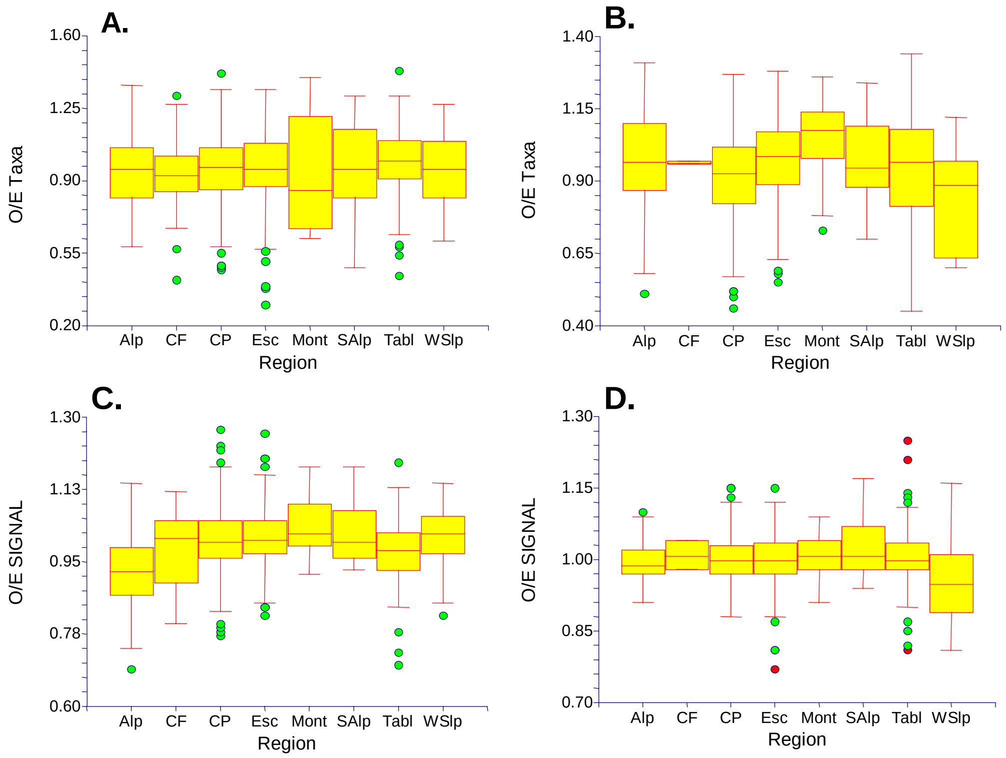


Fig. 13. Box plots showing O/E values from single season models for different natural regions in NSW. A. O/E-Taxa from Edge habitats, B. O/E-SIGNAL values from Edge habitats, C. O/E-Taxa from Riffle habitats, D. O/E-SIGNAL values from Riffle habitats. For explanation of box plots see Fig. 12. Alp = Alpine, SF = Coastal Fringe, CP = Coastal Plain, Esc = Escarpment, SAlp = subalpine, Table = Tablelends, WSlp= Western slopes.

O/E-SIGNAL values also performed consistently, yielding high values for reference sites (Fig 13). Values for edge samples were assessed as being in good condition with 25th percentile values generally greater than 0.9 for the various natural regions (Fig. 13). O/E-SIGNAL assessments for riffle habitats performed very well with 25th percentile values for most regions being greater than 0.97. The exception was again for western slope sites for which the 25th percentile was 0.87. Despite this, the bulk of O/E-SIGNAL assessments for reference sites indicated the sites were in good condition, irrespective of natural region.

Just as site assessments should not be affected by natural region, they should also not be affected by physical site variables. Spearmann rank correlation was used to compare the O/E assessments for reference sites with the site's altitude and distance from source. No strong correlations were evident between assessments and either distance from source or elevation, however, a weak but significant correlation between O/E-Taxa distance from source was detected (Table 2).

Table 2. Spearman rank correlations between O/E-Taxa and O/E-SIGNAL values and the distance from source and elevation of sites for which those assessments were made.

	Distance from Source	Elevation
O/E-Taxa	0.06 (0.027)	0.03 (0.216)
O/E-SIGNAL	-0.02 (0.394)	-0.01 (0.805)

3.3.3 Predictive capacity

The predictive modelling approach of AUSRIVAS is only one of many ways to rapidly assess the integrity of macroinvertebrate assemblages in running waters. There are many alternatives that may be simpler to use and less costly to develop. The simplest of these is taxon richness, which is the number of different types of invertebrates in a sample. This may be determined at the family, species or any other taxonomic level.

Another approach is to use a biotic index such as pollution tolerance scores, where each macroinvertebrate family, genus or species in a sample is allocated a score based on its tolerance/sensitivity to pollution. The average score for all taxa in a sample is used as the index value. Several different pollution tolerance indices have been developed worldwide, for example the ASPT index in the UK (Armitage et al. 1983), the BMWQ score in Spain (Camargo 1993) and the SIGNAL index in Australia (Chessman 1995).

The main strength of AUSRIVAS is that the assessments it provides are specific to different stream habitats. Because of this, AUSRIVAS should show greater consistency than non-specific indicators of macroinvertebrate community integrity The ability of these indices to assess specific nominal impacts is compared to that of O/E-Taxa and O/E-SIGNAL values, which are presented in Fig. 12.

In general, the use of taxon richness to assess broad geographic patterns is problematic. Although low taxon richness is often a reliable indicator of high level disturbance, moderate levels of disturbance are poorly indicated by this method. The main problem is that there is no benchmark with which to assess the loss of taxa. The number of taxa in samples from riffle and edge habitats at reference sites varies across natural regions in NSW (Fig. 14). Given the variability in taxon richness across the state, assessments of river health based on this measure are misleading, as differences between reference and test sites (Fig. 15) may be due to natural differences rather than disturbance. The variability in the number of taxa collected in samples from within each region casts doubt on the reliability of direct comparisons between reference and test sites even within each region.

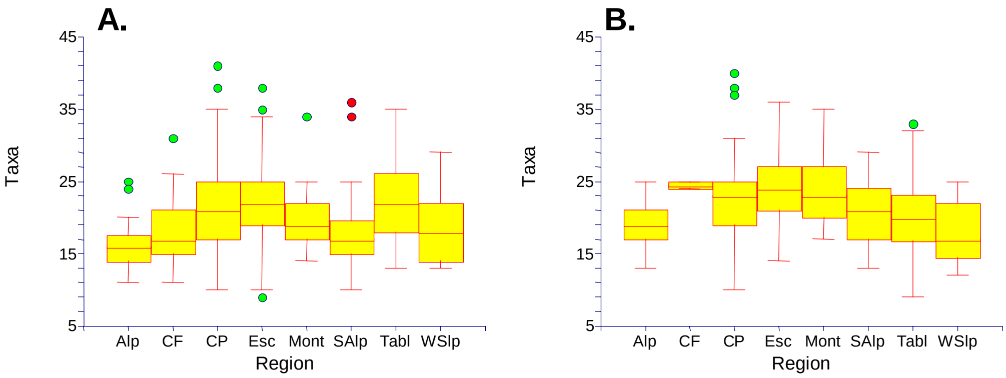


Fig. 14. Box plots showing the taxon richness from A. edge habitats and B. riffle habitats at reference sites in different natural regions across NSW. For explanation of box plots see Fig. 12. Alp = Alpine, SF = Coastal Fringe, CP = Coastal Plain, Esc = Escarpment, SAlp = subalpine, Tabl = Tablelends, WSlp = Western slopes.

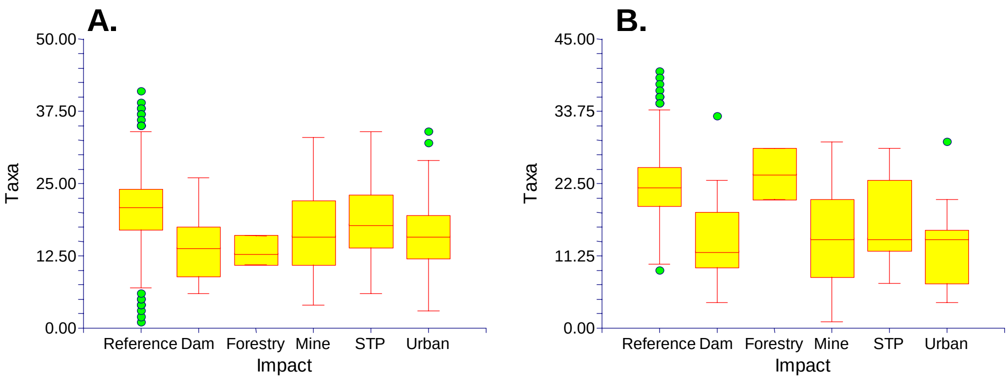


Fig. 15. Box plots showing the taxon richness from single season models for A. edge habitats and B. riffle habitats for various nominal impacts. For explanation of box plots see Fig. 12.

Assessments derived using the SIGNAL index (Fig. 16) show similar patterns to those of the AUSRIVAS outputs for respective habitats (Fig. 12), i.e., little or no effect from forestry activities and varying degrees of impact attributable to other disturbances. The SIGNAL values most closely follow the patterns in the O/E-SIGNAL values, more so than the O/E-Taxa values. In particular, SIGNAL values for samples from riffle habitats do not display the strong trends of mine impacts evident in the respective O/E-Taxa assessments.

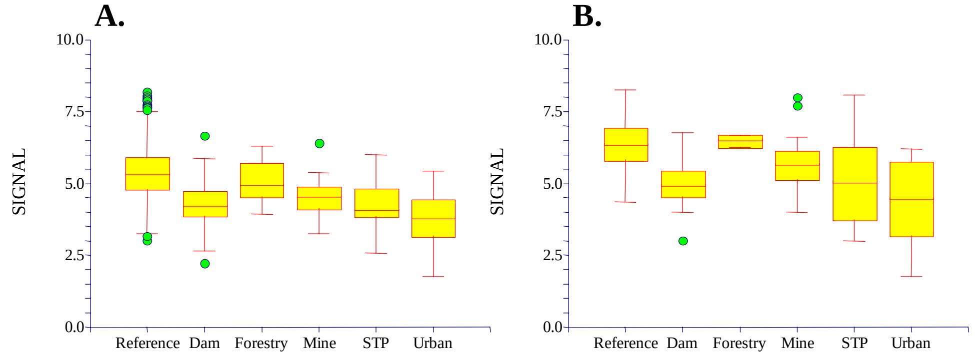


Fig. 16. Box plots showing the SIGNAL biotic index values from single season models for A. edge habitats and B. riffle habitats for various nominal impacts. For explanation of box plots see Fig. 12.

SIGNAL values from edge habitats show a greater degree of impairment than values from riffle habitats. This was consistent for both reference and impacted sites. As a result of this, the SIGNAL assessments for edge samples from reference sites (median value 5.37) indicates that 75 % of samples from edge habitats were mildly impacted or worse. For riffle habitats there was a greater degree of separation between reference an impacted habitats, with 75 % of samples from reference site riffle habitats being classified as unimpaired, and the majority of impacted samples (except those from forestry sites) being classified as mildly impaired or worse.

While the SIGNAL biotic index has many useful applications, the use of raw SIGNAL values for comparison at large spatial scales may present problems because of the lack of appropriate references. As for using the number of taxa as an indicator, differences in SIGNAL values occur between natural regions across NSW (Fig. 17). For this reason, O/E-SIGNAL and O/E-Taxa values are superior because the models that underlie them attempt to account for a likely reference condition. AUSRIVAS outputs (Fig. 13) do not have the same degree of variability across the state as does the SIGNAL values or taxon richness.

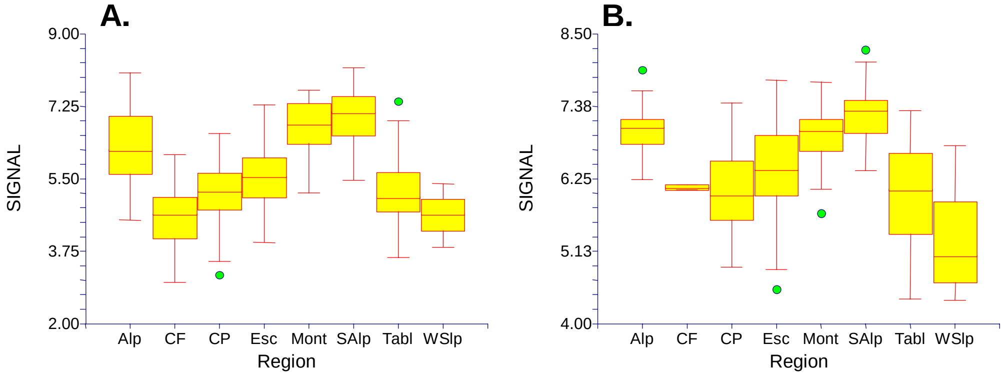


Fig. 17. Box plots showing the SIGNAL_98 values derived for samples collected from A. edge habitats and B. riffle habitats at reference sites in different natural regions across NSW. For explanation of box plots see Fig. 12. Alp = Alpine, SF = Coastal Fringe, CP = Coastal Plain, Esc = Escarpment, Hunter = Hunter Region, Salp = subalpine, Table = Tablelends, West = Western regions.

Taxon Richness had a very weak but significant correlation with distance from stream source as well as a weak and significant negative correlation with altitude (Table 3). SIGNAL however, had much stronger correlations with these factors. SIGNAL had a significant negative correlation with distance from source, and a significant but positive correlation with altitude (Table 3). These findings suggest that SIGNAL values are higher for upland streams than lowland rivers, irrespective of impact. In contrast, neither of the AUSRIVAS outputs were correlated with either distance from source or altitude (Table 2).

Table 3. Spearman rank correlations and significance (in parentheses) of taxon richness and SIGNAL index with the distance from source and elevation of sites for which those assessments were made.

	Distance from Source	Elevation
Taxon Richness	0.10 (0.000)	-0.08 (0.003)
SIGNAL	-0.37 (0.000)	0.46 (0.000)

3.4 Relating habitat assessment with model outputs

Habitat assessment data were collected for all sites visited from 1997 to 2000. Preliminary analysis was conducted on visual assessment scores of disturbance for the water, instream and banks/riparian zones. This analysis suggests that for some habitat models, the visual assessments of water quality, instream habitat, and riparian habitat may relate to O/E outputs, with those sites given poor visual assessments having lower O/E values. As an example, Fig. 18 shows O/E outputs from the combined-season riffle model decrease with increasing disturbance of the instream habitat.

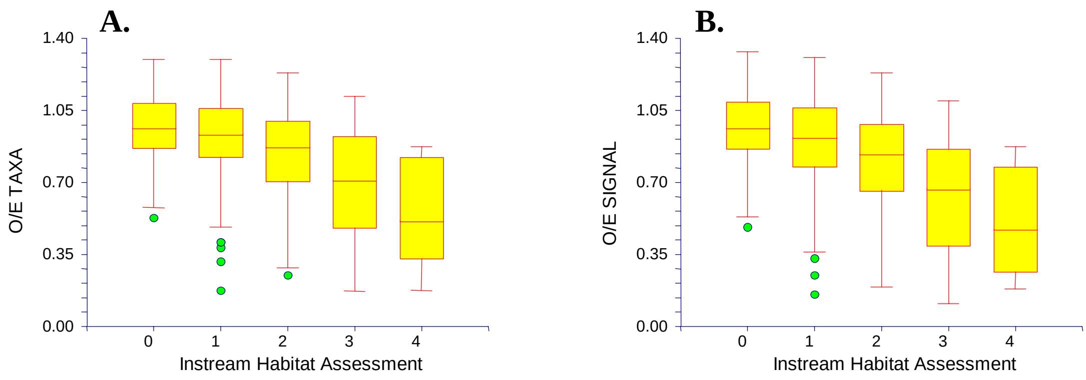


Fig. 18. Relationship between visual assessment of instream habitat and a) O/E-Taxa outputs and b) O/E-SIGNAL outputs from combined season riffle models. For explanation of box plots see Fig. 12.

4. Adoption of AUSRIVAS in environmental management.

4.1 Overview

In the course of the NRHP there has been an increasing interest in NSW for using biological indicators, in particular macroinvertebrates, in river management. The development of AUSRIVAS and the communication activities undertaken by the EPA including Training and Information Days have contributed significantly to this. The adoption of AUSRIVAS by state and local government, community groups and water resource managers has occurred in NSW in various ways. Examples of the main uses of AUSRIVAS in environmental management over the past few years are given below.

4.2 Assessment of the state of rivers in a catchment or small geographic area

Assessments of river health for small geographic areas have been undertaken at various scales. Hornsby and Kuringai Councils used AUSRIVAS to assess the condition of the catchments of several small streams in their area and to compare catchments with varying degrees of urban development. At a larger scale, the Bega Water Management Committee commissioned the assessment of 20 sites in the

Bega River catchment to provide ecological information for inclusion in water management plans.

4.3 Assessment of point source impacts for pollution investigations

The EPA has undertaken AUSRIVAS sampling on several occasions to assist in determining whether ecological harm had occurred following a pollution incident. Examples of incidents that were investigated using AUSRIVAS include: leaching of contaminants from a rubbish tip, subsidence of rubble at an illegal tip, organic pollution resulting from the rupture of a sewage pipe, sedimentation from a quarry, sedimentation from the construction of a pipeline and contamination of a creek with aircraft fuel.

4.4 Assessment of state-wide trends in river health

Statewide assessments of river health using AUSRIVAS have been included in State of the Environment reporting to provide information on large-scale trends in NSW. AUSRIVAS is nominated as a primary indicator in the proposed State Water Monitoring Strategy.

4.5 Assessing priorities for rehabilitation

AUSRIVAS assessments have been used to determine priorities for rehabilitation of derelict mines. Firstly they were used to determine how far downstream the ecological effects of mining were detectable, and secondly, to evaluate the use of AUSRIVAS assessments as a goal for the restoration of affected creek segments.

5. The elements of NRHP in NSW

5.1 Philosophy

The main philosophy in developing predictive models for AUSRIVAS is derived from the approaches adopted for the River Invertebrate Prediction And Classification System (RIVPACS) in the UK which was the first large-scale application of predictive modelling of macroinvertebrates (Wright 1995). The RIVPACS approach was adopted for the NRHP in Australia with some modifications (Davies 1994, Schofield and Davies 1996). The main modifications from RIVPACS that were adopted for the NRHP were habitat specific sampling and definition of season. Changes to the sampling protocol were also made. One feature of the NRHP strategy was that the first step in the program would be to identify key regions of management concern (Davies 1994). The selection of reference and test sites used to develop and test the AUSRIVAS models should then be based on this knowledge (Davies 1994).

The development of AUSRIVAS models for NSW, however, followed a slightly different course. The main aim in NSW was to develop a tool that would be applicable to all the major river systems in the state (Turak 1997). The first step was to partition the state into smaller, more ecologically homogeneous regions. A major assumption was that types of landscapes (defined as Natural Regions) could broadly represent natural variability in river systems. Reference sites were then chosen to represent each of these natural regions. Although an attempt was made to represent all running-water site types in NSW this was conducted at a broad scale and therefore models may not cover unusual site types that are rarely encountered but may be of great importance in particular locations.

The criteria for selecting reference sites required some thought on what condition the reference sites should represent. The reference condition will ultimately serve as a goal for those who use AUSRIVAS as a tool for river restoration and management. For the NSW program, the reference condition was defined as the *best condition attainable with good management practices in the short to medium term* (a few years to decades).

5.2 Site selection; process and rationale

Selection of reference sites follows the philosophy outlined above. The data set used for this procedure included the Natural Region Classification system, Biodiversity Advisory Committee 1992 and Catchment Boundaries of New South Wales, DLWC. Natural regions as defined in the NPWS Natural Region Classification system were used to partition catchments into subdivisions. These subdivisions served as the land units within which the reference condition criterion described above was applied. This resulted in the reference condition representing different degrees of deviation from naturalness in different parts of the state. The process of selecting reference sites was carried out in three stages as shown in Fig. 19.

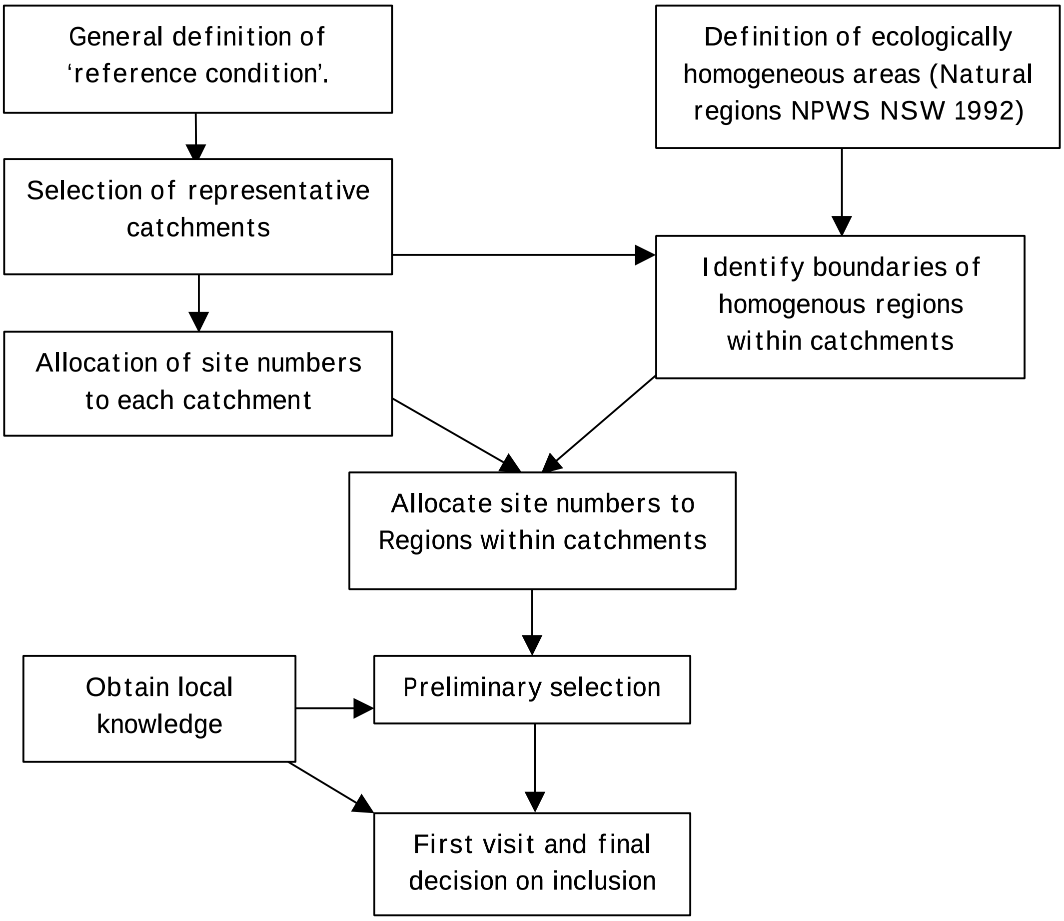


Fig. 19. Steps in preliminary site selection for the MRHI (March-September 1994)

The first stage in site selection for the NRHP was the selection of 250 reference sites, mostly from topographic maps, during the first year of the MRHI. These sites were sampled for two years over 4 consecutive sampling seasons from spring 1994 to autumn 1996. Preliminary models were developed using the data collected from these reference sites. In additional 22 test sites, representing distinct disturbance types, were sampled during this period and used for testing model performance. Each further stage of site selection was tied to a discrete stage in model development (discussed later in section 5.4).

AWARH began in 1997. During 1997, no new reference sites were selected, as the main objective of the sampling program in that year was to test the preliminary models. As part of the site selection procedure for this year a large number of government agencies were invited to nominate sampling sites affected by disturbances of management concern in their region. In total 350 test sites were selected covering a range of different disturbance types in all areas of the state. Degrees of disturbances also varied among sites and a few undisturbed sites were also selected as they were of particular interest to individual stakeholders.

In 1998 all previously sampled reference sites were reviewed and the performance of the models for different types of rivers and different geographic regions across the state were assessed. Stream types and geographic regions that required greater representation in the models were then identified. Appropriate sites were then selected to fill in these gaps. Stream types for which more reference sites were needed included lowland rivers in the Murray-Darling Basin, small creeks in sandstone geology, small acidic upland streams and low gradient coastal streams. As a result about 100 new reference sites were sampled during 1998. Over 100 new test sites were also selected for sampling in 1998. The procedure used for selecting these sites followed the overall strategy outlined below.

The overall strategy for selecting test sites was directed at meeting three main goals:

- Inclusion of sites subjected to the types of disturbance that represent the interests of a wide range of stakeholders.
- Inclusion of disturbed sites for all the stream types represented in the models.
- Providing a good coverage of sampling sites across the state including representation of all Natural Regions, all major land uses and all major stream types.

Dialogue was established and maintained throughout the program with other government agencies, local government and community groups. This provided them with opportunities to nominate sampling sites and identify important management issues.

Prior to the final year of sampling for AWARH in 1999 the coverage of sites for the entire state was revised and gaps in the geographic coverage were identified. The process of identifying gaps in the coverage was carried out in a number of steps using Geographical Information Systems (GIS), staff knowledge and local information. Firstly, all existing sites were mapped using GIS and the boundaries of river catchments and Natural Regions defined using the data sources mentioned above. The coverage of sampling sites within all major river catchments was then examined and natural regions that were poorly represented identified. Natural regions within catchments were used throughout this program as relatively homogenous land units. The next step was to overlay a land use datalayer and examine the coverage of sites within each land unit according to the range of land uses present. The NSW Department of Conservation and Land Management (CaLM) Land Use of New South Wales data set was used for this purpose. Land uses within each land unit that were poorly represented were then identified.

All relevant information was then complied including information gained by previous sampling events and consultation with local sources to determine any major river type or land use that required better representation. A large number of new test sites were then selected and sampled if proved suitable in the field following ground-truthing. During site selection for the 1999 sampling seasons some consideration was also given to achieving a balance in the number of sites at different levels of disturbance. For this reason many of the test sites sampled during this year were from relatively undisturbed rivers. In total an additional 272 new test sites were sampled in this final year. This probably makes the coverage of sites sampled throughout the NRHP in NSW suitable for reporting on spatial trends in river health throughout the state.

5.3 Sampling methodology

The sampling of macroinvertebrates and sample processing methods in NSW have been based on Davies (1994). The environmental data required for AUSRIVAS assessments in NSW includes most variables used by Davies (1994). Some changes, however, have been made to the live-pick methods and the habitat definitions. Sampling instructions have also been tightened and these are described in detail in the Sampling Manual (Turak and Waddell 2000a). New data sheets were designed to make the process of data collection as easy as possible. Copies of these are included with the Sampling Manual.

5.4 Model development

Over the duration of the NRHP, three versions of AUSRIVAS models have been developed. The first two versions developed in 1997 were preliminary and will be referred to as the beta models (β-1, β-2). These essentially served to determine a sound strategy for developing the final or alpha models that were developed in 2000.

5.4.1 Development of β models.

The first version (β-1) models were developed in March 1997 using data collected in spring and autumn 1995. Preliminary evaluation of Version 1 models indicated that the single season models were performing poorly for many rivers (Turak et al. 1997). The number of predicted taxa were low for most sites, and many of the test sites considered disturbed were assessed as being in good condition. Conversely many reference sites known to be undisturbed were assessed as being in poor condition. These results prompted a revision of the models.

The second version (β-2) models were developed in December 1997 using data from Autumn 96 instead of Autumn 95, together with data from spring 1995. Examining these results it was concluded that a major factor contributing to the unreliability of these models was data quality, especially for data collected in Autumn 1995 at which time many of the rivers had experienced a prolonged drought followed by floods.

Some of the unsuitable reference sites were excluded from use in the β-2 models and additional site attributes such as slope of the river at each sampling site were derived. These data were used to develop combined season models that were used to assess sites sampled for the AWARH in 1997. The results obtained using β-2 models for reference sites were then evaluated to determine types of streams that needed to be better represented for the models to be more reliable.

5.4.2 Development of α models

The third version (α-1) models were completed in June 2000. The procedures followed for model development are those described in published literature including Moss et al. (1987), Davies (1994) and Turak et al. (1999). The process of developing these latest models is described in the attached document titled *Development of AUSRIVAS Predictive Models for Rivers of NSW* (Turak and Waddell 2000b).

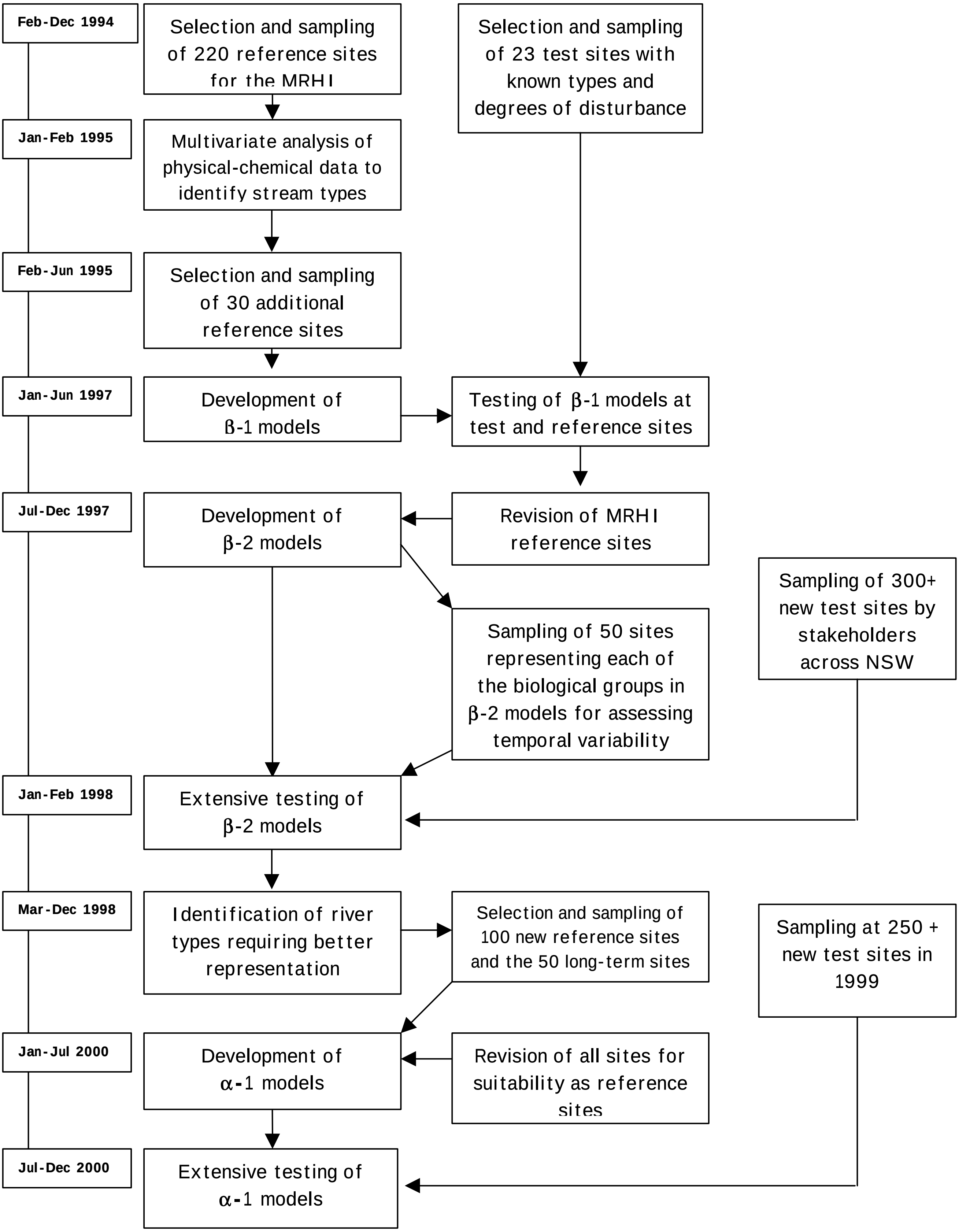


Fig. 20. Time frame for steps in site selection and model development for AUSRIVAS in NSW.

5.5 Quality control/Assurance

5.5.1 Internal QA/QC plan

An internal QA/QC program was implemented in NSW for the NRHP (National River Health Program) to ensure that only quality assured data were used in all aspects of model development, model testing and river site assessment. Quality control procedures were undertaken for field measurements, macroinvertebrate identification, data handling and storage, and the screening of poor quality environmental and biological. These were undertaken to ensure an acceptable standard of data quality was achieved throughout the program addressing issues of lineage, positional accuracy, attribute accuracy, logical consistency and completeness. All data collected from both reference and test sites throughout the MRHI and AWARH phases were included.

5.5.2 Internal QA/QC methods

Methods used in the QA/QC programs are described in detail in the attached document titled *Internal Quality Control and Quality Assurance Programs for the NRHP in NSW* (Waddell 2000). The procedures used for assessing error rates in macroinvertebrate identification followed the guidelines presented in Hawking and O'Connor (1997).

5.5.3 Internal QA/QC results

Errors in data entry and macroinvertebrate identification were very low and far below the error rate considered acceptable for the NRPH. For the majority of samples no identification errors were recorded and only a very small number failed the QA/QC criteria. Untrained/inexperienced staff from DLWC was responsible for most of the failed samples. These along with all others identified by inexperienced staff have been subsequently re-identified. Overall missed taxon was the most common error found. The only identification error with implication for the AUSRIVAS models in NSW was the confusion of two molluscan families Corbiculidae and Sphaeriidae. As a consequence these were combined in the latest version of the models.

Results of the biological screening procedure showed that most of the macroinvertebrate samples passed the QA/QC criteria as described in the attached QA/QC document (Waddell 2000). Untrained sorters were the most common reason for poor quality biological samples followed by extreme flow conditions. Unusual sampling conditions, unsuitable habitat or site, and sampling outside of the specified sampling seasons were also responsible for producing some macroinvertebrate samples of poor quality. Some inconsistencies in field data recording were also discovered for some of the more subjective variables such as substrate composition through the environmental data screening process. For more details on the QA/QC results refer to the attached QA/QC document (Waddell 2000).

5.5.4 Implications for data and models

One of the main objectives of the AWARH phase in NSW was to develop new AUSRIVAS models that were free of poor quality data (Turak and Waddell 2000b). The results of the QA/QC program suggest that this was achieved as an acceptable standard of data quality is assured for all aspects of the MRHI/AWARH in NSW including data entry and handling, macroinvertebrate identification and environmental and biological data collection. The extensive data screening procedures undertaken prior to model development for the latest version of the NSW AUSRIVAS models ensured that only quality assured environmental and biological data were used in all aspects of model construction and testing. Quality assured data were also important for providing accurate site assessments.

The QA/QC results also highlight the problems of sampling in extreme conditions such as very high flows and collecting samples from marginal or unsuitable habitats. They also illustrate the importance of training to ensure that high quality data is collected and used to make assessments using AUSRIVAS. More details on model implications are provided in the attached QA/QC document (Waddell 2000).

5.6 Communication activities

The communication plan within the state programs of the NRHP had two major aims. The first was to obtain support for, and participation in the program by a wide range of stakeholders so the objectives of the program could be met. The second aim was the adoption of AUSRIVAS in environmental management. Both of these aims have been achieved in NSW indicating that the communication activities undertaken have been effective and successful.

5.6.1 Activities

The main communication activities undertaken as a part of the NSW program are as follows:

- Collaboration with other government agencies.
- Involvement of community groups, local government and other stakeholders in site selection and sampling.
- AUSRIVAS training and information days: one-day workshops were held at several centres across NSW.
- *Publications*: Activities undertaken in NSW as a part of the MRHI/AWARH have been communicated in various type of publications including scientific papers, magazine articles, milestone and final report to LWRRDC and Environment Australia. A list of these publications can be found in Appendix 3. All reports are available at the library of the Environment Protection Authority (NSW).
- *Bioassessment workshops*: Presentations were made at the four national bioassessment workshops held between 1994 and 2000.
- *Scientific fora:* Presentations have been made every year at the conferences of the Australian Society for Limnology from 1995 to 2000 and other workshops and conferences. Details of conference and workshop presentations are given in Appendix 3.
- *Dialogue with a wide range of users or potential users of AUSRIVAS:* Ongoing contact and exchange of information with potential users of AUSRIVAS from community groups and government agencies has enabled developments in the program to be conveyed and feedback to be obtained on various aspects of the program.

5.6.2 Effectiveness

The support and input to the program from various stakeholders in NSW was greater than expected at the outset of the program. Substantial input was made into the NSW program from many other government departments both at the head office and regional office levels. In particular, regional offices of the Department of Land and Water Conservation (DLWC) have contributed significantly to the program. At the head-office level, DLWC was a collaborator in the project. At the regional level, State Forests and National Parks and Wildlife Service provided input at various stages of the program by nominating sampling sites, facilitating access to sites, nominating officers to assist in fieldwork and providing vehicles. There has also been similar input from numerous local councils and community groups.

The program has already been adopted widely (see section 4), often as direct consequence of communication activities. For example the AUSRIVAS training and information days have often served to generate local interest in AUSRIVAS sampling. Following the Workshop in Grafton several local groups and government departments initiated small sampling programs and used AUSRIVAS assessments to determine river condition in their area.

6 Performance of the program against NHT performance Indicators

6.1 NHT key result Indicators

6.1.1 Sites sampled

The number of reference and test sites sampled each year during the NRHP in NSW is given in Table 4.

Table 4. Number of test and reference sites sampled in each season of the program.

Year	Season	Reference sites	Test sites
1994	Spring	138	79
1995	Autumn	178	97
1995	Spring	172	93
1996	Spring	176	87
1997	Autumn	104	254

1997	Spring	101	238
1998	Autumn	127	124
1998	Spring	123	127
1999	Autumn	40	272
1999	Spring	37	286
2000	Autumn	3	64

The majority of these sites were only sampled in one year (for two seasons). A small number of these sites were sampled over 5 years. The number of sites that were sampled for different time intervals is given in Table 5.

Table 5. Number of sites sampled for different numbers of seasons.

Number of seasons Sampled	Number of sites
1	103
2	687
3	59
4	155
5	25
6	18
7	2
8	1
9	15
10	34
11	1

The spatial coverage of sampling sites in NSW is extensive and includes all major river catchments, geographic regions, ecoregions and landuse types. This extensive spatial coverage satisfies one of the key objectives of the program, which was to provide a comprehensive assessment of river health in NSW.

6.1.2 Detecting change in river condition

Detecting improvements in river condition over time was not one of the objectives of this program and could not have been achieved without compromising the spatial coverage. Repeating the sampling at a large number of the sites over many years would have meant that fewer sites would have been sampled and the state and national site number targets would not have been met. The existing temporal coverage in NSW does not allow any inference of change in the health of rivers in this state. The program only allowed a small number of sites to be sampled for the entire duration of the project (Table 5) and almost all of these sites are reference sites that are not expected to change significantly over time.

6.1.3 Contribution by state agencies and the partnership with federal government agencies

The MRHI/AWARH programs in NSW have been products of a collaborative effort between State and Federal Government Agencies. Although various State Government Agencies in NSW have participated in the program (including a sizeable contribution by the NSW Department of Land Water Conservation), the most substantial contribution of resources has been by the lead agency, the NSW EPA. As the lead agency, the EPA has been responsible for facilitating the partnership with Federal Government Agencies.

Table 6. The financial contribution from state and commonwealth governments to MRHI/AWARH programs in NSW.

Year	NSW contribution	Commonwealth contribution
1993-1994	20,000	163,410
1994-1995	230,300	212,931
1995-1996	200,300	241,931
1996-1997	142,031	162,927
1997-1998	425,000	365,751
1998-1999	452,310	300,000
1999-2000	330,000	330,000
2000-2001	35, 000	-
Total	**1,834,941**	**1,776,950**

6.2 Appropriateness, effectiveness and efficiency

6.2.1 Appropriateness

The NSW component of the NRHP provided resource managers, community groups and government departments with a practical and cost effective tool for monitoring rivers. The time and effort needed to derive AUSRIVAS assessments for a single site is usually less than one person-day.

AUSRIVAS is a particularly useful tool for river and catchment management because the assessment it provides is based on the best attainable condition for the type of river in concern. This feature of AUSRIVAS makes it preferable to other rapid assessment methods such as pollution tolerance scores (eg SIGNAL) that use a single criterion of river health to assess all types of rivers and are biased towards fast-flowing, small to intermediate sized streams (this is discussed further in section 3.4.3).

The absence of river-type specificity in pollution tolerance scores may lead to misleading and inappropriate assessments. For example, even well managed lowland / low gradient streams may be assessed as poor by such indices while poorly managed upland streams may be assessed as good. In this case the gains made by best management practices may never be detected in lowland streams while the ecological harm caused by poor management in some upland streams may never be detected.

The predictive modelling approach used for AUSRIVAS means that the best managed lowland streams are used as yardsticks for lowland streams and best managed upland streams are used as yardstick for upland streams. In this way AUSRIVAS accounts both for the ecological differences among different types of rivers and uses realistic “reference “ targets based on attainability in a short to medium time frame. This attribute of AUSRIVAS is likely to give managers greater confidence is using biological assessment as a part of their planning.

6.2.2 Effectiveness

Analyses of AUSRIVAS outputs indicate that in most cases, they provide an accurate indication of the integrity of macroinvertebrate assemblages at a site and that this is usually a good approximation of how well the river and catchment is managed. The current evaluation has, however, been based on generalised trends and limited use of evidence of human induced disturbance. It is desirable to perform more detailed tests of the accuracy of AUSRIVAS. This would require all evidence of disturbance (other than macroinvertebrate data) to be compiled for each sampling site. Analysis of the relationship among different types of disturbance and AUSRIVAS outputs as well as total extent of disturbance and AUSRIVAS outputs would then need to be performed.

6.2.3 Efficiency

AUSRIVAS assessments are obtainable with a relatively small amount of effort. The sample collection and processing component can be completed by non-expert staff providing they complete a formal training program. The environmental data required for AUSRIVAS can be obtained quickly from maps and field observations. The average time for obtaining all required environmental data and macroinvertebrate samples from an edge and riffle habitat at a site is less than two hours for a two-person team. Macroinvertebrate sample identification needs to be completed by appropriately qualified personnel and for most users the most efficient way of doing this would be to submit the sample to a laboratory. For appropriately trained personnel the time required to identify a sample will vary from about 15 minutes to about 1½ hours depending on the nature of the sample. Once identifications are complete, the data must be transcribed from data sheets into AUSRIVAS. This involves placing the environmental data in a spreadsheet using the AUSRIVAS variable names and biological data in a separate spreadsheet using AUSRIVAS taxa codes. This process might take up to 30 minutes for a single sample. But if there are a large number of samples this might be reduced to about 10 minutes or less per sample. In most cases single sample site assessments for AUSRIVAS in NSW can be obtained with 3-4 person hours excluding travelling time. Two habitat site assessments could be obtained with 5-6 person hours.

This means that it is quite feasible to report results of a single site assessment on the day of sampling engaging only two people. With a staff of two, it should be possible also, to complete a monitoring program of up to 10 sites within a week. Larger monitoring programs involving 20 sites or more may be completed and reported in a week by a two-person team plus identifiers if sampling sites are in close proximity to one another and identification proceeds concurrently with sampling.

7. Major accomplishments of the program

The NSW program for MRHI/AWARH has been the largest biological sampling program ever undertaken in freshwaters in NSW. It continued for 7 years and involved sampling at 1100 river sites, with numerous agencies and several hundreds of people being involved (see Appendix 4). This program has had a major influence on the practices of ecological assessments in NSW and considerably expanded the knowledge of invertebrate fauna and physical–chemical characteristics of running waters of NSW. Some specific achievements are as follows:

- Development of a practical tool for use in river and catchment management in the form of the NSW component of AUSRIVAS. 7 predictive models were completed for NSW and incorporated into AUSRIVAS in October 2000.
- Widespread participation by government agencies, the private sector and community groups in the implementation of AUSRIVAS sampling.
- The adoption of the "ecosystem health" perspective of assessing river condition by community groups and government agencies as a consequence of their involvement with AUSRIVAS and their participation in the AUSRIVAS training and information days.
- The use of AUSRIVAS outputs as evidence of ecological harm in several cases in the Land and Environment Court.
- Contribution to scientific knowledge through scientific papers and numerous presentations at scientific conferences.
- A well curated macroinvertebrate collection and its placement at the Australian Museum.
- Development of a sophisticated relational database system that will allow timely and efficient access to AUSRIVAS data.
- The accomplishment of the entire model development process by NSW State agency (EPA) staff and hence the development of local expertise.
- The use of AUSRIVAS outputs in NSW State of the Environment Reports and several State of the Rivers and Estuaries Reports.

- The incorporation of AUSRIVAS assessments into an internet based resource for local government (SoE direct) allowing local government to use them for local SoE reports.

8. The future of AUSRIVAS and biological assessment in NSW

There is little doubt that the trend towards the greater adoption and use of biological assessment tools including AUSRIVAS will continue in NSW. There is likely to be a growing demand from local government, state agencies, Water Management Committees and environmental consultants to use AUSRIVAS. This makes the issue of training and accreditation a critical one. A program to deliver good quality training in AUSRIVAS sampling, sample processing and output interpretation must be developed.

While users can be trained in sample collection, providing training for taxonomic identifications is more difficult. Expertise in identifying aquatic macroinvertebrates exists at several centres throughout NSW but the reliability of these identifications may vary. Access to information about where AUSRIVAS identifications can be done, and the reliability of these identifications is likely to be a major issue in the near future.

Various community groups and state and local government agencies are likely to adopt AUSRIVAS for their monitoring programs but may need assistance with the design of such programs and interpretation of the results. Some general guidelines for interpreting AUSRIVAS outputs is provided as a part of AUSRIVAS training but additional training in this area may be needed. Comprehensive interpretation of AUSRIVAS outputs is likely to rely on ecological expertise, which will not be available to most users. One of the tasks for the future will be to determine the level of expertise required for this and identify the sources of it across NSW.

Most data collected using AUSRIVAS in NSW (including that collected by agencies and groups) have been included into the NSW Monitoring River Health Initiative database held by the EPA. This made statewide and regional reporting and analysis of data possible. It also allowed temporal trends to be examined at sites where sampling was repeated for several years. The integration of AUSRIVAS data collected by disparate groups across the state into a single database is a significant achievement. This was possible because the AWARH provided a framework for all data collected to be placed into the central database in return for training, identification of invertebrate samples and assistance with equipment. Many local groups will be collecting new data and some have shown interest in continuing the sampling at some of the long-term sampling sites thus creating a great opportunity for examining temporal trends. This, however, will only be possible if a mechanism is found for data to be incorporated into one database and data quality can be assured.

There is potential for AUSRIVAS assessments to be incorporated into pollution control licences and water management plans in the future. However, when this might happen is difficult to predict.

While AUSRIVAS has already proven to be a powerful tool in management of rivers and catchments in NSW, its full potential is far from reached. Further work on the models can significantly increase its sensitivity and reliability in NSW. Widespread application of AUSRIVAS in environmental management in the near future will facilitate the development of objective performance criteria for AUSRIVAS. In many cases users will have access to detailed management history and records of environmental data at the sampling site. Compilation and analysis of these data will enable better evaluation of how AUSRIVAS is performing across NSW. It will be possible then to identify areas in which the models can be further refined. It is likely that further refinement of models will require sampling at a small number of carefully selected reference sites. Model refinement in NSW in the future would require less time than that needed for previous occasions. With the database construction completed and its capabilities tested thoroughly, preparation of the quality-checked data for model development can be achieved with minimal time and effort. The availability of the expertise and experience built during MRHI/AWARH will be a major factor affecting the feasibility and efficiency of further development of predictive models in NSW.

8.1 Recommendations

- Training programs must be run across NSW, which instruct participants in collecting and sorting macroinvertebrate samples and using AUSRIVAS. The primary aim of these programs should be to ensure that the NSW AUSRIVAS sampling protocol is applied and AUSRIVAS is used correctly.

- Detailed examination of AUSRIVAS outputs against independent evidence of human disturbance should be undertaken. The purpose of this is a comprehensive assessment of the performance of AUSRIVAS in response to different types of human disturbances.

- Model development should continue in NSW with selective sampling of new reference sites and application of the latest developments in performance assessment for such predictive models.

- Regional monitoring programs initiated by community groups, local government and regional agencies of state government should be encouraged and provided with support in experimental design and output interpretation.

- A mechanism should be developed by which all credible AUSRIVAS assessments are placed in to a central database so that sampling effort across the state contributes to a complete picture of the spatial and temporal trends in river health.

9. Acknowledgements

Thanks are due to Peter Davies, National Coordinator of the National River Health Program (NRHP) and Nick Schofield (LWRRDC) and Bruce Gray (EA) for management of the NRHP at various stages throughout the program. From the EPA, Peter Scanes, Klaus Koop, Russell Cowell and David Leece provided project management and Bill Hall database management. The contributions made by many staff from the EPA, DLWC, University of New England, State Forests, Charles Sturt University, Australian Water Technologies and various Catchment Management Committees and Shire Councils are also acknowledged. A list of names, organisation and their respective contributions to the NRHP are listed in Appendix 4. Special thanks, however, are due to Gunther Theischinger, Jaimie Potts, Joanne Ling, Alexander Leask, Joanne King, Frances Laurenson, Andrew Boulton, Bruce Chessman, Michael Bales, Michael Moroney, Meredith Royal, Doug Westhorpe, Peter Serov and Monika Muschal who provided contributions further to those of sample collection and identification. National Parks and Wildlife Service (NPWS), NSW Fisheries and NSW State Forests are also thanked for their involvement in the project. Financial support was provided by Land and Water Resources Research and Development Corporation (LWRRDC), Environment Australia (EA), NSW Environment Protection Authority (EPA), NSW Department of Land and Water Conservation (DLWC), NSW State Forests and NSW National Parks and Wildlife Services (NPWS). Finally thanks go to all landholders that gave permission and assisted with access through their properties for sample collection.

10. References

Armitage PD, Wright JF, Moss D, and Furse MT. 1983. The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. *Water Research*. 17:333-347.

Biodiversity Advisory Committee. 1992. A National Strategy for the Conservation of Australia's Biodiversity. Draft for Public Comment. Department of Arts, Sport, The Environment and Territories. Canberra, Australia.

Camargo JA. 1993. Macrobenthic surveys as a valuable tool for assessing freshwater quality in the Iberian Peninsula. *Environmental Monitoring and Assessment*. 24:71-90.

Chessman BC. 1995. Rapid assessment of rivers using macroinvertebrates: a procedure based on habitat specific sampling, family level identification and a biotic index. *Australian Journal of Ecology*. 20:122-129.

Davies PE. 1994. River Bioassessment Manual. National River Processes and Management Program, Monitoring River Health Initiative, February 1994.

Moss D, Furse M, Wright JF and Armitage PD. 1987. The prediction of the macro-invertebrate fauna of unpolluted running-water sites in Great Britain using environmental data. *Freshwater Biology*. 17:41-52.

Schofield N and Davies PE. 1996. Measuring the health of our rivers. *Water*. May/June. 39-43.

Turak E. 1997. The New South Wales program for the Monitoring River Health Initiative. Supporting document No.2. Final Report for the NSW Program for the MRHI to the Land and Water Resources Research and Development Corporation. 30 June 1997, 17 pp.

Turak E, Davies P and Koop K. 1997. The rationale for the Monitoring River Health Initiative (MRHI) and its role in environment protection in New South Wales. Supporting document No.1. Final Report for the NSW Program for the MRHI to the Land and Water Resources Research and Development Corporation 30 June 1997, 13 pp.

Turak E, Flack LK, Norris RH, Simpson J and Waddell N. 1999. Assessment of river condition on large spatial scales using predictive models. *Freshwater Biology.* 41:283-298.

Turak E and Waddell N. 2000a. New South Wales (NSW) Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual. December 2000. Environment Protection Authority. (http://AUSRIVAS.canberra.edu.au/man/NSW/)

Turak E and Waddell N. 2000b. Development of AUSRIVAS models for New South Wales. Supporting document, Australia Wide Assessment of River Health; New South Wales Program. Final Report to Environment Australia. Environment Protection Authority.

Waddell N. 2000. Internal Quality Control and Quality Assurance Programs for the NRHP in NSW. Supporting document, Australia Wide Assessment of River Health; New South Wales Program. Final Report to Environment Australia. Environment Protection Authority.

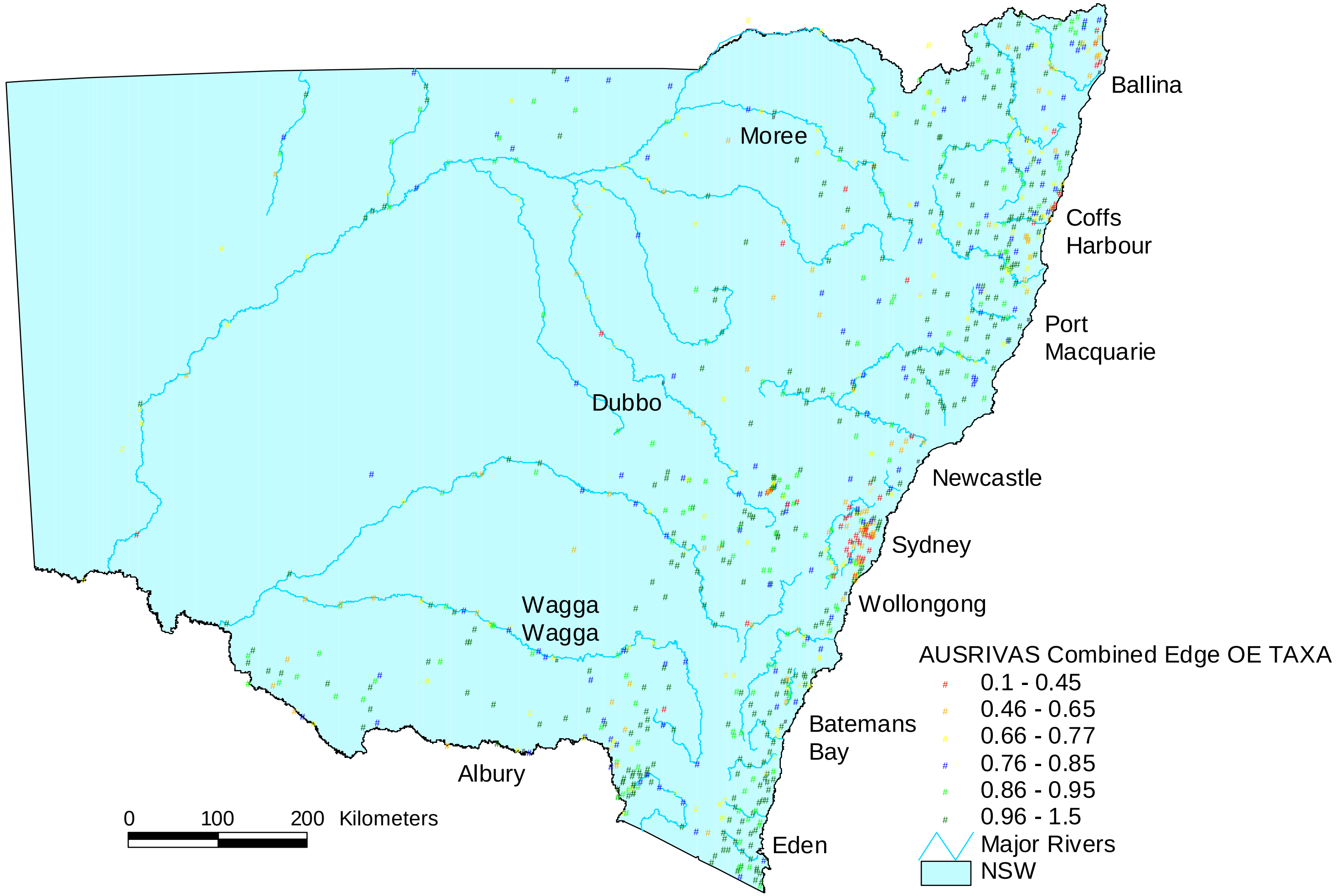
Wright JF. 1995. Development of a system for predicting the macroinvertebrate fauna in flowing waters*. Australian Journal of Ecology* 20:181-197.

Wright JF, Armitage PD, Furse MT and Moss D. 1989. Prediction of Invertebrate Communities using Stream Measurements. *Regulated Rivers: Research and Management.* 4:147-155.

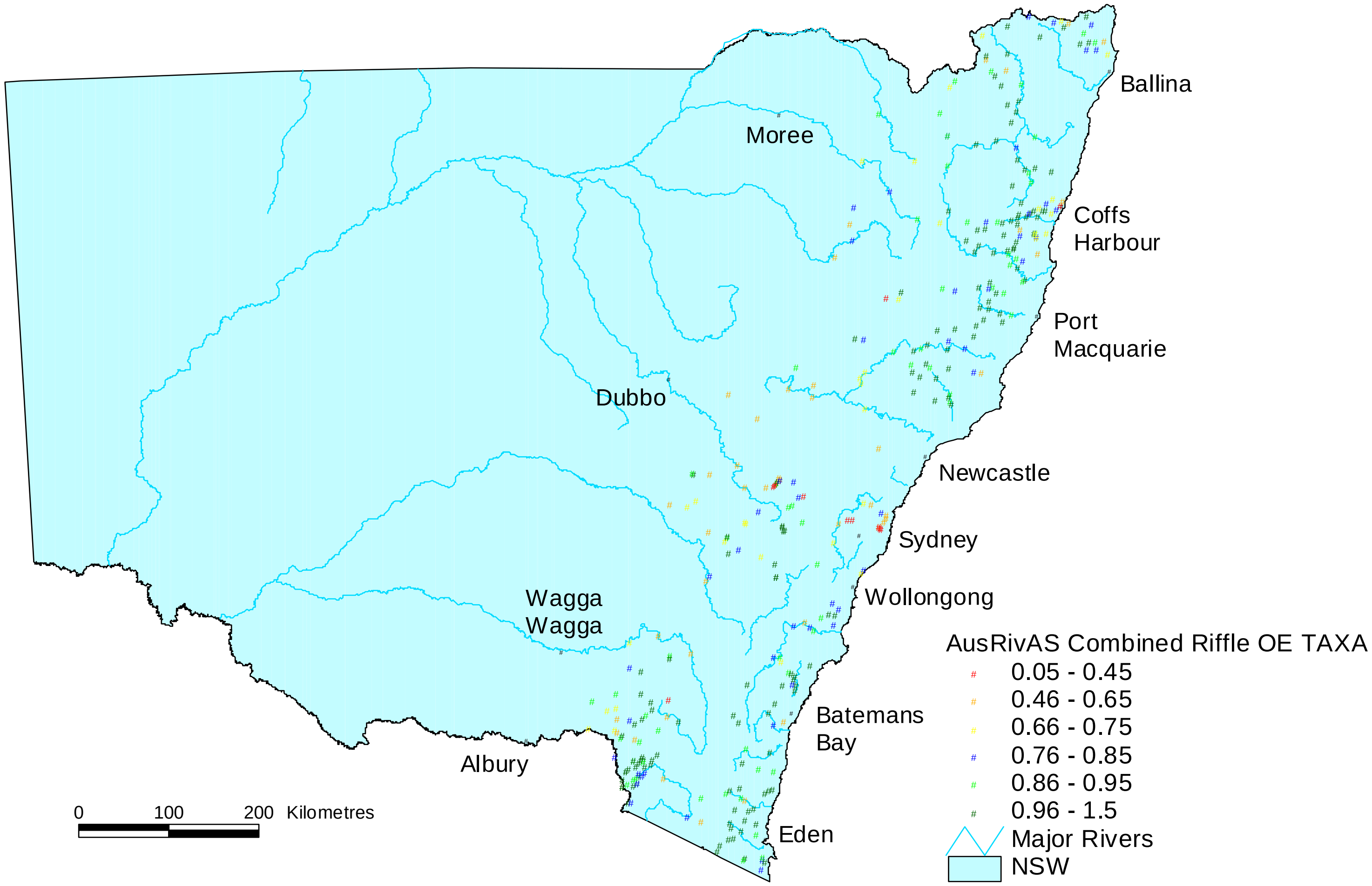
Wright JF, Moss D, Armitage PD and Furse MT. 1984. A preliminary classification of running-water sites in Great Britain based on macro-invertebrate species and the prediction of community type using environmental data*. Freshwater Biology.* 14:221-256.

Wright JF, Moss D, Gunn RJM, Blackburn JH, Winder JM, Symes KL, Grieve NJ, Furse MT and Clarke RT. 1993. Testing and Further Development of Rivpacs (Phase 2) progress report for the period January-March 1993.

Appendix 1: Combined OE-Taxa values for the edge habitat for all sites sampled in NSW as part of the MRHI/AWARH. (note median values are used where more than one assessment was available for a site).



Appendix 2: Combined OE-Taxa values for the riffle habitat for all sites sampled in NSW as part of the MRHI/AWARH. (note median values are used where more than one assessment was available for a site).



Appendix 3: Publications and conference presentations

Hose GC and Turak E. 2000. Can AUSRIVAS detect pesticide effects? 39th Annual Congress of the Australian Society for Limnology. Darwin, Australia, 7-10 July 2000. Oral presentation.

Leask AD, Flack LK and Turak E. 1997. Comparison of different picking efforts in a rapid assessment method using macroinvertebrates. 36th Annual Congress of the Australian Society for Limnology. Albury, NSW, Australia, 27-29 September 1997. Oral presentation.

Turak E. 1997. The New South Wales program for the Monitoring River Health Initiative. Supporting document No.2. Final Report for the NSW Program for the MRHI to the Land and Water Resources Research and Development Corporation. 30 June 1997, 17 pp.

Turak E. 1997. Biological and physico-chemical characteristics of small streams on the coastal fringe of NSW, Australia. 36th Annual Congress of the Australian Society for Limnology. Albury, NSW, Australia, 27-29 September 1997. Oral presentation.

Turak E. 1999. Assessment of river reaches using AUSRIVAS, GIS, satellite imagery and water quality data. New Zealand Limnological Society and Australian Society for Limnology Joint Conference. Wairakei, New Zealand, 29 November - 2 December 1999. Oral presentation.

Turak E. 1999. River health in NSW. *Rivers for the Future*, Issue10 (Spring 1999) pp 20-25.

Turak E, Chessman B and Scanes P. 1998. The ecological health of the rivers of New South Wales, Australia: a snapshot assessment using macroinvertebrates. 37th Annual Congress of the Australian Society for Limnology. Peak Crossing, Queensland, Australia, 3-6 July 1998. Oral presentation.

Turak E, Davies P and Koop K. 1997 The rationale for the Monitoring River Health Initiative (MRHI) and its role in environment protection in New South Wales. Supporting document No.1. Final Report for the NSW Program for the MRHI to the Land and Water Resources Research and Development Corporation 30 June 1997, 13 pp.

Turak E and Flack L. 1996. A step towards the classification of running water sites in New South Wales, Australia based on assemblages. 35th Annual Congress of the Australian Society for Limnology. Berri, South Australia, Australia, 29 September – 2 October 1996. Oral presentation.

Turak E, Flack L, Norris RH, Simpson J and Waddell N. 1997. The prediction of the macroinvertebrate fauna of relatively undisturbed running water sites in New South Wales, Australia using environmental data. Supporting document No.4. Final Report for the NSW Program for the MRHI to the Land and Water Resources Research and Development Corporation, 30 June 1997, 24 pp.

Turak E, Flack LK, Norris RH, Simpson J and Waddell N. 1998. Use of environmental data to predict macroinvertebrate assemblages from rivers in New South Wales, Australia. 37th Annual Congress of the Australian Society for Limnology. Peak Crossing, Queensland, Australia, 3-6 July 1998. Poster presentation.

Turak E, Flack LK, Norris RH, Simpson J and Waddell N. 1999. Assessment of river condition on large spatial scales using predictive models. *Freshwater Biology.* 41:283-298.

Turak E and Ling J. 1995. The NSW component of the Monitoring River health Initiative (MRHI) – Site selection strategy. 34th Annual Congress of the Australian Society for Limnology. Jenolan Caves, NSW, Australia, 17-20 September 1995. Poster presentation.

Turak E and Ling J. 1996. Comparison of operator efficiencies in the collection of macroinvertebrate samples of the Monitoring River Health Initiative (MRHI) in New South Wales, Australia. 35th Annual Congress of the Australian Society for Limnology. Berri, South Australia, Australia, 29 September – 2 October 1996. Oral presentation.

Turak E and Waddell N. 2000. New South Wales (NSW) Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual. http://AUSRIVAS.canberra.edu.au/man/NSW/.

Turak E and Waddell N. 2000. New models for old rivers. 39th Annual Congress of the Australian Society for Limnology. Darwin, Australia, 7-10 July 2000. Oral presentation.

Turak E, Waddell N, Leask AD, Ling J and Flack LK. 1996. Differences in the distribution and environmental requirements within selected aquatic invertebrate families in New South Wales. 35th Annual Congress of the Australian Society for Limnology. Berri, South Australia, Australia, 29 September – 2 October 1996. Poster presentation.

Waddell N. 1999. Temporal variation in AUSRIVAS outputs at long-term sampling sites in New South Wales, Australia. New Zealand Limnological Society and Australian Society for Limnology Joint Conference. Wairakei, New Zealand, 29 November - 2 December 1999. Oral presentation.

Waddell N and Turak E. 1997. The potential of rapid assessment method using macroinvertebrates for measuring stream health downstream from derelict mines. 36th Annual Congress of the Australian Society for Limnology. Albury, NSW, Australia, 27-29 September 1997. Oral presentation.

Appendix 4: List of participants in the NRHP (MRHI/AWARH) in NSW

1= Team member, 2 = Collector, 3 = Sorter, 4 = Identifier

Name	Organisation	Role
A Buchan	DLWC	1, 2, 3, 4
A Fitzgerald	State Forests	1
A McLean	DLWC	1, 2, 3
A Pinder	Uni of New England	1
Adam McLean	Beachwatch	1, 2, 3
Adrian Pride	Uni of New England	1
Ainslie Noakes	EPA Volunteer	1, 3
Alan Simmons	State Forests	1, 3
Alison Curtin	EPA	1
Amanda Jones	EPA Wollongong	1, 2, 3
Andrew Amos	EPA volunteer	1, 2, 3
Andrew Boulton	Uni of New England	1, 2, 3, 4
Andrew Brookes	DLWC	1, 2
Anke Heins	EPA	1
Anna Hobbs	EPA	1, 3
Bruce Chessman	DLWC	1, 2, 3, 4
B Lawson	DLWC	1, 2, 3
B Lee	DLWC	1, 3
Barbara Baginska	EPA	1, 3
Ben Luffman	Nambucca CMC	1, 2, 3
Bob Dean	State Forests	1, 3
Brian Hughes	EPA Grafton	1, 2, 3
Brian Wild	EPA Albury	1, 3
Bruce Gardiner	EPA Albury	1, 2, 3
C Ferguson	DLWC	1, 2, 3
C Williams	DLWC	1, 2, 3
Carmen Dwyer	EPA Bathurst	1, 2, 3
Catherine Trindall	EPA	1
Cathy Cunningham	AWT	1, 3
Cherie Partlete	DLWC	1, 4
Chris Dallow	EPA Volunteer	1
Chrisanya Martin	Great Lakes Shire Council	1, 3
Christine Mercer	EPA	1, 3
Colin Besley	AWT	1
Corrine Watson	Greencorp Volunteer	1, 2
D Goodridge	State Forests	1, 2, 3
David Hohnberg	DLWC	1, 2, 3
D Watson	DLWC	1, 2, 3
Name	**Organisation**	**Role**

Doug Westhorpe	DLWC	1, 2, 3
Dan Cross	DLWC	1, 2, 3
Daniel Couriel	EPA Grafton	1, 3
Danny Roberts	EPA	1
Daryl Albertson	EPA	1, 2, 3
David Greenhalgh	EPA	1, 2, 3
David Holleley	AWT	1, 2, 3
David Smith	Jenolan Trust	1, 2, 3
David Winfield	EPA Bathurst	1, 2, 3
Dean Jarvis	EPA volunteer	1, 2, 3
Eli Ussher	DLWC Kempsey	1
Eren Turak	EPA	1, 2, 3, 4
Eric de Schmidt	Greencorp Volunteer	1, 2, 3
Ernst Holland	Jenolan Trust	1, 2
Estelle Avery	DLWC Newcastle	1
Firoza Azim	DLWC	1, 2, 3, 4
Frances Laurenson	EPA/ DLWC	1, 2, 3, 4
Graham Carter	DLWC	1, 2, 3
Geoff MacDonald	DLWC	1, 2, 3
Glen Davidson	Volunteer	1, 2, 3
Glenda Pollard	Jenolan Trust	1, 2, 3
Graham Sherwin	EPA	1, 2, 3
Graham Turner	EPA	1
Grant Hose	Jenolan Trust/EPA	1, 2, 3
Greg Burrell	Uni of New England	1
Greg Robinson	DLWC	1, 2, 3
Gunther Theischinger	EPA	1, 2, 3, 4
H Glade	DLWC	1, 2, 3
H Keenan	DLWC	1, 2, 3
I Jarosinski	DLWC	1, 2, 3, 4
Ian Pye	EPA	1, 2, 3
Jennie Fenton	DLWC	1, 2, 3
J Gray	State Forests	1, 3
J Lander	DLWC	1, 2, 3
Jack Chubb	EPA Albury	1, 3
Jaimie Potts	EPA	1, 2, 3, 4
James Hook	Wollongong Uni	1, 3
Jan Peters	Uni of NSW	1, 3
Name	**Organisation**	**Role**
Jim Lancaster	Uni of New England	1

Jim Wright	Pretty Gully Land Care	1
Joanne King	EPA	1, 2, 3
Joanne Ling	EPA	1, 2, 3, 4
John Grace	DLWC	1, 2, 3
John O'Donnell	EPA Albury	1, 3
Jon Sayer	DLWC	1
Jude Harrison	State Forests	1, 3
Julie Boddy	DLWC	1, 2, 3
Julie Currey	EPA	1, 2, 3
Julie Porter	EPA	1, 3
K Browning	DLWC	1, 2, 3
K Page	DLWC	1, 2, 3
Karen Banwell	EPA	1
Kate Boyd	DLWC	1, 2, 3
Kate Herwig	Southern Cross Uni	1, 2, 3
Kate Robinson	Jenolan Trust	1, 2, 3
Klaus Koop	EPA	1, 2, 3
L Hardwick	DLWC	1, 2, 3, 4
Laurie Medway	Volunteer	1, 2, 3
Leeta Caiger	Robyn Tuft & Assoc	1, 2, 3, 4
Leon Hyland	Charles Sturt Uni	1, 4
Lisa Newhouse	EPA	1, 3, 4
Lisa Silva	AWT	1
Liz Gillies	Robyn Tuft & Assoc	1, 2, 3
Lloyd Flack	EPA	1, 2
Logan Smith	Greencorp Volunteer	1, 2, 3
Mark Beharrell	DLWC	1, 2, 3
M Simons	DLWC	1
Meredith Royal	DLWC	1, 2, 3, 4
Maria Doherty	EPA	1, 3
Maria Marzella	AWT	1
Marie Egerrup	EPA	1, 2, 3
Marina Peterson	Army	1
Mark Hopkins	AWT	1, 2, 3
Mark Nolen	Charles Sturt Uni	1, 2, 3
Mark Roberts	EPA	1
Martin Bowles	EPA	1
Martin Krogh	EPA	1, 2, 3
Matthew Dasey	EPA	1, 3
Matthew OHare	DLWC	1, 2, 3
Matthew Preston	EPA/ DLWC	1, 2, 3
Name	**Organisation**	**Role**
Max Carpenter	EPA	1
Maxine Rowley	DLWC	1, 3

Mia Thurgate	Jenolan Trust	1, 2, 3
Michael Fokker	Robyn Tuft & Assoc	1, 2, 3
Michael Moroney	DLWC	1, 2, 3
Michael Wood	Upper Clarence CMC	1
Michele Cassidy	EPA/AWT	1, 2, 3, 4
Mick Bales	DLWC	1
Monika Muschal	DLWC	1, 2, 3
Murray Greenaway	DLWC	1
Murray Root	EPA	1, 2, 3
N Searle	DLWC	1, 2, 3, 4
N Berriman	DLWC	1, 2, 3
Nadia Meucci	EPA	1, 2, 3
Natacha Ryan	DLWC	1
Natacha Waddell	EPA	1, 2, 3, 4
Natalie Knipler	Greencorp Volunteer	1, 2
Natalie OConnell	DLWC	1, 2, 3
Nicole Benkendorff	EPA Volunteer	1, 2, 3
Nigel Blake	EPA	1, 2, 3
Nigel Sargent	EPA	1
Peter Coad	Hawkesbury-Nepean Cat. Trust	1, 3
P Huhta	DLWC	1, 2, 3
P Lloyd Jones	DLWC	1, 2, 3
P Serov	DLWC	1, 2, 3, 4
Patrick	DLWC	1, 3
Patrick Pahlow	DLWC	1, 2, 3
Paul Lisle	Uni of New England	1
Paul Rendell	EPA	1, 2, 3
Paul Van Nimwegen	DLWC	1, 2, 3
Peter Scanes	EPA	1, 2, 3
Peter Tuft	Robyn Tuft & Assoc	1, 2, 3
Phil Allen	EPA	1, 3
Phil English	EPA Bathurst	1, 2, 3
R Bartley	DLWC	1, 2, 3
R Phillis	DLWC	1, 2, 3
R Wilson	Charles Sturt Uni	1, 4
Rebecca Hubbard	Wollongong Uni	1, 2, 3
Name	**Organisation**	**Role**
Rebecca Scrivener	EPA Newcastle	1
Renaye Cole	DLWC	1, 2

Rick Cumming	EPA Wollongong	1, 3
Rob Cook	Charles Sturt Uni	1
Rob Patterson	EPA	1, 3
Robyn Tuft	Robyn Tuft & Assoc	1, 2, 3
Rod Kerr	EPA	1
Rod Ruffio	EPA	1
Rodney Allen	Mallanganee Land Care	1
Ross Wilson	Charles Sturt Uni	1, 2
Russell Cowell	EPA	1, 2, 3
S Crawford	DLWC	1, 2
S Dudgeon	DLWC	1, 2, 3
S Powell	DLWC	1, 2, 3
S Skelton	EPA	1, 2, 3
Sandra Mitchell	DLWC	1, 2, 3
Sandy Leask	EPA	1, 2, 3, 4
Scott Carter	EPA	1, 2, 3, 4
Sean Hardiman	EPA	1, 3
Shane Flanigan	EPA Volunteer	1, 3
Sharon Cummins	EPA	1, 2, 3, 4
Sherrill Allen	Mallanganee Land Care	1
Sian Towell	Wyong Council	1, 2, 3
Simon Mitrovic	DLWC Alstonville	1,2, 3
Simon Williams	AWT	1, 2
Stephanie Wallace	EPA	1, 2
Stuart Bremmer	Jenolan Trust	1, 3
Sue Boting	Uni of New England	1, 2, 3
Sue Grau	EPA Wollongong	1, 2, 3
Sue Pretty	Streamwatch	1, 2, 3, 4
Sunila Srivastana	Robyn Tuft & Assoc	1, 3
T Dawson	DLWC	1, 2, 3
T Fulford	DLWC	1, 2
Tanya Rankin	Sydney Uni	1, 2, 3
Thea Hughes	EPA Volunteer	1, 3, 4
Tim Cox	Ben Chifley CMC	1, 3
Tim Ingleton	EPA	1, 2, 3
Tim Pritchard	EPA	1, 2, 3, 4
Tim Riding	EPA	1
Name	**Organisation**	**Role**
Tony Church	EPA	1, 3
Tony Pither	DLWC	1
Tony Roach	EPA	1
Tracey Chambers	DLWC	1, 3
Tracy Fulford	DLWC Barwon	1, 3
Tsuyoshi Kobayashi	EPA	1, 2, 3
V Crawford	DLWC	1, 3
Victoria Adair	EPA	1, 2, 3, 4
Vijay Valecha	EPA	1, 3
Volunteers	Greencorp Volunteers	1
W Mawkinney	DLWC	1, 2, 3
W Wilson	DLWC	1, 2, 3
Warren Martin	DLWC	1, 3
William Dove	EPA Wollongong	1
Yale Garden	Charles Sturt Uni	1, 3, 4

AWT= Australian Water Technologies
CMC= Catchment Management Committee
DLWC= Department of Land and Water Conservation
EPA= Environment Protection Authority