and in their base method. However, all are based on similar theory and all require established and documented quality assurance and quality control systems to ensure that the integrity and veracity of the models used, and the results they produce, are maintained.

1.2 AusRivAS- National Context

The Australian River Assessment System (known as “AusRivAS”) was developed by the Cooperative Research Centre for Freshwater Ecology in partnership with state and territory river management agencies, under the auspices of the Australian Government’s National River Health Program (NRHP). The NRHP was established in the Prime Minister’s Environment Statement in 1992 (O’Connor *et al.* 1996).

The objectives of National River Health Program were to:

- provide a sound information base on which to establish environmental flows;
- undertake a comprehensive assessment of the health of inland waters, identify key areas for the maintenance of aquatic and riparian health and biodiversity, and identify stressed inland waters;
- consolidate and apply techniques for improving the health of inland waters, particularly those identified as stressed; and
- develop community, industry and management expertise in sustainable water resources management and raise awareness of environmental health issues and the needs of our rivers.

The NRHP, initially called the National River Processes and Management Program commenced in December 1992 (Davies 1994; O’Connor *et al.* 1996). The Monitoring River Health Initiative (MHRI) – a key component of the NRHP – used aquatic invertebrates to assess on a national level the ecological condition of Australian rivers (Smith & Kay 1998). As part of the MHRI more than 1500 reference sites were sampled across all states and territories during 1994/96 to establish the predictive AusRivAS models.

The second phase of the NRHP utilised the AusRivAS models to undertake the First National Assessment of River Health (FNARH) (Smith & Kay 1998), later referred to as the Australia-wide Assessment of River Health (AWARH). The FNARH - AWARH commenced in 1997 and nearly 6000 sites have been assessed nationwide. Australia is the first country in the world to undertake such a continental-scale assessment of the ecological health of its rivers (PIE 1998).

The bioassessment component of AusRivAS uses a series of models to predict the composition of the aquatic macroinvertebrate community expected at a specific site in the absence of environmental stress (expected taxa (E)). This is compared with the macroinvertebrate community composition actually found at the site (observed (O)). AusRivAS assessments are reported as the ratio of observed to expected (O/E) taxa for the site, which are then assigned to a band indicating the extent to which a site has been impacted.

Importantly, the veracity and national consistency of the AusRivAS–based river health assessments are reliant on the collection and entry of accurate and precise data.

The current project, the *National River Health Program - AusRivAS Quality Assurance and Quality Control Project*, provides a national external audit of data collected by the various state and territory government agencies using AusRivAS for river health assessment. Information from this project augments previous quality assurance and quality control (QA/QC) work conducted under the NRHP and focuses on QA/QC during field operations and subsequent laboratory sample

processing and data entry, for both biological and environmental data associated with AusRivAS bioassessment for the NRHP.

The audit encompasses all Australian states / territories and assesses their QA/QC procedures, field and analytical techniques and methodologies, personnel training, and data collection, validation and transcription. The purpose is to identify deficiencies and areas for improvement within state and territory agencies to ensure accuracy and consistency in the application of the AusRivAS model.

WATER ECOscience (formerly AWT Victoria) was commissioned to undertake the *National River Health Program - AusRivAS Quality Assurance and Quality Control Project*.

1.3 Project Outline

The *National River Health Program - AusRivAS Quality Assurance and Quality Control Project* was part of the Toolbox component of the Australia-Wide Assessment of River Health and involved a national, external audit of data collected by the various state and territory agencies using AusRivAS to assess river health.

The objectives of the project were:

1. Assess and report on state agency performance for macroinvertebrate sampling, processing and identification procedures against existing criteria.
2. Develop criteria for assessing agency performance in the collection of environmental and habitat field data.
3. Assess and report on agency performance in the collection of environmental and habitat data and macroinvertebrate data.
4. Provide feedback and advice on the problems of staff performance in AusRivAS methods to state / territory agencies and to the new Training and Accreditation Project of AusRivAS.

The project includes liaison with two other toolbox projects:

- AusRivAS error analysis project - provide advice on actual error magnitudes in environmental data to enable evaluation of the consequences of errors associated with this type of data.
- Training and Accreditation Project - liaison with the Principal Investigator to ensure deficiencies detected in the implementation of AusRivAS methods by lead agency staff can be addressed in any proposed training program.

Stated tasks for the National River Health Program - AusRivAS Quality Assurance and Quality Control Project are listed in Appendix A.

The *AusRivAS Quality Assurance and Quality Control Project* involves two types of audit, broadly categorised as: i) Veracity of macroinvertebrate sample processing and taxonomic identification, and ii) Collection and entry of field environmental (ie. habitat) data.

The project commenced in January 2000 with a scheduled duration of 18 months. It was to be conducted in a two-stage process, with stage one consisting of the first 12 months and stage two the final six months. These stages correspond to the first and 'second' years of the project respectively. Some project tasks spanned both stages, while others were restricted to a single stage.

A series of delays were experienced during the first stage of the project. Due to logistical, resource, and budgetary constraints, completion of stage 1 of the project, originally scheduled for February 2001, was delayed approximately 12 months.

The following factors contributed to the delay:

- First drafts of major deliverables (Habitat Audit Plans, Habitat Audit Report (Stage 1) and Literature Review) were forwarded to the Department of the Environment and Heritage between August and October 2001. The Stage 1 Milestone and Final Report could only be completed after comment on the drafts had been received from the Department of the Environment and Heritage and any required edits incorporated into the final products. This review / edit process was not completed until early 2002.
- Resource constraints caused delays in several areas of the data analysis process.
- Although WATER ECOscience had been ahead of delivery schedule and had commenced some of the Stage 2 tasks, this work was temporarily halted until the Department of the Environment and Heritage was able to confirm the Stage 2 budget. The decision to suspend work on the project was based on the results of a financial risk assessment.

The remainder of the report outlines the project's objectives, work program, progress towards milestones, and summary of outputs produced. Full copies of completed outputs are included as separate volumes and are appended to this report.

1.4 Work Program

The two stages (ie. years) of the project consisted of ten distinct phases of activity (Table 1). Phases 1–3 and 5 were conducted during Stage 1, phases 7-10 during Stage 2 and phases 4 and 6 spanned both stage. Some phases, and / or activities within a phase, required completion of previous phases before they could proceed. The relationship and association between the various phases of the project are depicted schematically in Figure 1.

The development of key objectives for the audits of state and territory lead agencies and appropriate audit plans were seen as important to the success of the project. The project agenda and key objectives were identified at an inception meeting in Canberra on January 10, 2000 attended by representatives of: the Department of the Environment and Heritage, the Museum of Victoria, the CRC for Freshwater Ecology (CRCFE), the Murray-Darling Freshwater Research Centre (MDFRC), the National River Health Program (NRHP), Environmental Research Institute of Supervising Scientist (ERISS) and WATER ECOscience.

Audit plans were developed after extensive consultation with lead agencies in each state and territory in accordance with the defined key objectives. Specific audit plans were required for each state and territory, as each uses AusRivAS models with different variables.

Table 1 Outline of work program indicating project phases and the activities associated with each.

<p><i>Phase 1: Inception Meeting (Stage 1)</i></p> <p>Inception meeting with the Department of the Environment and Heritage and representatives of NRHP, ERISS, CRCFE and MDFRC to establish project objectives and identify key agencies, general requirements etc.</p>
<p><i>Phase 2: Literature Review (Stage 1)</i></p> <p>Literature review on QA/QC methodology and criteria for the physical habitat assessment will be completed. An assessment of similar methods used overseas and their applicability to Australian conditions and the AusRivAS model. This will be combined with the collation of any current internal QA/QC procedures currently undertaken by lead agencies. Results will be reported.</p>
<p><i>Phase 3: Audit Plan Development (Stage 1)</i></p> <p>From the results of Phases 1 and 2, criteria will be developed for an internal and external audit of the physical site assessment. The audit plans will be assessed by an internal review panel, before comment from the Department of the Environment and Heritage steering committee.</p>
<p><i>Phase 4: Assess Lead Agency Physical Habitat Assessment Methods (Stages 1 and 2)</i></p> <p>Auditing of the lead agencies with regard to physical site assessment will be conducted using audit plans developed in Phase 3. This will involve travel to the lead agencies by two team members. Auditing will be conducted under the Australian Standard AS 3911.1-3 –1992. Agency audits to be conducted in two stages spread over two or more years, depending on parliamentary appropriations and Ministerial discretion.</p>
<p><i>Phase 5: Milestone and Stage 1 Report (Stage 1)</i></p> <p>Report to include progress against milestones, audit plans for all state / territory lead agencies and results from stage 1 of the physical habitat assessment audits.</p>
<p><i>Phase 6: Assess Lead Agency Macroinvertebrate Sample Processing (Stages 1 and 2)</i></p> <ol style="list-style-type: none"> 1. Running concurrently with the auditing of physical habitat assessment (Phase 4) will be an assessment of lead agency internal QA/QC procedures associated with processing of macroinvertebrate sample. An audit of the 1997-1998 FNRHA macroinvertebrate samples will be completed for all lead agencies. 2. An audit of the 1999 FNRHA macroinvertebrate samples will be completed on lead agencies that use live picking methods. Residue samples from this sampling period will be analysed using the Whole of Individual Sample Estimate (WISE) (Mount and Humphrey 2001) approach to ascertain the effectiveness of internal QA/QC procedures.
<p><i>Phase 7: Recommendations on Changes to QA/QC Procedures (Stage 2)</i></p> <p>Based on audit results from Phase 4, procedures will be recommended for future internal and external QA/QC of physical site assessment.</p>
<p><i>Phase 8: Milestone and Stage 2 Report (Stage 2)</i></p> <p>Report to include progress against milestones, results from stage 2 of the physical habitat assessment audits, results of macroinvertebrate sample processing audits and recommendations for changes to QA/QC Procedures.</p>
<p><i>Phase 9: Pre Final Report Liaison (Stage 2)</i></p> <p>Extensive liaison with all lead agencies, Training and Accreditation project principal investigator, Error analysis project principal investigator and the steering committee will be maintained.</p>
<p><i>Phase 10: Final Report (Stage 2)</i></p> <p>Production of final report incorporating information from reports from Stage1 and Stage 2.</p>

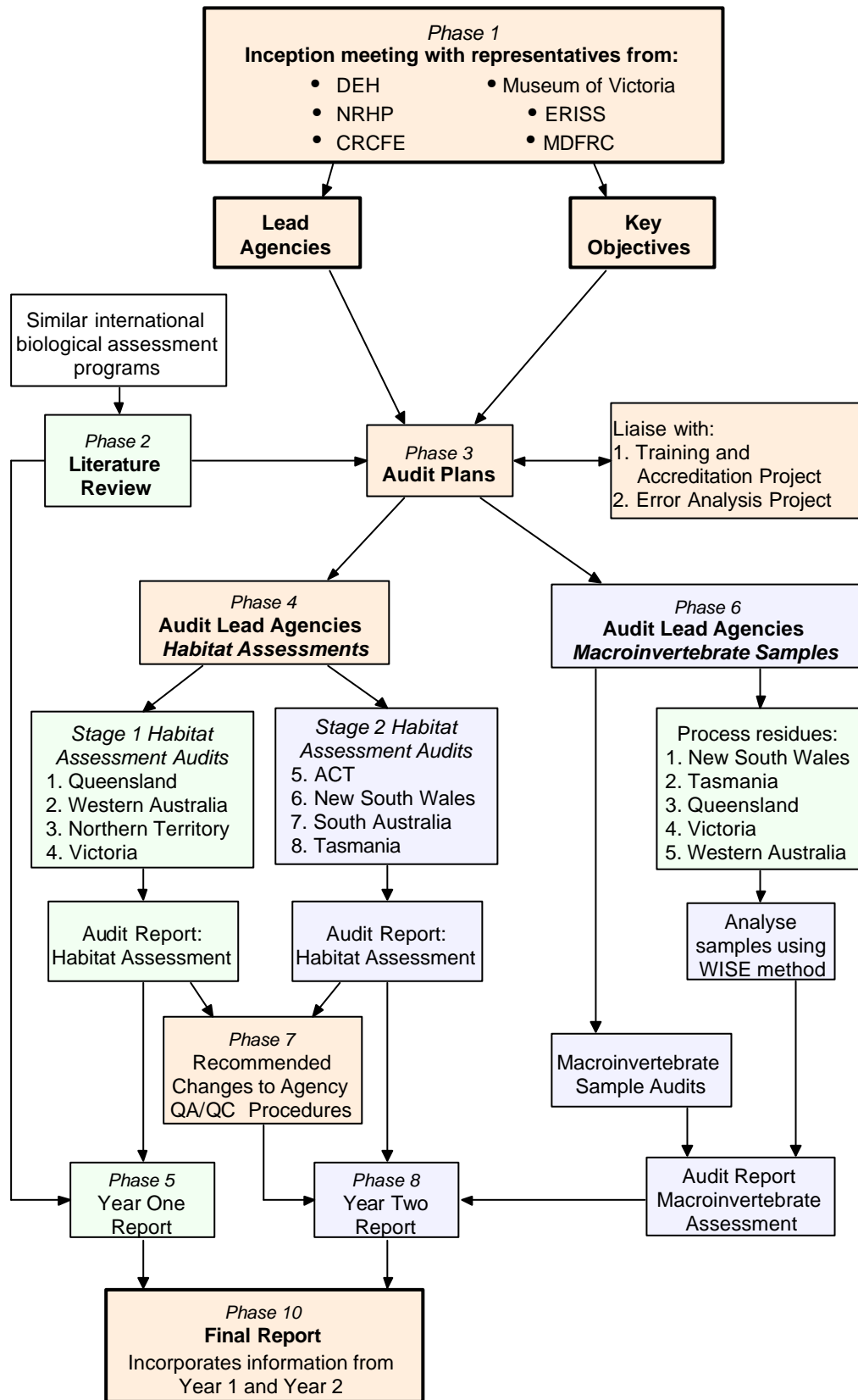


Figure 1 Schematic flow diagram of the relationship and association between the various project phases. Refer to Table 1 for details of activities associated with each phase

1.5 Project Milestones

Separate milestones were associated with the two stages of the project. Milestones for stage 1 (Year 1) are listed in Table 2. The project successfully met all required stage 1 milestones to a standard acceptable to the Department of the Environment and Heritage.

Table 2 List of project milestone tasks and status/outputs for Stage 1 of the project.

Milestone	Task	Status/Outputs
1a	<i>Sign contract</i> Sign contract	<i>Completed</i>
1b	<i>Attendance at Inception meetings with EA</i> Key agenda and lead agencies will be identified and the objectives of the study identified.	<i>Met with EA</i> Key agenda and lead agencies identified. Objectives established.
2	<i>Review Quality Assurance/Quality Control methods of lead agencies</i> Complete Literature review of QA/QC methods and criteria used by national and international lead agencies for physical habitat assessment.	<i>Completed</i> Literature Review submitted to EA.
3	<i>Produce plans for lead agency auditing of physico-chemical and habitat parameters measured during MRHI program.</i> Audit Plans devised and sent to relevant lead agencies and The Department of the Environment and Heritage.	<i>Completed</i> Audit plans for all states and territories sent to EA and lead agencies. Milestone Report.
4	<i>Liaise with the AusRivAS error analysis project.</i> Provide advice on actual error magnitudes in environmental data to enable evaluation of the consequences of errors associated with this type of data.	<i>Completed</i> Data report for stage 1 habitat audits provided to EA and lead agencies. Participated in phone conferences, meetings.
5	<i>Liaise with Principal Investigator of the Training and Accreditation Project.</i> Ensure deficiencies detected in the implementation of AusRivAS methods by lead agency staff can be addressed in any proposed training program.	<i>Completed.</i> Participated in meetings, general liaison.
6	<i>Complete stage 1 of lead agency physico-chemical and habitat data audits.</i> Physico-chemical and habitat data audits of Victoria, Queensland, Northern Territory and Western Australia.	<i>Completed</i> Stage 1 audit data and analyses submitted to EA
7	<i>Complete audit of macroinvertebrate residue samples from states / territories that live pick.</i> Macroinvertebrate samples processed for Victoria, Western Australia, New South Wales and Tasmania.	<i>Completed</i> Macroinvertebrate species lists provided for each state / territory assessed.
8	<i>Produce Stage 1 Milestone and Final Report.</i> Provide written reports as agreed with EA.	Combined Milestone and Final Report

Completed Activities: Stage 1

The inception meeting referenced by milestone 1 (Table 2) was convened by WATER ECOscience in Canberra on January 10, 2000 to identify the project's

agenda and key objectives. Further clarification of various issues was gained at the National River Health Workshop in Canberra in February 2000.

Inception meeting participants (Canberra: January 10, 2000)

Meeting participants included:

- Peter Komidar (Department of the Environment and Heritage, Director-Sustainable Water Section)
- Bruce Gray (Department of the Environment and Heritage)
- Kerry Olsson (Department of the Environment and Heritage)
- Richard Marchant (Museum of Victoria)
- Peter Davies (National River Health Program Science Advisor)
- Richard Norris (CRC for Freshwater Ecology)
- Chris Humphrey (Environmental Research Institute of Supervising Scientist)
- John Hawking (Murray Darling Freshwater Research Centre)

Liaison and consultation associated with milestones 4 and 5 were conducted to a level acceptable to the Department of the Environment and Heritage and the parties involved. Activities associated with milestones 2, 3, 6 and 7 were completed and associated deliverables have been submitted to, and accepted by, the Department of the Environment and Heritage.

Submitted Material

The following material was submitted to the Department of the Environment and Heritage during *Stage 1* of the project.

- Literature review of QA/QC methods and criteria used by national and international lead agencies for physical habitat assessment (included as Appendix B in this report).
- Physico-chemical and habitat audit plans (Stage 1 and Stage 2) for all states and territories (included as Appendix C in this report).
- Stages 1 Physico-chemical and habitat audit error report (included as Appendix D in this Report).

Completed Activities: Stage 2

Milestones associated with stage 2 (Year 2) of the project are listed in Table 3 and their linkage with stage 1 milestones is depicted in Figure 1. Details of activities associated with stage 2 milestones are presented in Table 1.

Requirements for the second year of the project were to complete Phases 4 and 6, which had commenced in *Stage 1*, and Phases 7 to 10, which were restricted to *Stage 2* only.

Activity Associated With Stage 2 Milestones

Milestones 9 and 10

Phone conversations, involving discussion of project findings, have been conducted with the principal investigators of both the 'Training and Accreditation Project' and 'AusRivAS Error Analysis Project'

Milestone 11

During *Stage 2*, milestone 11 was completed and the remaining four states and territories (New South Wales, the Australian Capital Territory, South Australia and Tasmania) were audited in regard the collection of physical, chemical and environmental data. Results were analysed in the same manner as for the states and territories audited in *Stage 1* (milestone 6) and the findings for all states and territories have, where possible, been compared.

The original reporting structure proposed that the findings for the Stage 1 and 2 physico-chemical audits initially be reported (and analysed) separately, after which the results would be combined (and reanalysed) into a single report. This was considered inefficient and the Department of the Environment and Heritage agreed that a separate report for the Stage 2 Physico-chemical audits was unnecessary.

Dr MacNally, who conducted statistical analysis of Stage 1 audit data, was unavailable to do the analysis of the combined Stages 1 and 2 physico-chemical audit data. Instead, this analysis was conducted by Dr Philip Rayment, School of Applied Sciences, Monash University (Gippsland campus) using the same statistical methods as that employed by Dr MacNally in the Stage 1 analysis. Prior to commencing analysis, Dr Rayment confirmed the MacNally statistical approach to ensure compatibility with results for the Stage 1 analysis.

The combined Stage 1 and 2 Physico-chemical audit report is attached as Appendix D.

With the successful completion of milestones 6 and 11 Phase 4 of the project has also been completed.

Milestones 12 and 13 (Phase 6)

Analysis of the macroinvertebrate residue audits using the WISE software (Mount and Humphrey, 2001) was completed (milestone 12) to draft stage in November 2003. The delays in completing this task were attributable to several factors. While the analysis itself was relatively straightforward, reformatting state / territory taxonomic data to conform with the very specific structure required by the WISE program was extremely time consuming. In addition, difficulties were experienced in confirming the veracity of taxonomic sample data supplied by state / territory lead agencies against which WATER ECOscience residue results are to be compared.

The audit of state / territory macroinvertebrate processing (milestone 13) was also delayed, primarily due to the difficulty in obtaining both hard copy and electronic versions of site taxonomic data from the state / territory lead agencies.

Table 3 *List of project milestone tasks and status/outputs for Stage 2 of the project. (Milestone numbering is continued from Stage 1 milestones)*

Milestone	Task	Status/Outputs
9	<i>Liaison with Principal Investigator of the Training and Accreditation Project.</i> Ensure deficiencies detected in the implementation of AusRivAS methods by lead agency staff can be addressed in any proposed training program	<i>Completed</i>
10	<i>Liaison with the AusRivAS Error Analysis Project.</i> Provide advice on actual error magnitudes in environmental data to enable evaluation of the consequences of errors associated with this type of data.	<i>Completed</i> Project findings discussed with Dr Leon Barmuta
11	<i>Complete stage 2 of lead agency physico-chemical and habitat data audits.</i> Physico-chemical and habitat data audits of New South Wales, the Australian Capital Territory, South Australia and Tasmania.	<i>Completed</i> Draft Stages 1 and 2 audit data and analyses submitted to EA
12	<i>Macroinvertebrate Residue Analysis (Using data from milestone 7 in Stage 1)</i> Macroinvertebrate residue analysis using WISE (Mount and Humphrey 2001) for the four states and that live pick samples (Victoria, Western Australia, New South Wales and Tasmania).	Draft submitted to EA
13	<i>Audit macroinvertebrate sample processing of all lead agencies.</i> Audit 1997-1998 FNRHA macroinvertebrate sample results from all lead agencies.	Draft submitted to EA
14	<i>Recommendations on Changes to QA/QC Procedures</i> Based on macroinvertebrate sample audit results, recommend procedures for future internal and external QA/QC of physical site assessment.	Draft submitted to EA
15	<i>Produce Stage 2 Milestone and Final Report.</i> Provide written reports as agreed with EA.	Draft submitted to EA
16	<i>Produce Final Report</i> Final report will incorporate Stage 1 and Stage 2 draft final reports, and the literature review.	Draft submitted to EA

Milestones 14 to 16

These milestones involved the current Stage 2 milestone report and production of the project's final report. The final report differs little from the Stage 2 milestone report, as the latter involves all project outputs, including the final report for the state / territory physico-chemical audits (ie. Stages 1 and 2 combined).

2 Overview of Project Outputs/Reports

2.1 Literature review of national and international QA/QC methods

The literature review puts the AusRivAS program into a world context and compared the Quality Assurance and Quality Control procedures of AusRivAS with that of similar programs internationally.

Some of the available information concerning Australian and overseas bioassessment QA/QC programs is in the form of unrefereed 'grey' literature, such as published and unpublished reports and manuals produced by the relevant agencies involved (including those published via web sites). In the review process, every effort was made to source the original literature.

Although the rapid bioassessment of freshwater systems is now used in a number of countries, only the United States' Rapid Bioassessment Programs, the United Kingdom's RIVPACS program, the Canadian BEAST program, and the Australian AusRivAS program use comprehensive models that integrate macroinvertebrate and physico-chemical data to compare test sites to a benchmark or reference condition.

A number of different components of each of these programs were investigated including: the selection of reference and test sites, habitat assessment, field sampling and laboratory sorting procedures, general and sampling processing QA/QC procedures, training, and data outputs.

The bioassessment programs used by these four countries vary in the extent to which they are applied and in their base method. However, all are founded on similar theory and all require established and documented quality assurance and quality control systems to ensure that the integrity and veracity of the models used, and the results they produce, are maintained.

In the UK, USA, Canada, and Australia bioassessment protocols utilising macroinvertebrates have been established to reduce the cost and effort associated with more traditional approaches to sampling and data analysis. The major difference between the programs is that in the USA rapid bioassessment programs are based on the multimetric approach, where several indices related to ecological values are used to present the findings. In contrast, the approach in the UK, Australia and Canada has been to use models based on multivariate statistics to assess biological impact by predicting the fauna expected to occur at a test site.

Although bioassessment protocols and programs differ across the four countries, they have several important features in common, such as the use of aquatic macroinvertebrates as key indicator species and importance of habitat assessment and QA/QC systems.

2.2 Physico-chemical and Habitat Audit Plans

Detailed audit plans were developed after extensive consultation with lead agencies in each state / territory in accordance with the current protocols for collection of environmental data in the field. Specific audit plans were drawn up for each state / territory as each uses AusRivAS models with different variables.

In each case a list of AusRivAS model variables was provided together with the methods for assessment of variables, including those based on map work, field habitat and physico-chemical water quality. In addition a methodology for identification and assessment of data entry errors was provided.

2.3 Stages 1 and 2 Audits and Data Analysis Physical Habitat Assessment

Introduction

Following discussion with the principal investigator of the Error Analysis Toolbox Project, three sources of error were identified:

- i. incorrect measurement of the variable;
- ii. entry of incorrect data; and
- iii. unaccounted for changes in environmental variables over time.

Field data audits involved assessing all state / territory quality assurance and quality control (QA/QC) procedures, field and analytical techniques and methodologies, training of personnel, and data collection, validation and transcription. The purpose was to identify deficiencies and areas for improvement within the state and territory agencies to ensure accuracy and consistency in the application of AusRivAS protocols, thereby assuring end users of the quality of AusRivAS models and their outputs. For each state / territory, approximately ten per cent of sites per were audited.

The project involved two phases spread over two years. Phase 1 was conducted in 2000/2001 and comprised audits of Victoria, Queensland, Western Australia and the Northern Territory. Phase 2 was conducted during 2002 and entailed audits of the Australian Capital Territory, New South Wales, South Australia and Tasmania. Phase 1 audit results were presented as an interim report in the projects Stage 1 Milestone and Final Report (WATER ECOscience 2002). The results of each auditing phase were originally reported separately, and have more recently been integrated into a final report.

Analysis of Stage 1 audit results revealed that only the Victorian map data were amenable to statistical analysis and this component was not continued for the Stage 2 audits.

The report presents the combined findings from the Stage 1 and 2 audits and addresses objectives three and four of the project. It reviews and reports on agency QA/QC methods and approaches for field collection of site environmental data, with particular emphasis given to data used as predictor¹ variables in AusRivAS models.

The report address the following three areas:

1. Audits of state / territory agency field methods and laboratory procedures. That is, physical and chemical data collection as well as environmental variables and data entry procedures.

¹ Predictor - Predictor variables are those variables used in the AusRivAS model to predict the Expected taxa at a site.

2. Identification and assessment of anomalies identified during the audit process. Error types associated with data entry, map work and field validation were classified and their frequency statistically assessed *within* and, where possible, *between* individual state / territory agencies.
3. Discussion of various QA/QC methods used in different states / territories, with recommendations for additions to, and/or modification of, current procedures and training based on the results of the error analysis.

Approach and methods

The audit process generally involved WATER ECOscience staff visiting the state / territory lead agency laboratory and accompanying agency personnel as they sampled sites for the AusRivAS program. The audit of lead agency physical, chemical and environmental data collection involved two distinct components:

1. Field visits to assess the techniques, accuracy and QA/QC procedures of lead agency collection of site physico-chemical data;
2. Desktop-based audit and data analysis assessing the:
 - efficacy of lead agency QA/QC procedures for field procedures and data entry/validation.
 - accuracy with which lead agencies entered / transcribed site physico-chemical data from field sheets into the agency database.
 - accuracy with which lead agencies calculated particular map variables for selected sites.

Audit Plans

WATER ECOscience provided draft audit plans to each state / territory agency prior to the site visit. Plans were specific for each state / territory and outlined the intended audit process proposed to assess methods, techniques, results and data integrity. Draft audit plans were not definitive and during the course of each visit methods changed and, in some cases, different variables to those originally indicated were measured.

QA/QC procedures

QA/QC procedures documented in the methods manuals of the lead agency in each state / territory were assessed subjectively with respect to their adequacy, level of detail and thoroughness of application. Lead agency manuals were assessed for field procedures, sampling, site assessment, live sorting procedure, field sheet procedure, lab QA/QC procedures and data entry and validation. In addition, undocumented practices were considered where they fulfilled QA/QC requirements.

Data Audits

For each state and territory, data from approximately ten percent of reference sites from the MRHI stage of the program was audited to determine error rates in data collected for entry into the AusRivAS models. The values held in agency databases were compared with raw data on field sheets.

Mapwork

Categorical² map data used in the models include distance from source, stream slope, altitude, latitude, longitude, catchment area and reach category. Apart from possible errors in data entry, it is difficult to assess many of these categories.

Protocols used to determine these physical parameters from maps were obtained from the various lead agencies concerned and replicated by WATER ECOscience. As not all sites could be visited, site location could only be assessed by a general scan of latitude and longitude values, to ensure that they corresponded to the approximate known location. Where a GPS was used to locate sites, the potential for error was determined from the manufacturer's specifications for the unit used. Where planimeters and other techniques were used to measure map parameters (altitude, distance from source, stream slope and catchment area) the accuracy was assessed from the variability between ten users measuring characteristics from the same sites in low, mid and high catchments. For the Queensland model, stream orders were recalculated for ten per cent of the reference sites. The values obtained were then compared to those determined by state / territory agency staff.

Field based measurements

Field auditing of agency personnel involved observing QA/QC procedures and assessing agency field techniques particularly the accuracy of visual assessments of substrate heterogeneity and stream width. No field audits were possible in the Northern Territory, due to crocodiles in the rivers visited, or in Queensland, as coordinated visits with Department of Natural Resources and Mines staff could not be arranged.

Measurements for some variables, for example water chemistry, could not be assessed for errors using the adopted methodology since they involve field measurements which could not be reproduced. For such variables, error analysis involved examining the error specifications and frequency of calibration of field meters used.

Substrate heterogeneity and stream width were selected for audit, since they are the only field parameters readily amenable to independent verification and are visually estimated by all state / territory lead agencies. The accuracy of these visual estimates was then compared to WATER ECOscience measurements using more objective techniques. These techniques included size templates and sieves for substrate heterogeneity and a measuring tape or range finder for stream width in combination with a transect method. Variables such as percentage emergent macrophytes, submerged macrophytes, detritus, overhanging vegetation were also recorded using the transect method.

The accuracy of the agency visual estimates was then compared to the audit measurements (except for South Australia, where time restraints prevented agency staff providing multiple estimates of stream width).

Physico-chemical variables

Most physico-chemical variables were measured *in situ* by agency staff during each sampling event and consequently could not be reproduced by WATER ECOscience personnel during the audit. Where laboratory visits were conducted, field meter calibration sheets were checked, along with the meter type and specifications for

² Categorical - Categorical variables are those variables whose values consist of a small number of integer values (Barmuta *et al.* 2001)

correct calibration during field measurements. This provided a means of assessing field data integrity.

Data Analysis

State / territory audit results for data entry error checking, map variables and field stream width assessments were analysed statistically. Analyses involved data-checking of various forms, but mainly dealt with data-entry errors and comparisons of field notes with data sheets. Variables measured for AusRivAS models frequently differ between the states and territories.

State / territory audit data were analysed in for error rates among variables within and between each state / territory, as well as overall error rates.

Observations

The WATER ECOscience auditors, in addition to collecting raw data for error analysis, made observations in relation to data collection techniques, data entry procedures and data consistency. These observations help to explain some of the errors observed and procedures relating to data collection and data entry.

Audit Results

QA/QC Procedures

The level and detail of documentation of QA/QC procedures for data collection and entry was variable amongst states / territories and fell short of the documentation for sampling, live-sorting and laboratory procedures. Whilst the two states with the highest data entry error rates predictably had no documented QA/QC procedures, the availability of such procedures did not necessarily confer low error rates on an agency. This suggests that lack of adherence to documented procedures may be a significant issue.

Most state / territory agencies had adequate to good procedures for field sheets, except Victoria. Sampling QA/QC procedures were mainly poor in all states and only adequate in Tasmania. Site assessment was mostly poor and adequate, with only New South Wales and Tasmania with good QA/QC procedures. Live sorting and laboratory QA/QC procedures were adequate to excellent. Three states, Victoria, Australian Capital Territory and South Australia, did not have documented QA/QC procedures for data entry or validation. In Victoria entered data is checked against data sheets but this procedure was not documented in the Victorian manual. The documented data entry or validation procedures in the Northern Territory were poor and the remaining states had good or excellent procedures.

Data Entry

Errors in data entry were a feature for all states and territories with transcription errors generally the highest, and error rates were unacceptably high at 5%. Practices which appeared to control transcription errors included entry of data by a single operator and validation of data entered onto agency databases. The validation processes included printing out database records for checking against the original data sheets and scanning for erroneous, extreme, outlier or 'out of range' values for habitat and physico-chemical data.

Another important source of error is the estimation of values for missing field data. Both averaging errors and guess errors arise from this practice which is common to all states and territories. For stream width, missing data is completed from estimates from site photographs or from average recorded values; these practices introduce significant, uncontrolled errors to the data collection (Murray-Bligh 1999).

A useful practice is the incorporation of a coversheet for field sheets with a checklist of variables to be measured and tasks to be completed for each site. This kind of reminder is invaluable in the field when a large number of variables are measured and several sheets need to be filled in by more than one operator.

Further QA/QC training is required for agency operators, with particular emphasis on adherence to procedures for the collection, entry and validation of data.

Map work

Values calculated from map readings, such as catchment area using a planimeter, requires judgement by operators. Consequently, there are potentially large variations in measurements by different operators. The use of electronic planimeters to measure catchment area for FNARH sites offers significant improvement in errors associated with judging catchment boundaries and in completing calculations.

Field methods

Visual estimates of both substrate heterogeneity and stream width were found to be inherently inaccurate. For substrate heterogeneity, high operator variability and large discrepancies between estimated and measured values suggest that the visual estimation process is a prime source of error in field methods.

Similarly, visual estimation of stream width was a major contribution to error, and was more often associated with sites situated on wide rivers. The use of range finders to measure stream width, especially for larger rivers, would remove a major source of data error in all states.

2.4 Stages 1 and 2 Audits and Data Analysis Macroinvertebrate Sample Processing

Introduction

The QA/QC of state / territory agency performance for macroinvertebrate sampling, processing and identification was based upon those states using live pick protocols (Victoria, Tasmania, NSW, Queensland and Western Australia). All lead agencies that use the live pick methodology have kept residue samples from the Australia-wide Assessment of River Health program that began in 1997. A comparison of the family list derived from residue with that collected by each agency was conducted using the method developed by Humphrey and Thurtell, (1996).

This report is associated with objectives three and four of the project covers Phase 6 Assessment of Lead Agency Macroinvertebrate Sample Processing, and includes auditing conducted over both the first and second year of the project.

Approach and Methods

Audit and analysis of data involved three stages:

1. Audit of data entry errors associated with a random selection of sites sampled during the 1997 – 1999 FNARH program. Errors associated with missing or extra taxa and incorrect abundances were identified.
2. Audit of live-sort residues from the five states using this practice. This included sub-sampling and picking of sample residues, and analysis of the performance of live-sorting using the WISE procedure.
3. Discussion of the impact of the various data entry error types and live-sorting performance on the outcome of AusRivAS river health assessments, and the adequacy of agency QA/QC practices; with possible improvements and further investigations recommended.

QA/QC procedures

QA/QC procedures are documented in the methods manuals of the lead agency in each state / territory agencies; these were assessed subjectively, together with the level of actual QA/QC practiced by agency staff, respect to their level of detail and thoroughness.

Data Entry Audit

Lead agencies for each state / territory provided a list of all the sites sampled during the 1997 – 1999 FNARH program, of which ten percent were randomly selected for assessment. The electronic data held on agency databases was compared with the original macroinvertebrate identification sheets and errors or discrepancies in the taxa or abundances noted and classified into different error categories.

Live-sort Audit

The five states conducting live picking provided a total of 250 residue samples selected at random (stratified with respect to habitat) from those retained from the FNARH program for assessment. These live-sort residues were sub-sampled and counted in the laboratory at WATER ECOscience. The data for the residues was then compared with the live-sort data using the Whole Individual Sample Estimate (WISE) procedure to evaluate whether the live-sort taxa were representative of the whole sample using the Live Sort / Whole Sample Estimate ratio and the Bray-Curtis dissimilarity value.

Audit Results

QA/QC Procedures

The documentation and application of QA/QC procedures was found to vary between lead agencies. Most states and territories were judged to have adequate to good procedures for sampling, live-sorting and laboratory operations, but fewer had established procedures for data entry and validation. The assessment was subjective since a number of agencies had informal QA/QC practices which, although undocumented, were rigorously followed and may have been more effective than the documented procedures. These same agencies may also have had low levels of staff turnover and comprehensive training to reinforce the informal QA/QC practices. Nevertheless, good procedures and implementation must be

seen as an essential, basic requirement that is not vulnerable to staff turnover and levels of experience.

Practices for data entry mostly included independent checking of entered data against the original documents; double entry of data had been practiced by one agency, however this was later replaced by an independent check.

In some cases additional 'range' or outlier checks were also undertaken with the acceptable range determined from historical data for the parameter of interest. Also, electronic data entry forms have been set up by some agencies to mimic the layout of field and laboratory data sheets in an effort to minimise errors.

Data Entry Audit

The overall rate of correct data entry from taxonomic identification sheets was adequate, with an average of fewer than 1% errors and approximately 90% of all data sheets with no errors. However, the data entry error rates varied among states / territories, with one state with as many as 20% of sheets affected. Also, the error rates did not appear to correlate with the degree of assessed QA/QC practiced by each agency.

The two error types associated with identification of taxa, missing and extra taxa, have the greatest potential to affect river health assessment, particularly for sites with a small number of predicted taxa. Whereas errors of incorrect abundances are unlikely to influence assessments as only presence / absence data are used in the AusRivAS predictive models. Nevertheless the rates of data entry errors are significant and have the potential to affect the outcome of river health assessments using AusRivAS.

Other potential sources of error, such as the coding systems used for macroinvertebrate families, may also make significant contributions to the overall rate.

Live-sort Audit

More than 75% of the live-sorted samples passed the WISE criteria, a significant improvement on the 47% achieved in the first external QA/QC assessment of live-sorting procedures (Humphrey and Thurtell, 1997). This suggests that improvements in AusRivAS procedures implemented after the first external audit (minimum count of 200 or extended counting time, and establishment of formal training facilities) have been successful, and is an endorsement of the external audit process. However, the present level of live-sorted sample failures still means that as many as a quarter of all river health assessments using AusRivAS are potentially incorrect due to inadequate picking procedures.

These failures suggest that the number of taxa picked is unrepresentative in live-picked fractions and consequently that AusRivAS outputs may be systematically under estimating river health. If the number of taxa in the live-sort was less than that collected in the whole sample the site would be falsely assessed as in poorer condition, with the magnitude of the poorer health assessment depending on the number of taxa missed and the numbers expected to occur at a site. However, it should be kept in mind that the very same systemic biases are replicated in the expected taxa lists generated by the AusRivAS models.

The main habitats affected by inadequate picking in the present report were edge and riffles; fewer QA/QC failures were found for channel, macrophyte and bed

habitats. Other factors found to affect the accuracy of the live-sort procedure are the failure to count small and cryptic taxa and the effects of turbidity and small sample size.

An alternative approach to this issue of probable biases is to accept that live-sorting in the field and laboratory examination under a microscope are essentially two different methods which produce different types of data (Victorian EPA, 2001) and that, like all sampling methods, there will be some inherent bias with live-sorting with some taxa consistently over or under-estimated. Provided all reference and test site samples are collected in a consistent manner, and the biases well understood, then issue in QA/QC terms is less problematic.

2.5 Recommendations on changes to QA/QC Procedures arising from both Audits

The value of external auditing has been demonstrated for the previous audit of live-sort procedures (Humphrey and Thurtell, 1997). The benefit for this project in focussing attention on general AusRivAS quality assurance practices will also become apparent in future audits. The following recommendations arise from the physico-chemical and habitat audit and the macroinvertebrate sample processing audit. They are suggestions for the consideration of the Department of the Environment and Heritage and the state / territory agencies and, for completeness, include aspects of QA/QC not directly related to observations arising from the audit.

General

Procedures for field work, desk-based assessments and laboratory work should be adequately documented and made available for staff to follow in the laboratory, office, or the field. Nationally standardised forms should be used for entry of field data, desk assessments and laboratory work to ensure that all required data is obtained and calculations carried out correctly. Similarly, nationally standardised labels should be used for all samples to ensure that they can be correctly identified and processed. All samples should be either logged on field sheets or logged on return to the laboratory / office so that they can be tracked through processing as well as providing an inventory of stored samples.

A cover sheet should be included with field sheets with a checklist of the required data to be collected for the relevant state / territory AusRivAS program. This will reduce the incidence of missing data and so decrease the abundance of averaging and other errors in data sets.

Field instruments should be calibrated using standard solutions or other techniques to meet manufacturer's recommendations as a minimum; and records of calibration and repairs maintained.

Data entry and validation should be included in documented QA/QC procedures. This should include data validation through the use of data format validation rules written into state / territory data bases, or by printing out database records for independent checking by another operator against the original data sheets.

In addition, these documented procedures should include scanning for erroneous, extreme, outlier or 'out of range' values based on historical data or collective experience. Electronic data should be stored in a readily-retrievable format and should be backed up to ensure that it is available for the long term.

Nationally agreed targets for acceptable rates of error should be nominated and adopted as a matter of priority, even if only on an interim basis. These should be based on experiences gained in both this and the previous 1996 audit. The objective of these targets should be to improve the quality of AusRivAS outputs and provide end users of AusRivAS outputs with know levels of error. National QA/QC standards should seek to ensure that QA/QC processes are embraced as an integral component of AusRivAS assessment processes. They should also provide guidance on sample preservation for QA/QC assessment; target error rates for data entry and taxonomic misidentification; and set criteria for live-sort performance.

Also, QA/QC training should be undertaken, in addition to existing AusRivAS training, for all operators involved in field and laboratory procedures and data entry. This training should include ongoing assessment of competencies similar to that incorporated into basic AusRivAS training programs.

It is recommended that all such targets and procedures be integrated into a coordinated national QA/QC program and through a process of external auditing that this program then be reviewed to assess its efficacy.

Habitat Procedures

Stream width estimation should be made by actual measurement across transects or the by the use of range finders. Similarly, substrate variables should be estimated from size templates and sieving to ensure accuracy and freedom from operator subjectivity.

As indicated above, a coversheet should be included with field sheets to ensure that all required variables are captured for the applicable state / territory AusRivAS model.

Map variables

For map variables the use of standard procedures, including electronic rather than manual planimeters, should be applied to increase the accuracy and reliability of derived values. Even greater accuracy could be achieved by replacing current manual measurement of variables with techniques based on GIS systems.

Live-sort Procedures

It is recommended that the external audit process undertaken in 1996 (Humphrey and Thurtell, 1997) be continued on a regular basis, to support an on-going improvement in the practices and QA/QC associated with AusRivAS assessments. The substantial improvements in live-sort performance since 1996 are validation of the external audit process, which included feedback of results to participants and actions to improve performance.

As edge samples were the main habitat type failing live-sort QA/QC the potential for further improvements in the way that edge samples are live-sorted should be further examined.

A more extensive study is therefore recommended to determine the reasons for poor performance of the live-sort protocol in particular turbid habitats and to recommend techniques to resolve it. This study should include a larger number of sites for the states using live-sort protocols; and assess the types of taxa found in whole sample residues but not live-sort fractions to determine whether there is any bias for different habitat types in the different states. This more detailed study would

provide an understanding of the biases present and whether their elimination or further reduction is warranted.

It is probable that live-sort sampling bias is inherent to the method and that possible future improvements will not further reduce this bias. A recent assessment of potential improvements to live-sort protocols were judged to offer no improvement to the efficiency of the technique or the validity of the results obtained. Nevertheless, should this inherent bias be accepted, there is a need to better understand the quantum of the live-sorting biases and their implications for AusRivAS assessments.

3 References

- Davies, P. (1994) River Bioassessment Manual Version 1.0: National River Processes and Management Program, Monitoring River Health Initiative. LWRDC, Canberra.
- Humphrey, C. and Thurtell, L. (1996) External QA/QC of MRHI agency subsampling and sorting procedures. Milestone Report to LWRDC, December 1996.
- Lenat, D.R and Eaton, L.E. (1991) Comparison of a rapid bioassessment method with North Carolina's macroinvertebrate collection method. *Journal of the North American Benthological Society*, **10**: 335-338.
- Mount, T. and Humphrey, C. (2001). WISE Database V2.2d: Users' Guide. Environmental Research Institute of the Supervising Scientist and The Department of the Environment and Heritage, Commonwealth of Australia, Canberra. <http://www.ausrivas.canberra.edu.au/training>.
- Murray-Bligh, J. (1999). Procedures for collecting and analysing macro-invertebrate samples. BT 001. Environment Agency, Bristol.
- Norris, R.H. and Norris, K.R. (1995). The need for biological assessment of water quality: Australian Perspective. *Australian Journal of Ecology*, **20**: 1-6.
- O, Connor, N.A., Lloyd, L.N. and Moore, S.J. (1996). Evaluation of the National River Health Program. WATER ECOscience Report No. 56/96.
- PIE-Newsletter of Australia's International and National Primary Industries R & D Organisations. International Acclaim for Aussie River Program August 98 edition. <http://www.affa.gov.au/pie/98autumn/>
- Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K. and Hughes, R.M. (1989). *Rapid bioassessment protocols for use in streams and rivers. Benthic macroinvertebrates and fish*, EPA/440/4-89/001, United States Environmental Protection Authority, Office of Water Regulations and Standards, Washington, DC.
- Resh, V.H., Norris, R.H. and Barbour, M.T. (1995). Design and implementation of rapid assessment approaches for water resource monitoring using benthic macroinvertebrates. *Australian Journal of Ecology*, **20**: 108-121.
- Smith, M. and Kay, W. (1998). AusRivAS in Western Australia. An overview of the development and use of AusRivAS models for assessing river health in Western Australia. Department of Conservation and Land Management, WA Wildlife Research Centre, Wanneroo.
- Victorian EPA (2001). The Australia Wide Assessment of River Health; Final Report of the National River Health Program from Victoria. Environment Protection Authority, Victoria.
- WATER ECOscience (2002). National River Health Program- AusRivAS Quality Assurance and Quality Control Project. Year 1 Milestone and Final Report. WATER ECOscience Report No. 655/02.

Wright, J.F. (2000). An introduction to RIVPACS. *In: Assessing the biological quality of fresh waters: RIVPACS and other techniques.* Wright, J.F., Sutcliffe, D.W. & Furse, M.T (Eds.) Freshwater Biological Association, UK. pp 1-24.

Appendix A Project Tasks

Stated tasks for the *National River Health Program - AusRivAS Quality Assurance and Quality Control Project* were:

1. Based on recommendations of the previous Phase 1 NRHP QA/QC research project, and following discussions with a project steering Committee, implement and report on the external audit of macroinvertebrate sampling, sample processing procedures (with particular emphasis placed on agencies who use live-sort protocols), and sample identification for samples from all state / territory lead agencies.
2. Review and report on methods and approaches used for QA/QC procedures for field collection of site environmental data, with particular emphasis given to data used as predictor variables in AusRivAS computer models.
3. Assess and report on the performance of state / territory lead agencies in data collection.
4. Provide feedback and advice on deficiencies of staff performance in AusRivAS methods to lead agencies and make recommendations on improvements to AusRivAS methods.
5. Extensive liaison with state / territory lead agencies:
 - To ensure supply of materials for audit purposes
 - To ensure full audit assessment of field procedures
 - To provide feedback on agency performance
6. Liaison with the AusRivAS error analysis project to provide advice on actual error magnitudes in environmental data to enable evaluation of the consequences of errors associated with this type of data.
7. Liaison with the Principal Investigator of the Training and Accreditation Project to ensure deficiencies detected in the implementation of AusRivAS methods by lead agency staff can be addressed in any proposed training program.
8. Participation in meetings called by the project Steering Committee involving:
 - Presentation of progress reports and addressing issues raised by that committee
 - Undertaking to receive direction from the Steering Committee on aspects of the project
9. Liaison with the National River Health Program Co-ordinator and with the Technical Advisory Committee where considered necessary by the Project Steering Committee.
10. Provide written reports as agreed to in the milestones
11. Provide a report to the Department of the Environment and Heritage on all aspects of the project.