Report no. 4
DRAFT

Assessing conservation of the major **Murray - Darling Basin** ecosystems

Phase 3: Towards a conservation strategy for the conservation of ecosystems and endangered and vulnerable species

by
A.L. Bull
R. Thackway
I.D. Cresswell
1993

Final report to the Murray - Darling Basin Commission

ENVIRONMENTAL RESOURCES INFORMATION NETWORK
AUSTRALIAN NATURE CONSERVATION AGENCY

Assessing conservation of the major Murray-Darling

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AUSTRALIA

1993

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Executive Summary

General

In 1985 the Commonwealth Government established the National Index of Ecosystems (NIE) for Australia, as a collaborative project with the State and Territory nature conservation agencies to help provide a framework for developing a truly national system of protected areas in Australia, with the aim of conserving representative examples of ecosystems. In 1989 a decision was taken to accelerate the development of the NIE by incorporating it with Environmental Resources Information Network (ERIN).

This project was initiated in 1988 as a result of a successful application for funding from the Murray-Darling Basin Commission (MDBC) under its Natural Resources Management Strategy (NRMS) program. The project titled "An assessment of the major ecosystems in parks and reserves of the Murray-Darling Basin" had three phase as follows:

Phase 1: Review and evaluate the availability and access to environmental data, including site based records of vulnerable and endangered species.

Work for Phase 1 was completed in 1990 and report (Thackway 1991) was submitted to the MDBC. The data base compiled during Phase 1 are held at ERIN as part of the continental data base on vulnerable and endangered species.

Phase 2: Involves two parts of conservation assessment

Part 1 Using available environmental data for the Basin classify and define the major ecosystems within the Basin; and

Part 2 Analysis of the relationship between vulnerable and endangered species in relation to these ecosystems and nature conservation reserves; and

Phase 3: Involves using the findings from Part 2 of Phase 2 to develop a strategic plan for the conservation of the major ecosystems and vulnerable and endangered species in the Basin.

Phase 3

The report for Phase 3 presents an example of the application of a conservation options algorithm. The results provide an indicative approach to the design of a protected area system based on broad scale data for ecosystems, vulnerable and endangered species, naturalness of vegetation and existing protected areas.

The procedure involved defining a set of conservation targets, which were expressed as 4 conservation options. The four conservation options and the steps involved are presented in Appendix 2. Appropriate data sets were then selected and analysed. The output of these analyses are referred to as conservation options solutions.

The results show that the existing protected areas system does not adequately represent all environmental groups and vulnerable and endangered species. The inclusion of the existing protected areas in the design of a candidate protected areas network to conserve 5% of all regions plus the vulnerable and endangered species, increases the amount of land required from 4.7 to 6.3% of the total area of the Basin. The inclusion of the existing protected areas system in the design of a new protected areas network to conserve 10% of all regions plus the vulnerable and endangered species, increases the amount of land required from 7.2 to 8.4% of the total area of the Basin.

The conclusion from these analyses is that if the aim of having a protected area network is to conserve biodiversity in the most efficient possible way, then the inclusion of existing protected areas can result in a loss in the efficiency of this process. Protected areas as they now exist have often been chosen for reservation for aesthetic reasons or for other reasons which may have little to do with the contribution of the area to the maintenance of biodiversity.

There are, of course, major limitations on this conclusion given the incomplete nature of the data, and in particular the species data. One could not claim species records alone to be representative of biodiversity. This exercise, does, however, illustrate the point that the existing system of reserves may not only be inadequate to preserve biodiversity, but that in some cases we may be maintaining large areas of land which contribute very little to the conservation of biological diversity.

The algorithm selected clusters of cells wherever possible, and particularly the ability to "add on" to existing protected areas, has important practical implications for management. Large clustered areas are much more likely to be viable and are more practical to manage than small widely scattered areas. This is particularly true in the case of existing protected areas. Increasing the representativeness of the existing protected area system by adding on to existing protected areas, would seem to be the most practical solution as in many cases the management infrastructure and experience is already in place.

The results of this study are preliminary and present only an indicative approach on how a network of protected areas could be developed. Further research is required to optimise the input data into environmental regionalisations, and then the resultant groupings need to be validated against the known distributions of species and habitats. Similarly, the extant natural vegetation derived from satellite imagery requires field validation. The addition of more data on the distributions of rare, threatened or vulnerable flora and fauna would naturally enhance the results.

These algorithms do not necessarily find the optimum solutions. Therefore, it should be stressed that the solutions presented here are only examples which would change if any step of the algorithm was altered. Flexibility is inherent in these algorithms as the rules governing the algorithms can be altered as required. In addition the availability of additional data would introduce a greater level of flexibility into the methodology. Depending on the available data and the desired result, steps can be altered to choose for example, the largest or smallest site where there is a choice.

This process of explicitly defining reserve networks based on the best available data highlights the need for flexibility in our conservation goals. As better data becomes available and conservation needs change, then we need to be able to alter management practises to reflect this. That is, some areas previously held for strict nature conservation could be released for multiple uses, whilst other areas become included in the protected areas network. This scenario is predicated on the entire landscape being managed in an ecologically sustainable manner, such that the conservation values of areas outside of the network remain intact. Hence the protected areas network constitutes only those areas with the highest conservation values and the highest protection, with appropriate management of adjoining lands, other areas of intact natural vegetation, and production lands, to best conserve our natural heritage. If we truly intend to protect biodiversity then fundamental changes to management of the entire continent are necessary.

Techniques such as that documented in this report are essentially scaleless, and could be applied at finer scales than that used here if the supporting data was available. What is necessary is to have a consistent level of data for the entire domain under consideration, as the technique is based on complementarity and comparison, i.e. in order to select a representative set it is necessary to know what is "next door".

One of the major limitations to developing outputs such as that presented in this report is access to appropriate data. As more data and data of better quality becomes available there is a need to revise the outputs. In addition, there is a need to refine the rules or steps used in the project. This should be done as part of a cooperative effort between the State and territory nature conservation and land management agencies and should address the need for candidate reserve designs to be developed at a range of scale both for the whole Basin and for sub-catchments within the Basin.

RECOMMENDATIONS

The need for better quality data sets

There is a need for continued revision and refinement of key primary data sets relating to biodiversity. Most of the detailed information relevant to the establishment of a Basin-wide system are held by State and Territory agencies. The development of cooperative arrangements between the relevant Commonwealth, State and Territory agencies for the compilation of the requisite data sets is required.

Crucial to the success of these arrangements will be the development of protocols satisfactory to both spheres of Government governing the use of those data sets that are compiled.

The need to refine and revise conservation options algorithms

There is a need to investigate a greater range of computer-based explicit methodologies for assisting conservation planners and managers in reserve identification and design. A range of methodologies are in existence, or are under development, both within State and Territory nature conservation agencies and research institutions, including the CSIRO.

The need to define the appropriate mix of protected area regimes

There is a need to investigate the ecological as well as the socio-economic costs and benefits of strict protected areas categories compared with those which provide for conservation agreements while still permitting specified development activities within a conservation framework.

The need for connectivities with off-reserve conservation measures

There is a need to develop intelligent approaches to conservation management, within and outside protected areas, taking into account integrated classification of landscape and optimal allocation of land uses to maximise the conservation of biological diversity at the landscape scale. This is a relatively new area of scientific activity which needs to be examined along with principles of ecological sustainable development, the economic viability and packages of incentives for a range of suitable land uses, and minimum viable populations of selected species.

The need to revise nomenclature for protected areas

There is a need to refine and revise the number of protected area categories in the Basin. Currently, there are about 29 designations for protected areas applied in the different jurisdictions. The analyses presented in this report (i.e. Basin-wide protected areas aggregated into five categories devised by the IUCN) provide a much improved basis for comparative assessment of protected areas across the Basin.

The need for more cross-border cooperation where ecosystems and species populations and assemblages are shared

There is a need for the increased application of cross-border ecological and biological surveys where ecosystems and species populations and assemblages are shared between jurisdictions. Also there is a need for consistent management of the same ecological systems and populations where these abut on State and Territory borders. More cooperative agreements between managing agencies and stakeholders, such as the Australian Alps Agreement, should be encouraged.

The need for data and information and data standards on threatening processes

There is a need to undertake an analysis of the perceived threatening process which impact upon ecosystems and species. An analysis of the loss of habitat by clearance, thinning or modifications would be the first step in determining major threat. Clearly such a very narrow consideration of threatening process would be primarily applicable to higher rainfall areas where the vegetation has been modified or cleared for agricultural, horticultural, industrial and urban land uses. The inclusion of other data sets on threatening processes such as wildfire, competition from plants and animals, and predation would provide a different and more complete picture.

1.0 INTRODUCTION

1.1 Background to the Project

In 1985 the Australian National Parks & Wildlife Service (ANPWS) commenced the National Index of Ecosystems (NIE) project to develop methods and techniques to classify ecosystems and environments. The aim of the project was to provide a sound basis for designing a representative system of national parks and protected areas in Australia. Thackway (1989) presents the findings of an extensive review and assessment of available ecosystem classification methods that were undertaken between 1984 and 1989. During this period several pilot projects were initiated to test and select appropriate methods.

This project was initiated in 1988 as a result of a successful application for funding from the Murray-Darling Basin Commission (MDBC) under its Natural Resources Management Strategy (NRMS) program. The project titled "An assessment of the major ecosystems in parks and reserves of the Murray-Darling Basin" had three phase as follows:

Phase 1: Review and evaluate the availability and access to environmental data, including site based records of vulnerable and endangered species.

Work for Phase 1 was completed in 1990 and report (Thackway 1991) was submitted to the MDBC. The data base compiled during Phase 1 is held at ERIN as part of the continental data base on vulnerable and endangered species.

Phase 2: An analysis of the conservation of major ecosystems, vulnerable and threatened species in parks and protected areas in the Basin

Part 1 Using available environmental data for the Basin classify and define the major ecosystems within the Basin; and

Part 2 Assess the relationship of vulnerable and endangered species in relation to these ecosystems and protected areas; and

Phase 3: Using the findings from Phase 2 develop a strategic plan for the conservation of the major ecosystems and vulnerable and endangered species in the Basin.

1.2 Why develop a strategic plan for the conservation of major ecosystems and endangered species?

Human demands (urban expansion, food and fibre production, waste disposal, recreation) on the environment (i.e. on the natural resources) are steadily increasing. To be effective in managing the impacts of these demands on the natural environment we need to be innovative in developing new economic, social, legal and political paradigms. The Australian government has set in train one process which seeks to involve the whole community in changing and improving our industries, enterprises and life styles towards the principles and practices of Ecologically Sustainable Development (ESD).

The responsibility for managing the biological and ecological resources of Australia lies with the whole community. All levels of government, community groups, research agencies, and individual land managers need to embrace the concepts of ESD. In order to facilitate this process, all of these groups need access to information regarding the biota and the landscape of the group in which they live and how best they can manage these resources to ensure long-term ecological sustainable development.

A strategic framework which encapsulates and organises the sum total of our knowledge (not just data and information) about the patterns and processes of the Australian natural environment is required if we are to be successful in the face of increased pressures on our ecological systems.

We need to be developing and providing access to environmental spatial information systems capable of underpinning environmental policy development and land management at all scales, from local to global levels. Such systems require data and information on climate, landform, species, etc., but more importantly, they also need expert understanding on the role of species within ecosystems. These inputs are fundamental to our understanding of how to mitigate against undesirable impacts to the biota and the environment. In the absence of comprehensive data and information about these entities, we will need to develop models to explain and predict changes. In addition, we will need to commit resources to monitoring the health of the environment.

This strategic plan for the conservation of major ecosystems and endangered and vulnerable species in the Murray-Darling Basin seeks to set the scene rather than supply all the details for individual decision makers. At the outset of undertaking this task it is clearly apparent that there is an obvious lack of data, information and understanding about managing ecological processes and patterns at a regional/landscape scale. Conversely, there is also a need for information from other areas to place the Murray-Darling Basin in context, including considerations of its' national and international significance.

Regional planning in which environmental characteristics are a major determinant of boundaries is considered to be of major importance for the conservation of biodiversity. Development of a bioregional framework could lead to a systematic basis for understanding the biodiversity within each environmental region, and development of regional conservation strategies to integrate a representative protected area system with off reserve measures and ecologically sustainable development.

1.3 What is biodiversity

Biodiversity is the term used to describe the entire variety of living organisms which inhabit the earth, from bacteria, viruses and other microorganisms through to fungi, plants and animals. This variety can be stratified into a number of different levels. Three commonly recognised levels of biodiversity are:

1. Genetic diversity: This refers to the sum total of the genetic information contained within the genes of biota. This genetic information differs between individuals of the same species, between different populations of the same species, and between species.
2. Species diversity: refers to the variety of different species of organisms on the earth.
3. Ecosystem diversity: this refers to the different ecosystems and communities of organisms which occur on the earth. An ecosystem can refer to a particular ecosystem, a biotic community, or relate to an ecological process. The incredible variety of organisms present on the earth form an almost infinite variety of communities, which in turn have inter-relationships with other communities and with ecological processes. This level of biodiversity thus includes groups or units of la which may be distinct combinations of climate, geology and vegetation.

Biodiversity has thus become an all encompassing term which relates to the variety of species within and between ecosystems, and the often complex relationships between them. The term biodiversity can also be used to include the evolutionary potential which exists within the genetic material of present life forms.

1.4 Why conserve biodiversity

Conservation of biological diversity or biodiversity is not only worthwhile for its own sake, but is essential to maintain quality of life and indeed essential for continued human survival. We must also remember that once lost, many aspects of biodiversity are irreplaceable.

The most important benefits of biodiversity for humans are often the least obvious, for example the continuous microbial processes which assist in maintaining plant growth, soil fertility and water quality. Knowledge of many of these processes is at best limited, and consequently the effects of interfering with these processes remain largely unknown. More obvious benefits of maintaining biodiversity include for its aesthetic qualities, for recreational benefits, and for the potential scientific and technological benefits.

The protection of biodiversity at all levels is a necessary component of ecologically sustainable development, and is essential for our long term survival. Protection and maintenance of biodiversity concerns everyone, and thus it is the responsibility of all.

1.5 How to conserve biodiversity

One of the major problems with conserving biodiversity is that the majority of species remain unknown and undescribed. It is generally accepted that the majority of the diversity of species is to be found among the invertebrates and lower plants. Very little is known about what may represent thousands of species.

1•5•1 A pragmatic solution

The practical implications of this lack of knowledge are that planning for conservation of biodiversity must be based largely on the protection of entire ecosystems, communities and ecological processes. In the absence of comprehensive and accurate data about species and species communities, environmental regionalisations may be used as a surrogate for assessing and planning the conservation of species and ecosystems. We do not have the luxury of sufficient time to wait until we better understand the patterns and processes around us. In the light of our knowledge, a reasonable insurance policy against loss of biological diversity is the conservation of large areas of ecosystems through bioregional plans of management which incorporate representative protected area networks.

As a result, it is generally accepted that the protected area network is essential for the maintenance of biodiversity. The 1992 World Resources Institute/United Nations Environmental Program Global Biodiversity Strategy states that "an essential feature of any strategy to maintain biodiversity is a system of protected areas, which should be designed and managed to represent and protect the diversity of ecological communities, species and gene pools." This principle is reinforced through international obligations under the South Pacific APIA convention and the International Convention on Biological Diversity ratified recently by Australia.

1•5•2 The limitations of protected areas and government programs

It is not enough to simply identify and declare a protected area. These areas may require extensive, resource intensive and expensive management practices in order to maintain the values for which they were protected originally. There are numerous threats to our biodiversity which need to be better understood and controlled. Difficulties experienced with management of threatening processes can be innate difficulties with the threats themselves or can be due to lack of research into and/or resources to manage the threats in the most practical manner.

Apart from problems with the ongoing management of protected areas, a protected area network alone will not be adequate for the task of conserving biodiversity. The major reasons that protected area networks are not sufficient to maintain biodiversity are:

1. The present protected area systems do not adequately sample ecosystem biodiversity, partly due to the fact that historically, protected areas have been selected on an *ad hoc* basis, usually based on values other than biodiversity.
2. Some ecosystems no longer exist in any form which could be reserved, even if they are able to be contained within protected areas, for example ecosystems which have been severely fragmented by land clearing and other land uses. Other ecosystems may have been badly degraded by these processes.
3. Conservation of biodiversity will continue to be affected by threatening processes going on within and around protected areas. These processes are often beyond the control of the protected area management, and therefore require a bioregional framework to set the planning/management context across the landscape.
4. Continual competition for various land uses ensures that there are limitations on the size and location of protected areas.

There is the need, as far as is possible, to maintain biodiversity and the patterns and processes associated with it in the areas which are populated by humans. This need spans both the physical and psychological aspects of human existence.

1•5•3 An alternate model - public participation at the landscape scale

The conservation of biodiversity requires the involvement of the entire community. It cannot be achieved by government agencies alone. There is a real need for consistency of approaches by governments and for improved information flow between all sectors of the community. It is also important for governments to facilitate greater public involvement in planning, environmental impact assessment and programs to evaluate and protect biological diversity. It is time we recognised the importance programs which could, for example, provide compensation for private landholders in order to conserve key sites, patterns and processes.

1.6 Conservation of biodiversity - the role of protected areas, and what are the gaps

It is widely acknowledged that the present system of protected areas in Australia is inadequate. There are large gaps due to the fact that some ecosystems are not represented at all or are severely under represented. A report of the House of Representatives Standing Committee on Environment, Recreation and the Arts "Biodiversity The Role of Protected Areas" (HORSCERA, January 1993) identified a large number of ecological communities as urgently requiring adequate protection. Many of these communities occur in arid and semi-arid areas.

The gaps in our system of protected areas are the result of historical biases in selection of areas to reserve. We have a tendency with regard to tree dominated communities, of acquiring areas of higher rainfall, high elevation and scenic value and with taller, denser vegetation cover. Within the Murray-Darling Basin this tendency can be seen in that the majority of protected areas are to be found in the south eastern part of the Basin. In terms of the 50 group environmental regionalisation for the Basin (Report 3, Thackway et al, 1993), 43 of the environmental groups presently have less than 10% of their area in protected areas with IUCN categories I and II. Most of these groups occur in the central and western portions of the Basin.

1.7 Options for filling in the gaps in the system of protected areas

It is generally agreed that an ideal protected area system should be both representative and comprehensive, and should thus contain representatives of all ecosystems and species (Austin and Margules, 1984). This is not a readily achievable target. However, a system of protected areas should aim at representing all ecological communities and environments, including viable populations of constituent species. Given the direct link between the modification and destruction of ecosystems and the decline and extinction of species and species assemblages, it would seem that the best way to conserve species and species assemblages is to identify and then conserve intact examples of ecosystems.

The identification of candidate areas to be protected should therefore be made on an ecological basis, rather than setting a target of reserving a certain percentage of total land area. However, in order to have a complete system of protected areas we should not only consider areas which are reserved in the traditional manner of creating national parks, but areas which are protected to varying degrees by alternative means. It is now recognised that reserving large parcels of land for management by government agencies is not the most effective or viable solution to the problem. To establish a national system of representative protected areas in Australia it will be necessary to implement alternative land management options which may involve, for example, encouragement and incentives for private individuals and groups to manage the land in a manner sympathetic with conservation objectives (Thackway and Stevenson, 1989).

The lack of a generally accepted and easily applied measure of representativeness is one of the most significant factors hindering assessments of the effectiveness of the present protected area system. The simplest measure that has been used is the percentage of land reserved under a particular level of protection. These percentage targets have been promoted internationally in a number of fora, most notably the Fourth World Congress on National Parks and Protected Areas in 1992 which endorsed the goal of reserving 10 percent of each major ecosystem by the end of the present decade.

Given that there are gaps in our system of protected areas, there are essentially two options available with respect to future protected area identification. Firstly, the opportunistic approach to protected area acquisition which relies heavily on the opinions of individuals with expert knowledge of the areas in question. Historically, protected areas have been acquired using this approach. An alternative is to investigate flexible iterative (fit) procedures for the identification of new protected areas.'Fit' procedures use biological and/or environmental data in combination with a set of selection rules (i.e. an algorithm) to produce a protected area network.'Fit' procedures scan through a list of candidate sites, choosing the best candidate at each step according to explicit rules. Use of "fit" procedures provides a scientifically defensible method and result. The ability to justify identification and identification of particular areas for reservation cannot be underestimated in the face of increasing competition for various land uses and conflict between land uses. It should be stressed that these procedures are'minimum sets' procedures, and identify the minimum necessary set of objects to achieve the specified goal.

A number of reserve selection procedures based on the principle of complementarity have been developed for indicating the best places for reserves to be located in order to maximise the likelihood that regional biodiversity is represented (e.g. Kirkpatrick, 1983; Margules and Nicholls, 1987; Margules *et a l*, 1988; Nicholls and Margules (in press); Pressey and Nicholls, 1989; Vane -Wright *et al*, 1991).

'Fit' procedures require a clear statement of goals or targets to be conserved in a protected area system. One of the major problems with "fit" procedures is the lack of data, particularly biological records, at the scale necessary for analysis. This is one of the reasons that environmental regionalisations are useful as a surrogate as they provide a representation of biological productivity and hence a basis for conservation assessment. ERIN has adopted environmental groups as an appropriate surrogate for ecosystems, and records of endangered and vulnerable flora and fauna as surrogates for biological diversity in the absence of comprehensive species population and species assemblage data.

1.8 Scope of this report

1. To develop further the conservation assessment of ecosystems and endangered and vulnerable species, undertaken in Phase 2 of this project (see Report 3, Thackway *et al*, 1993). That report identified the gaps in the current system of protected areas.
2. To undertake a series of indicative reserve designs for the Basin and to satisfy the criteria for a system of protected areas which is representative of the major ecosystems and vulnerable and endangered species in the Basin.

2.0 METHODS

2.1 Setting targets for conservation assessment

2•1•1 Goals

The design and evaluation of a comprehensive system of protected areas requires that an explicit goal be identified. The goal identified for Phase 3 was to represent all ecological communities/ecosystems and vulnerable and endangered species in a series of reserve designs. Viable options for reservation of each environmental group were set at 5 and 10% of the area of each group. The IUCN suggested minimum level of representation is 10% of each ecosystem type. The rationale for choosing 5 and 10% of the area of each environmental group is that the environmental groups are representative of ecosystem types. It is accepted that this is not necessarily the most appropriate measure of adequacy of representation, but rather an indicative approach to provide a starting point for discussion.

2•1•2 Data

Once the goals are defined we need to specify data requirements to make decisions, and what criteria will be used to compare and evaluate the merits of different parcels or areas of land.

With this goal in mind the following four datasets were defined as inputs:

1. In the absence of data about populations and viability of populations of constituent species, site data of endangered and vulnerable fauna species were used
2. A map of "naturalness" of vegetation was used to define the availability of natural ecosystems
3. The 50 group regionalisation for the Murray-Darling Basin was used as a surrogate for ecological communities
4. The Public and Aboriginal Lands dataset (Australian Survey and Land Information Group (AUSLIG), 1991) was used to obtain data for nature conservation reserves in Australia

2.2 Designing a protected area network - the application of an explicit methodology

In December 1992, ERIN, through the Director of ANCA, entered into a high level agreement (through the signing of a position statement) with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Wildlife and Ecology, the purpose of which was to establish a framework for mutually beneficial collaborative arrangements between the two organisations.

As part of this much larger collaborative project between ERIN and CSIRO on the role of biological and environmental data in assessing and planning protected areas, a collaborative project was initiated with funding from the ANCA NIE project involving the application of reserve design and identification algorithms. The Murray-Darling Basin was selected as a case study to investigate the application of conservation options algorithms. This procedure described below is an example of one technique, however others are available.

2•2•1 Data collation and preparation

Datasets supplied to the CSIRO are described below.

<u>2.2.1.1 Species based data</u>

Data used included the rare and threatened Australian plants database (ROTAP), and the Murray-Darling Basin endangered and vulnerable database compiled during Phase I of this project (Thackway, 1991). The species included in this database are listed in Report 1. Data used were as supplied to ERIN by the custodians, and are not guaranteed to be free of error by those custodians. A map showing the ROTAP specimen data (gridded to 1/20th of a degree) is shown in Figure 1. The endangered and vulnerable animal data, also gridded, is shown in Figure 2. These site based species data were generalised to fit the 1/20th degree grid, that is approximately $5km^2$.

2.2.1.2 Ecosystem based data

In the absence of more detailed biological data, the 50 group environmental groups were used as a surrogate for ecological communities. The derivation of a 50 group regionalisation is described in Report 2 (Cresswell *et al*, 1993). The 50 group regionalisation comprises 40,184 grid cells (see Figure 3). The 50 group regionalisation was selected for this exercise in order to remain consistent with the approach taken in Phase 2 of the project. Each of the 40,184 grid cells were extracted along with the number of the environmental group in which it occurs.

2.2.1.3 Naturalness of vegetation

A preliminary analysis of the National Oceanographic and Atmospheric Administration (NOAA) satellites advanced very high resolution radiometer (AVHRR) scanner data was used to derive a coverage representing naturalness of vegetation. Figure 4 depicts a map of areas of modified vegetation within the Basin, which were to be excluded from the conservation options analysis. Figure 4 was derived from a map of 24 vegetation classes (Figure 5) for the Basin. Two classes, defined as cropland and sown pasture, were aggregated to form the mask shown in Figure 4. The map of 24 vegetation classes was derived by expert analysis of the spectral signatures in the NOAA AVHRR data for the period January 1991 to January 1992. It should be noted that these classifications are not definitive and are currently being validated and refined. Figure 4 thus presents a map of those grid cells which were excluded on this basis.

2.2.1.4 Protected Areas

The Public and Aboriginal Lands (PAL) dataset were compiled by the Australian Land Survey and Information Group (AUSLIG) and supplied to ERIN in the Public and Aboriginal Lands database (AUSLIG, 1991). This dataset contains boundaries and information on individual land tenure parcels including nature conservation reserves.

2.2.1.5 Aggregation of PAL nature conservation reserves into IUCN protected area categories

The Murray-Darling Basin covers five State and Territory jurisdictions, each with their own nature conservation and land management agencies and different procedures for identifying and managing protected areas. Within the MDB component of the AUSLIG Public and Aboriginal Lands dataset there are 29 different protected area types. These different types are not consistent between the State and Territory jurisdictions.

In order to derive a consistent set of protected area classifications across Australia, ANCA (formerly ANPWS) requested the various State and Territory agencies across Australia to supply an update of the protected area estate and indicate for each protected area the IUCN category which each agency considered best described its function according to IUCN definitions (Hooy and Shaughnessy, 1991). Protected areas which were classified by the State and Territory agencies into IUCN categories I - V have been used in this analysis (see Table 1 for definitions of the IUCN categories). It should be noted that the IUCN protected areas dataset used here is a revised version of that used in Phase 2 Part 2 (Thackway *et al*, 1993).

2•2•2 Data transfer

Data were transmitted to CSIRO Division of Wildlife and Ecology in Canberra as flat ASCII files by electronic mail on the AARNET (Australian Academic Research Network). Each line of information was tagged with a unique pre-defined cell number corresponding with each of the 5km X 5km grid cells. A total of 40,184 cells were delineated within the MDB. The data were recompiled and analysed at the CSIRO DWE using Fortran based algorithms on a Sun workstation running the UNIX operating system.

2•2•3 Conservation options algorithm

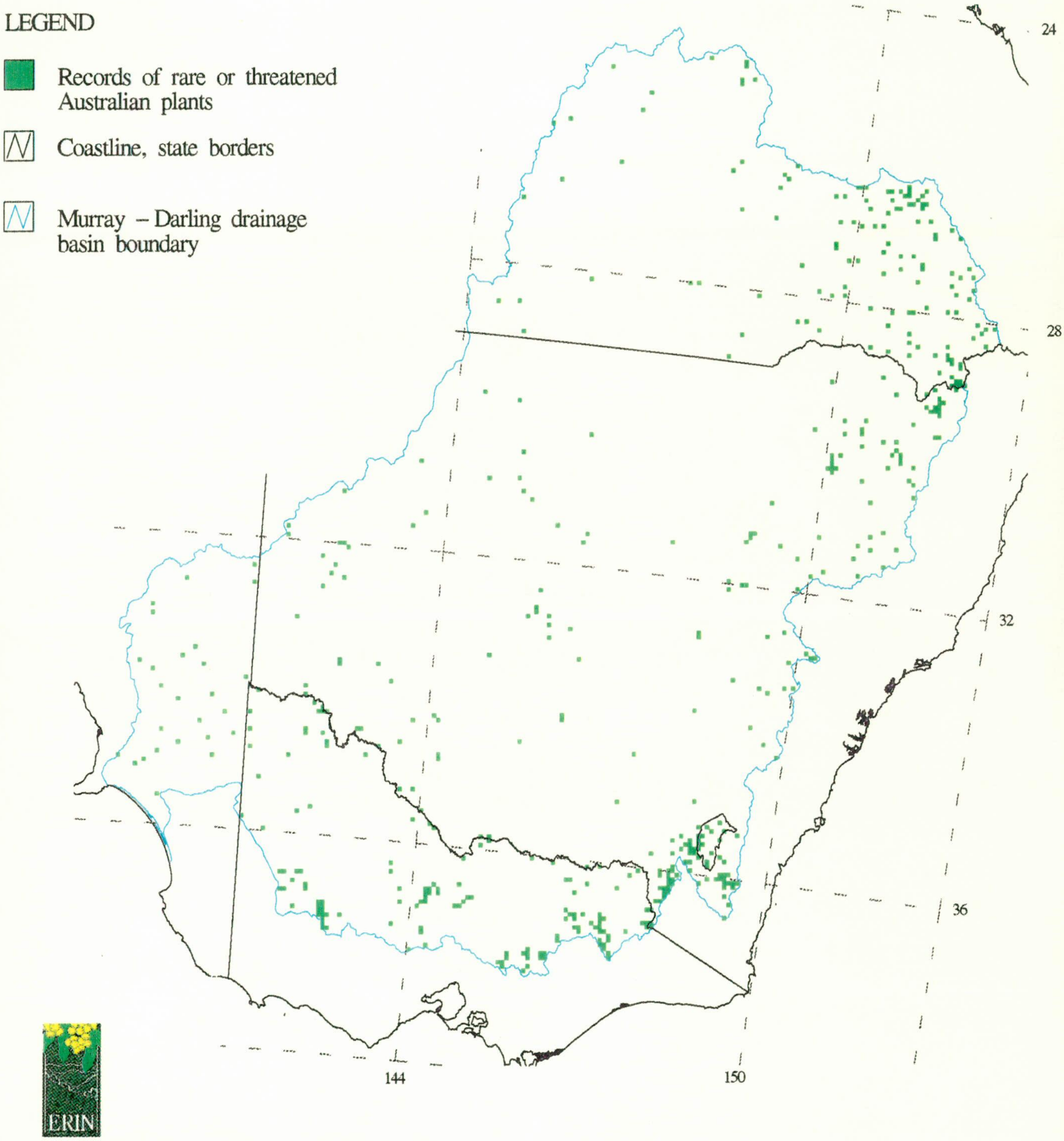
The conservation options algorithm used for this project has been developed by Nick Nicholls and Chris Margules (unpublished, 1993) at the CSIRO Division of Wildlife and Ecology in Canberra. The aim of this algorithm is to identify the minimum number of sites required to represent each ecosystem with a representative sample of biological diversity.

Table 2 presents four options for an indicative reserve design for the MDB. Options 1 and 2 did not include existing protected areas while Options 3 and 4 included existing protected areas in the initial step. Grid cells indicating an obvious seasonal difference in vegetation greenness, suggestive of crops and sown pastures, were excluded from the analysis. This process excluded, for example, larger areas of cropped land in the south eastern half of the Basin (See Figure 4). For options 3 and 4 which included existing protected areas, these were included in the conservation options analysis irrespective of whether the vegetation mask indicated that they included modified vegetation.

The conservation options analysis algorithm was applied to data supplied by ERIN to produce four solutions for a protected area network which would included areas with records of ROTAP species, endangered and vulnerable animals and percentages of each of the 50 environmental groups. These solutions thus represent, in terms of what was identified, the explicit targets which were set at the beginning of the exercise.

The conservation options algorithm proceeded by taking the seed grid cells which included records of ROTAP species or endangered and vulnerable animals or because they occurred within existing protected areas; and then identified an adjacent cell for each seed in turn until it had completed this procedure for all the seeds. The process then begins again, returning to the original seed cell each time which results in identified sets which are "circular" rather than linear. This process is repeated for each option until the identified set contains 5 and 10% of each of the environmental groups. All of the additional cells were identified from the set where existence of "natural" vegetation was indicated from the AVHRR analysis.

Figure 1: Map showing the distribution of records of rare or threatened Australian plants in the Murray - Darling Basin

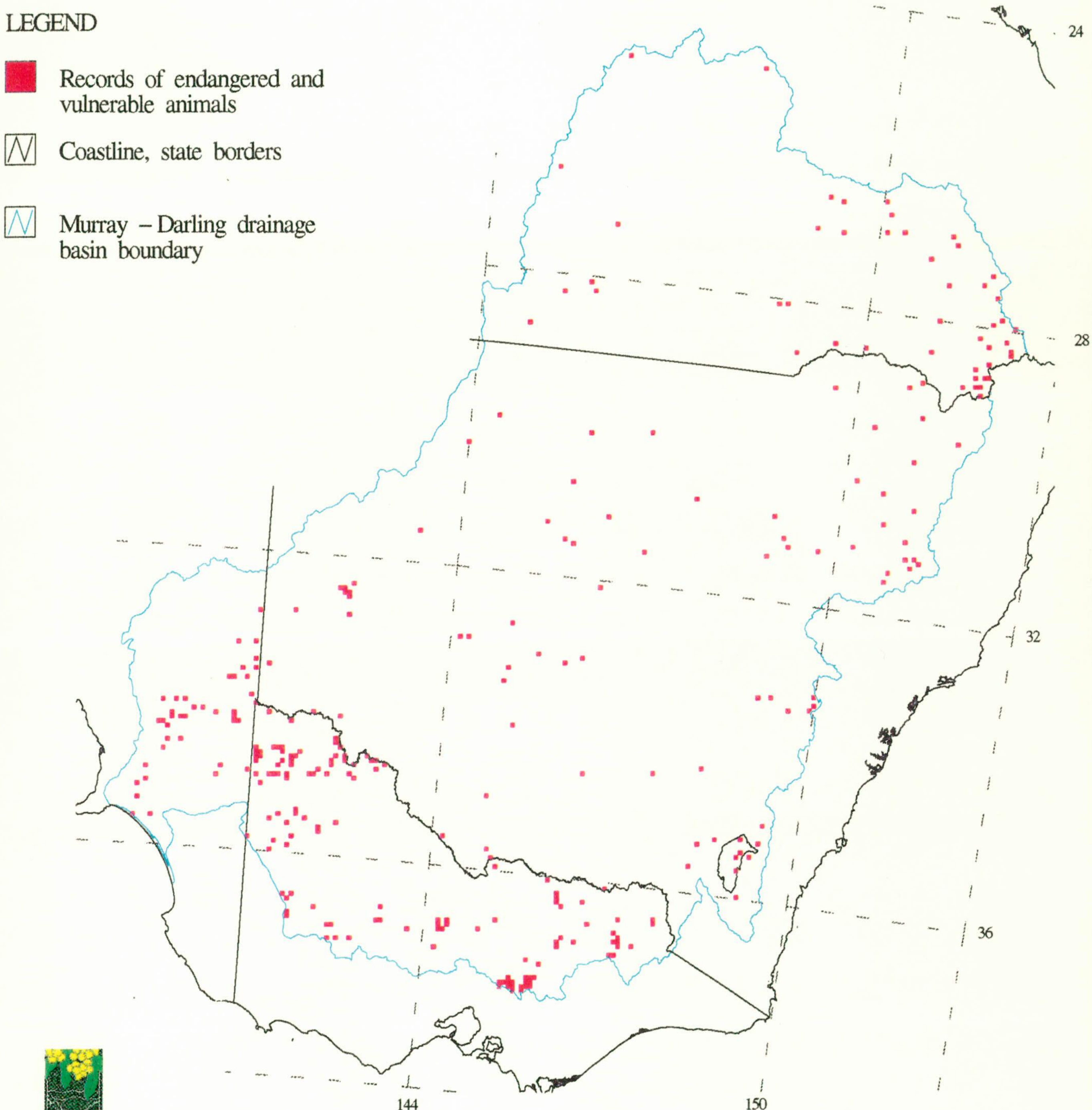


Environmental Resources Information Network October 1993

SCALE 1:9,000,000

Projection: Albers Equal Area
Standard Parallels: 18 and 36 degrees South
Central Meridian: 132 degrees East
Australian Spheroid
SOURCES:
The digital coastline and drainage basin data were purchased from the Australian Surveying and Land Information Group.
Species data were obtained from the Murray Darling Basin Endangered Species Database, ERIN (see Report 1: Thackway(1991)

Figure 2: Map showing the distribution of records of endangered and vulnerable fauna in the Murray - Darling Basin



Environmental Resources Information Network October 1993

SCALE 1:9,000,000

Projection: Albers Equal Area

Standard Parallels: 18 and 36 degrees South

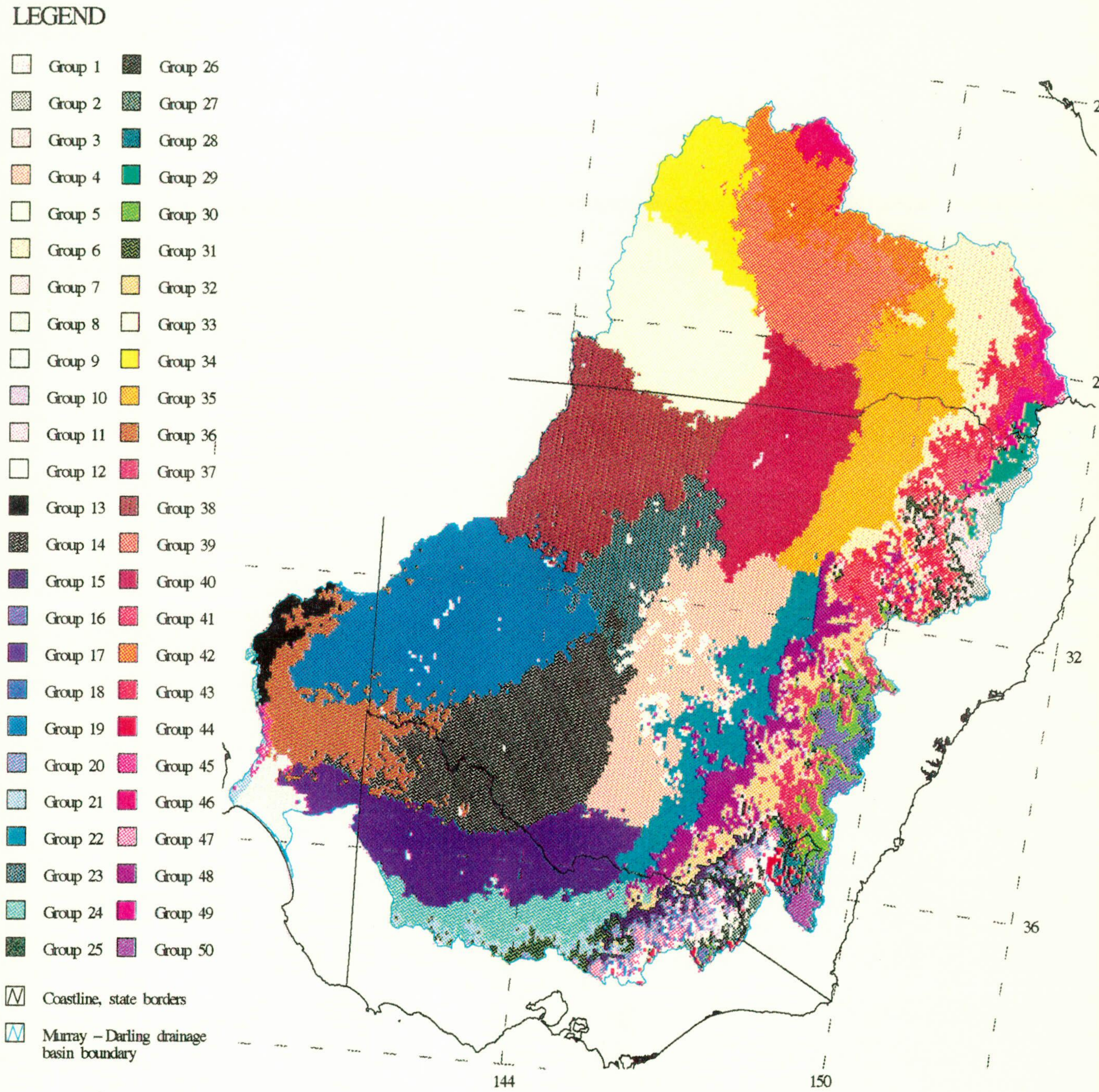
Central Meridian: 132 degrees East

Australian Spheroid

SOURCES:

The digital coastline and drainage basin data were purchased from the Australian Surveying and Land Information Group.
Species data were obtained from the Murray Darling Basin Endangered Species Database, ERIN(see Report 1: Thackway(1991).

Figure 3: Map depicting the 50 group environmental regionalisation for the Murray-Darling Basin.



SCALE 1:10,000,000

Projection: Albers Equal Area

Standard Parallels: 18 and 36 degrees South

Central Meridian: 132 degrees East

Australian Spheroid

SOURCES:

The digital coastline and drainage basin data were purchased from the Australian Surveying and Land Information Group.
Species data were obtained from the Murray Darling Basin Endangered Species Database, ERIN.

ERIN

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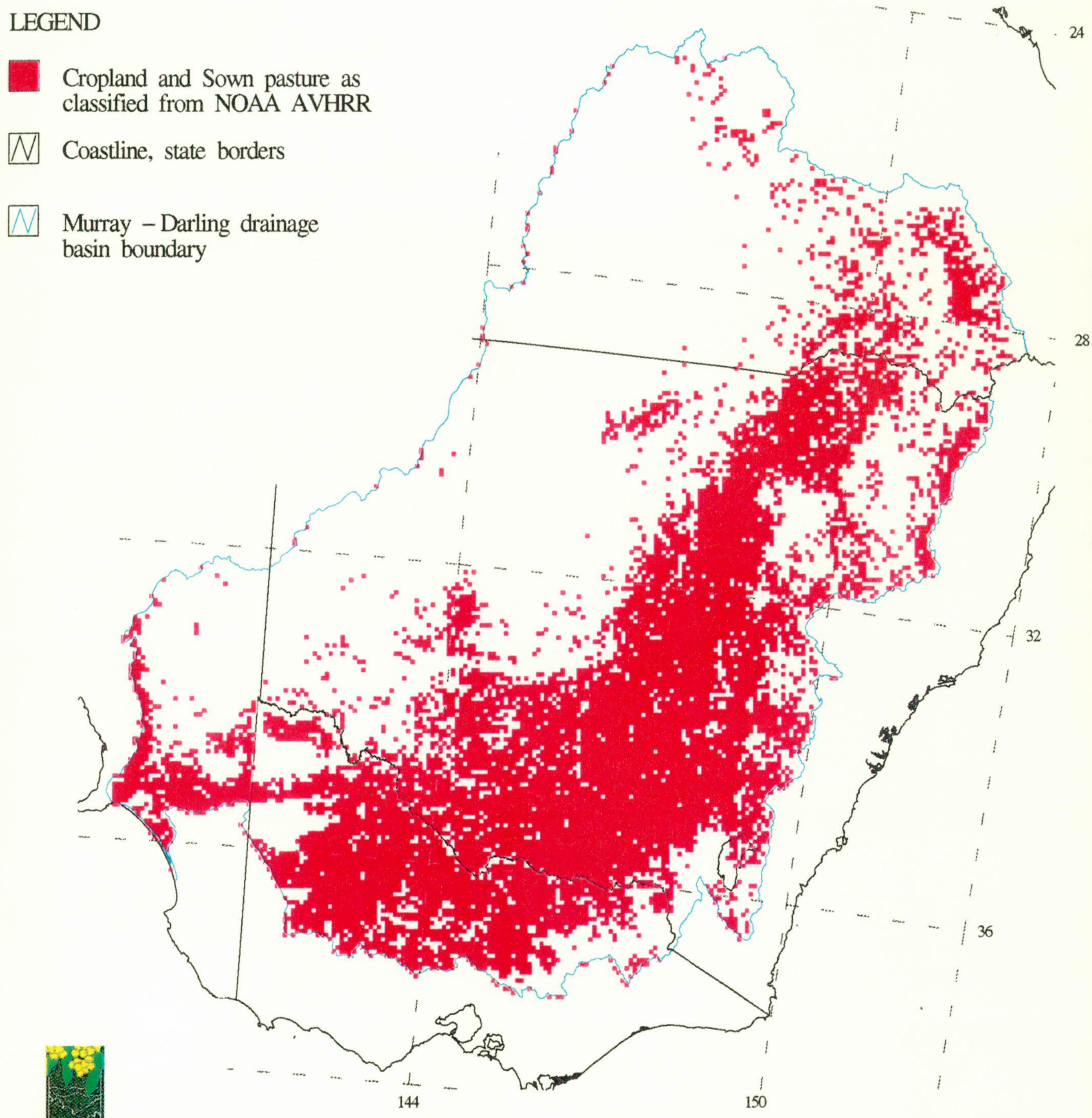
Information Network
October 1993

Figure 4: Map showing areas within Murray - Darling Basin which were excluded from consideration in the conservation options analysis.



ERIN

Environmental Resources Information Network October 1993

SCALE 1:9,000,000

Projection: Albers Equal Area

Standard Parallels: 18 and 36 degrees South

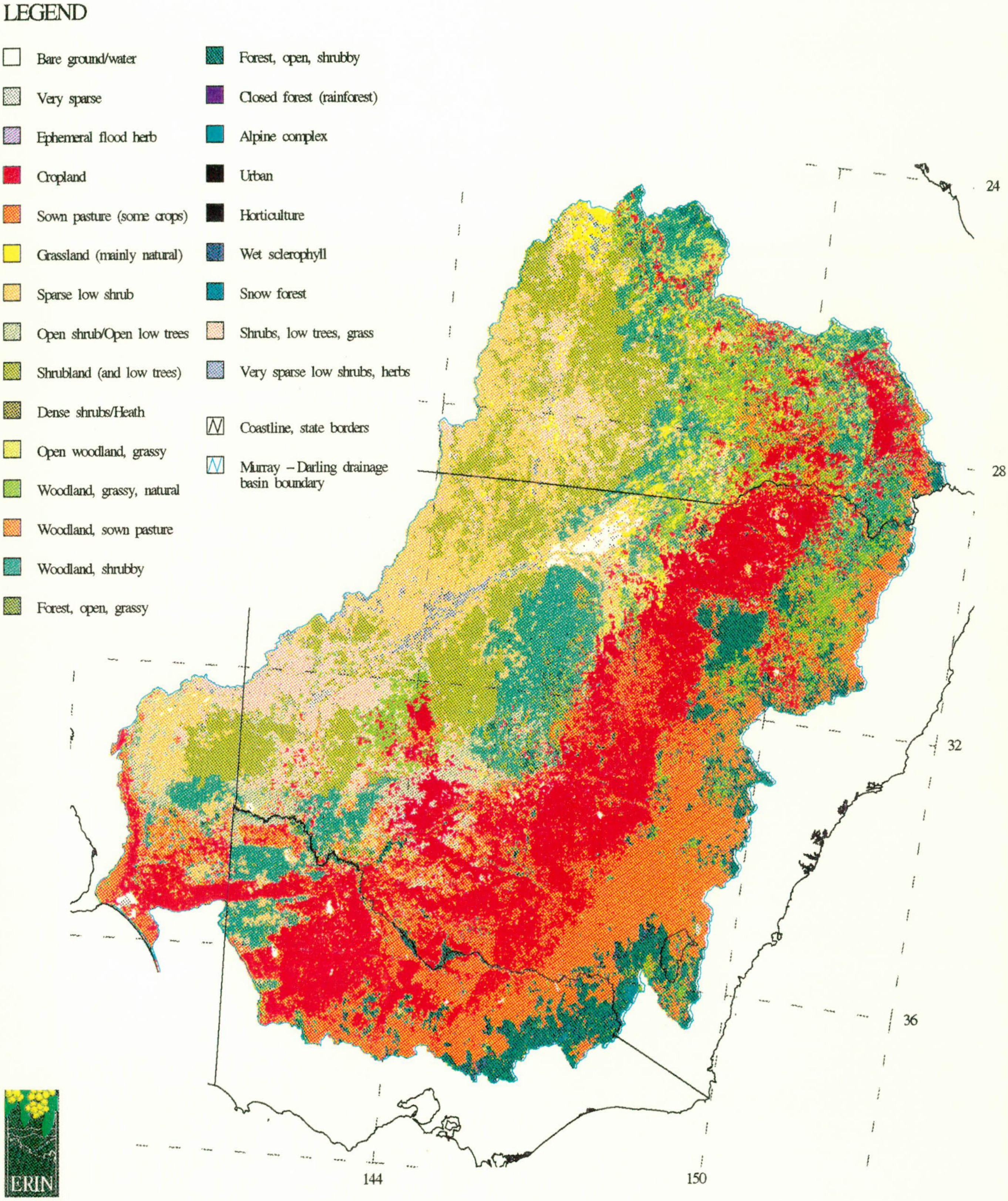
Central Meridian: 132 degrees East

Australian Spheroid

SOURCES:

The digital coastline and drainage basin data were purchased from the Australian Surveying and Land Information Group. Vegetation classes are based on digital NOAA AVHRR satellite data obtained from the Division of Oceanography, Hobart.

Figure 5: Map showing the results of a preliminary analysis of vegetation classes in the Murray - Darling Basin using AVHRR NOAA data



ERIN

Environmental Resources Information Network October 1993

SCALE 1:9,000,000

Projection: Albers Equal Area

Standard Parallels: 18 and 36 degrees South

Central Meridian: 132 degrees East

Australian Spheroid

SOURCES:

The digital coastline and drainage basin digital data were purchased from the Australian Surveying and Land Information
Vegatation classes are based on digital NOAA AVHRR satellite data obtained from the CSIRO Division of Oceanography, Hobart.

Table 1: Protected areas classified by the state and territory agencies into IUCN categories I - V have been used in this analysis

Areas Recognised/Designated under International Instruments:

I	Scientific Reserves Wilderness Areas eg Nature reserves, Ecological reserves
II	National Parks and Equivalent Reserves eg National, State, Provincial Parks Native/Tribal/Customary Ownership
III	National Monuments eg Geological Phenomena, Archeological Sites
IV	Habitat and Wildlife Management Areas eg Wetlands, Refuges, Sanctuaries
V	Protected Land/Sea Scapes eg Landscapes, Marine Areas, Scenic Rivers, Waterways, Recreational Areas, Trails, Protected Forests

IUCN: The International Union for the Conservation of Nature

Table 2: The four conservation option analyses and the steps involved.

Conservation options disregarding existing protected areas:
Option 1: 5% level and Option 2: 10% level

Option 1: Includes records of ROTAP species, endangered and vulnerable animals plus up to 5% of each of the 50 environmental groups.

Option 2: Includes records of ROTAP species, endangered and vulnerable animals plus up to 10% of each of the 50 environmental groups.

Step 1: The AVHRR data was used to give a list of grid cells thought to contain, as nearly as possible, "natural" vegetation. This provided a list cells which were potentially available for identification.

Step 2: All cells containing records of rare or threatened Australian plants or endangered and vulnerable animals which were in the available set were identified as seeds for the identification process.

Step 3: The algorithm then added to the seeds sequentially from the cells containing 'natural' vegetation (as determined by AVHRR) until the identified set contained 5% and then 10% of each of the 50 environmental groups.

Conservation options including existing protected areas:
Option 3: 5% level and Option 4: 10% level

Option 3: Includes existing protected areas, records of ROTAP species, endangered and vulnerable animals plus up to 5% of each of the 50 environmental groups.

Option 4: Includes existing protected areas, records of ROTAP species, endangered and vulnerable animals plus up to 10% of each of the 50 environmental groups.

Step 1: The AVHRR data was used to give a list of grid cells thought to contain, as nearly as possible, "natural" vegetation. This provided a list cells which were potentially available for identification.

Step 2: All cells containing records of rare or threatened Australian plants or endangered and vulnerable animals which were in the available set were identified as seeds for the identification process.

Step 3: All cells which were within the included set of nature conservation reserves were selected as seeds, regardless of whether they were in the AVHRR selected set or not.

Step 4: The algorithm then added to the seeds sequentially from the cells containing 'natural' vegetation (as determined by AVHRR) until the identified set contained 5% and then 10% of each of the 50 environmental groups.

3.0 RESULTS

3.1 Results of the conservation options exercise

The four conservation options solutions have been mapped in Figures 6 and 7 as combinations of solutions 1 and 2, and 3 and 4 respectively:

Solution 1: Records of ROTAP species, endangered and vulnerable animals plus up to 5% of each of the 50 environmental groups.

Solution 2: Records of ROTAP species, endangered and vulnerable animals plus up to 10% of each of the 50 environmental groups.

Solution 3: Existing protected areas, records of ROTAP species, endangered and vulnerable animals plus up to 5% of each of the 50 environmental groups.

Solution 4: Existing protected areas, records of ROTAP species, endangered and vulnerable animals plus up to 10% of each of the 50 environmental groups.

3•1•1 Level of representation of the 50 environmental groups

Table 3 lists the area identified from each group for reservation to meet the nominated percentage level for each of the four solutions. The total area of each group is listed, as is the area of each group which remained for identification excluding the modified vegetation (the available area). It can be seen from this table that in the case of some groups only a small percentage of the total area of the group was available for identification. For example group 22 has a total area of 37775 km^2, of which 1684 km^2 were available for identification. This means that less than 5 percent of the area of this group was available, as most of the environmental group was classified as cropland or sown pasture, and therefore was excluded from consideration.

The identification of grid cells to make the identified area up to 5 or 10% was made from the available area, so for each of the four solutions the algorithm has ensured that at least 5 or 10% (depending on which solution you consider) of the **available** area has been identified.

Two of the 50 environmental groups, 9 and 45, contained no records of vulnerable and endangered species or existing protected areas, and hence no seed grid cells. In addition, most of Group 45 is excluded because it is considered modified vegetation. In both cases the algorithm chose one cell per group to represent each group at the nominated percentage area, that is one 5 X 5 km grid cell represented at least 10% of the area of the group. These single cells represent the first cell encountered by the algorithm. In the case of some of the other groups the level of species records and/or protected areas within the group is such that the result of including these cells as seeds is that the level of representation exceeds the 5 or 10% area level (for example Groups 1, 3 and 18).

3•1•2 Comparing the results with and without existing protected areas

Table 4 presents the relative difference between the 5% and 10% levels for solutions 1 and 2, and solutions 3 and 4. The differences between solutions 1 and 2, and 3 and 4, have been placed into 3 classes: nil change, medium change or doubling depending on the difference in area required to move from 5% to 10% reservation of the area of each group.

Table 4 indicates that there are 8 environmental groups which show a lesser difference between the 5 and 10% solutions when the existing protected areas are included (asterisked). This indicates that for these groups the inclusion of the protected areas as seeds brought them closer to the 10% area threshold and less additional area was then required to be identified to make them up to 10%. For example, groups 14 and 46 required a doubling of the identified area between solutions 1 and 2 but no change in area between solutions 3 and 4. Such a significant decrease in the relative differences suggests that the protected areas were not coinciding with the records of ROTAPs and endangered and vulnerable animals, as addition of the protected areas was resulting in more area being identified initially as seeds.

Groups for which there was nil change between solutions 1 and 2 (28 groups) in all cases also required nil change between solutions 3 and 4 as obviously there were enough endangered and vulnerable species and ROTAPs to account for at least 10% of the area of the group. Generally these were small groups, or groups which were effectively small for the purposes of this analysis due to consisting largely of cropped land and/ or sown pasture. Groups which required an increase in identified area to move from 5 to 10% representation of the group obviously did not contain sufficient seed grid cells to encompass 10% of the area of the group. In general, groups in this category were the larger groups.

Figures 8 and 9 present graphically the data shown in Table 3. Areas encompassed by the seed grid cells (ROTAPs and endangered and vulnerable animals plus existing protected areas for solutions 3 and 4) are graphed along with areas encompassed by the various solutions for each of the 50 environmental groups. Where there is a large difference in height between the peaks for solution 1 and 2 (Figure 8) or solutions 3 and 4 (Figure 9) there has been a large increase in the area required to move from the 5 to the 10% level of representation. It is also obvious on these graphs where the lines are coinciding that the actual level of representation of the group is being driven by the seed cells.

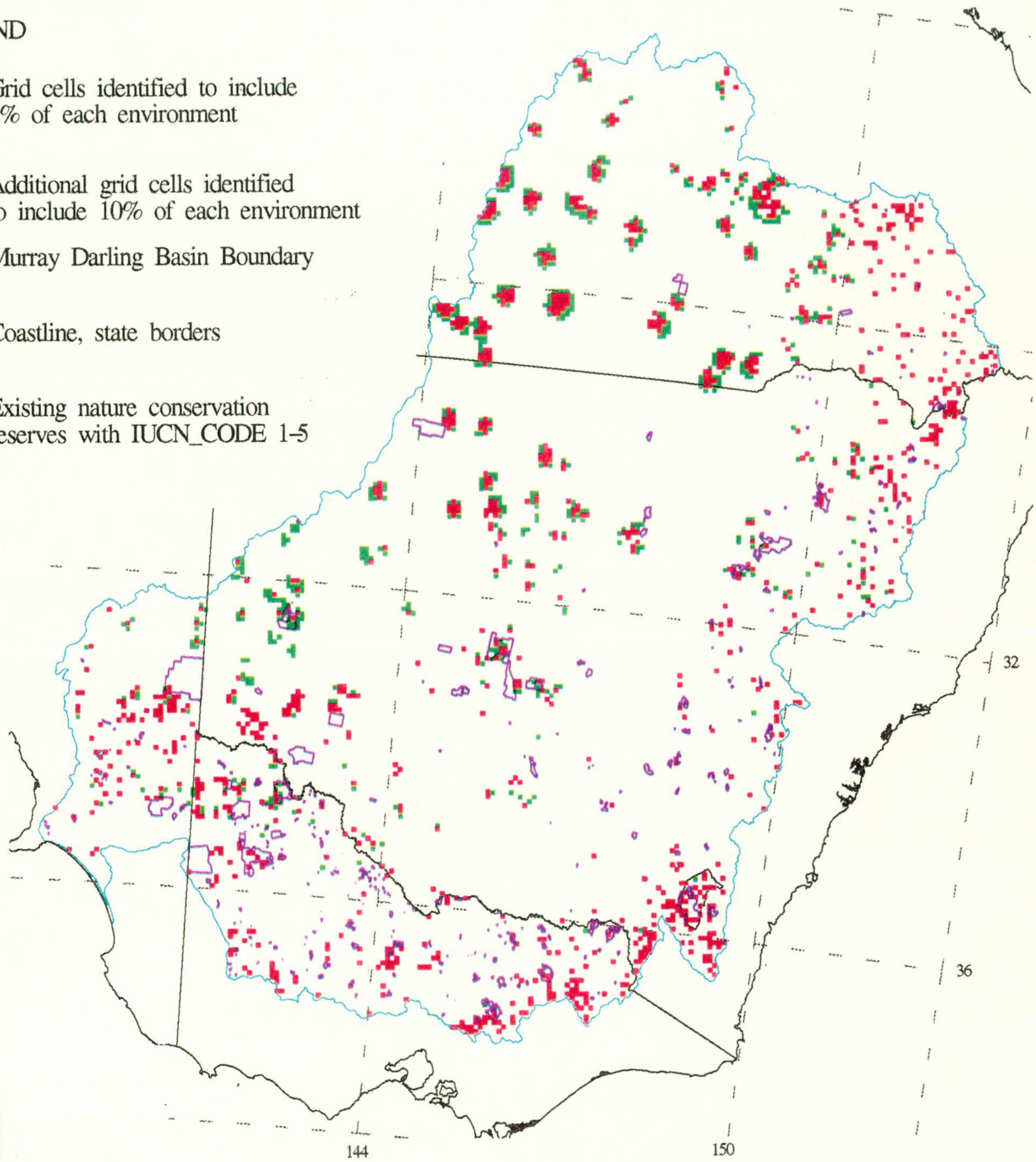
3•1•3 Total area required for each solution

The approximate total area of land involved in each of the four solutions obtained are presented in Table 5. The areas are given in hectares, and also as a percentage of the total area of the Murray-Darling Basin. The maximum area involved is for the solution which was obtained by initial inclusion of existing protected areas and which contains 10% of each of the 50 environmental groups, and represents approximately 8.4% of the total area of the Basin. Both of the solutions which include the protected areas require more land than the corresponding solutions without the protected areas.

Figure 6: **Map showing the results of using the conservation options algorithm to identify areas with records of rare or threatened Australian plants and endangered and vulnerable fauna species in addition to 5% and 10% of the area of each of the 50 environmental regions.**

LEGEND

- Grid cells identified to include 5% of each environment
- Additional grid cells identified to include 10% of each environment
- Murray Darling Basin Boundary
- Coastline, state borders
- Existing nature conservation reserves with IUCN_CODE 1-5



Environmental Resources Information Network October 1993

SCALE 1:9,000,000

Projection: Albers Equal Area

Standard Parallels: 18 and 36 degrees South

Central Meridian: 132 degrees East

Australian Spheroid

SOURCES:

The digital coastline and drainage basin data were purchased from the Australian Surveying and Land Information Group. The Protected Areas digital data were purchased from the Australian Surveying and Land Information Group. Classification of Protected Areas into IUCN Categories was developed by ERIN prior to the IUCN revisions supplied to ANPWS by state Nature Conservation Agencies for inclusion into Hooy and Shaughnessy, 1991, "Terrestrial and Marine Protected Areas in Australia."

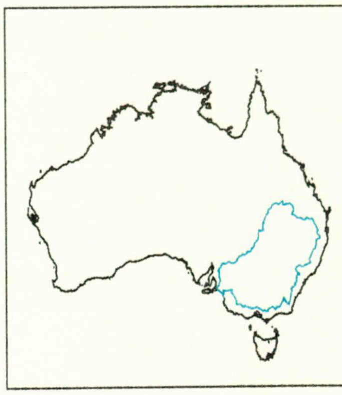
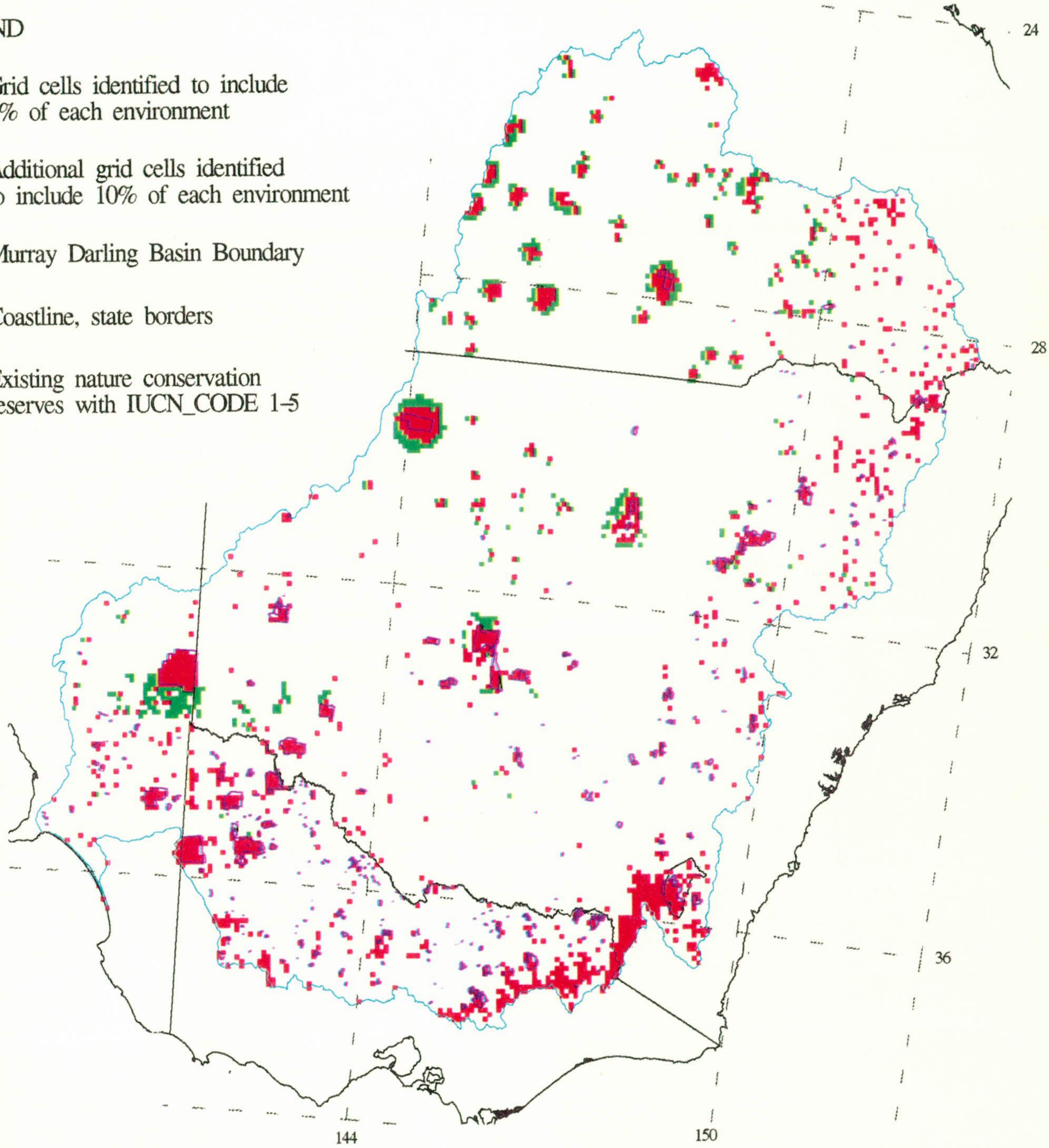


Figure 7: **Map showing the results of using the conservation options algorithm to identify existing nature conservation reserves, areas with records of rare or threatened Australian plants and endangered and vulnerable fauna species in addition to 5% and 10% of the area of each the 50 environmental regions.**

LEGEND

- Grid cells identified to include 5% of each environment
- Additional grid cells identified to include 10% of each environment
- Murray Darling Basin Boundary
- Coastline, state borders
- Existing nature conservation reserves with IUCN_CODE 1-5



Environmental Resources Information Network October 1993

SCALE 1:9,000,000

Projection: Albers Equal Area

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Central Meridian: 132 degrees East

Australian Spheroid

SOURCES:

The digital coastline and drainage basin data were purchased from the Australian Surveying and Land Information Group.
The Protected Areas digital data were purchased from the Australian Surveying and Land Information Group.
Classification of Protected Areas into IUCN Categories was taken from the revisions supplied to ANPWS by the States and Territories (Hooy and Shaughnessy, (eds) 1991.Terrestrial and Marine Protected Areas in Australia."

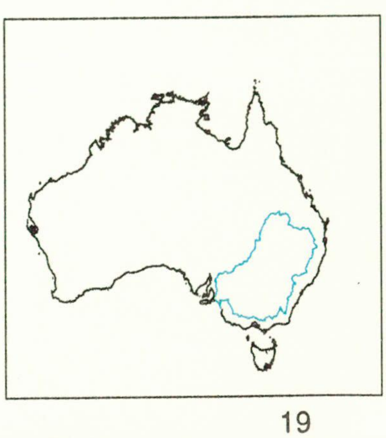

Figure 8: Area of grid cells containing a) ROTAP and endangered and vulnerable species records, b) Area of solution 1, and c) Area of solution 2 for each of the 50 environmental groups.

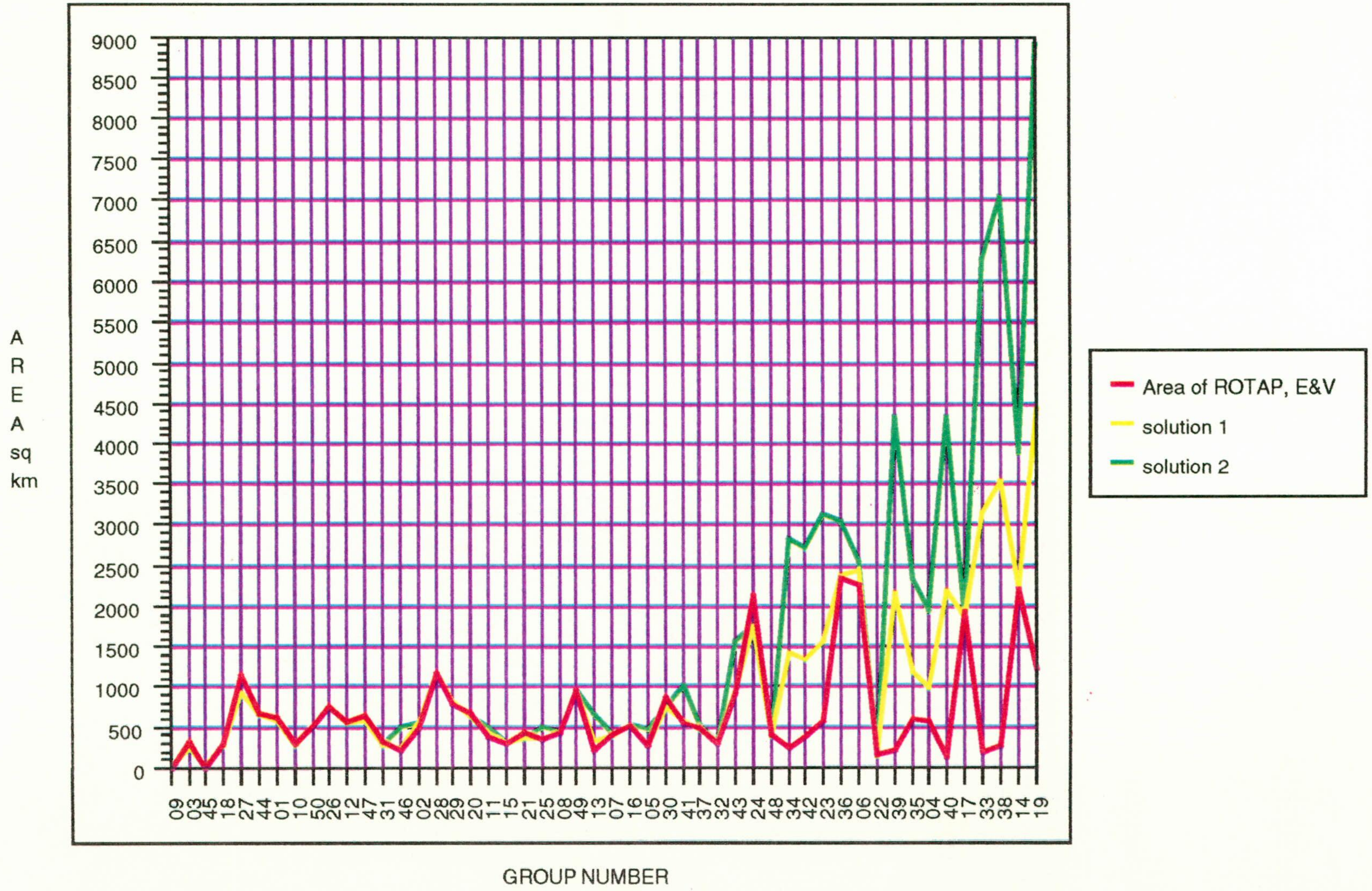

Figure 9: Area of grid cells containing a) ROTAP and endangered and vulnerable species records, b) Area of solution3 and c) Area of solution 4 for each of the 50 environmental groups.

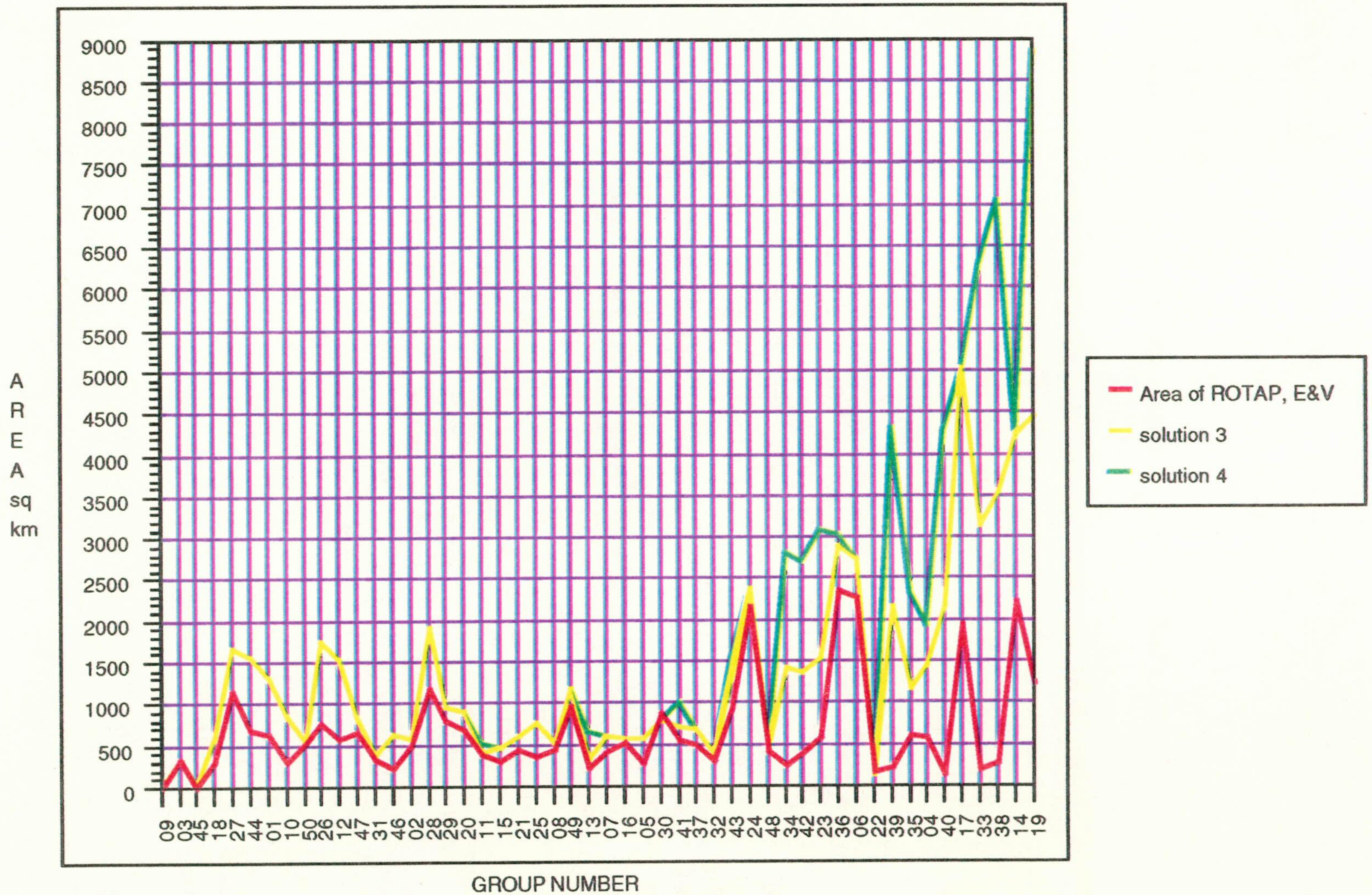

Table 3: Table of four solutions to the conservation option analyses: percentage of available area and area in kilometers reserved of the 50 environmental groups

50 Grp	5% nil_PA sol1_km	10% nil_PA sol2_km	5% with_PA sol3_km	10% with_PA sol4_km	ROTAP & E&Vs	Area of PAs	Total area by group	Extant nat area	Extant % left
01	576	576	1320	1320	625	1050	2265	2214	97.75
02	536	536	562	562	500	75	5129	2060	40.16
03	247	247	322	322	325	300	421	421	100.00
04	981	1938	1451	1940	575	900	56911	20594	36.19
05	285	466	568	568	275	350	9819	5132	52.27
06	2438	2544	2729	2729	2275	300	37617	29840	79.32
07	391	415	595	595	400	300	8207	4498	54.81
08	429	429	529	529	450	125	7562	1668	22.05
09	25	25	25	25	0	0	303	127	41.80
10	276	276	850	850	300	725	2319	1871	80.71
11	400	506	400	506	375	0	6460	5504	85.21
12	543	543	1517	1517	575	1100	3856	3536	91.70
13	336	646	335	646	225	0	7728	6694	86.63
14	2215	3890	4235	4235	2225	2225	78762	45822	58.18
15	300	300	473	473	300	200	7003	1196	17.08
16	510	510	586	586	525	100	8557	4070	47.56
17	1857	1857	5027	5027	1950	3575	61406	13751	22.39
18	272	272	594	594	300	450	1584	1559	98.43
19	4435	8898	4456	8852	1225	3150	94793	94635	99.83
20	629	629	902	902	675	400	6180	3887	62.90
21	346	346	593	593	425	375	7093	1385	19.53
22	127	152	127	152	175	0	37775	1684	4.46
23	1554	3111	1543	3094	575	500	31307	31307	100.00
24	1759	1759	2380	2380	2150	975	23093	5300	22.95
25	367	496	752	752	350	375	7180	5233	72.88
26	761	761	1741	1741	775	1225	3613	3310	91.59
27	944	944	1665	1665	1150	1600	2037	1988	97.57
28	1178	1178	1909	1909	1175	1300	5340	4085	76.50
29	810	810	945	945	800	125	5650	4115	72.83
30	738	738	789	789	875	75	11419	5659	49.56
31	274	274	372	372	325	225	4840	1311	27.09
32	307	307	385	385	300	175	19174	3296	17.19
33	3150	6273	3150	6273	200	0	62641	62230	99.34
34	1413	2826	1413	2826	250	75	28353	28159	99.31
35	1168	2337	1167	2335	600	75	55316	31254	56.50
36	2373	3033	2906	3032	2350	700	36363	34691	95.40
37	464	515	670	670	500	225	15676	5692	36.31
38	3539	7050	3533	7041	275	625	71700	71297	99.44
39	2174	4320	2165	4304	225	225	44150	44150	100.00
40	2184	4342	2164	4302	125	150	59061	48114	81.46
41	586	1010	718	1008	550	150	12073	11678	96.73
42	1352	2705	1352	2705	375	0	31271	30606	97.87
43	968	1555	1339	1550	925	375	21936	19659	89.62
44	649	649	1550	1550	675	1400	2121	1873	88.33
45	26	26	26	26	0	0	1475	128	8.66
46	251	503	615	615	225	400	4913	4829	98.30
47	572	572	819	819	650	300	4182	3784	90.48
48	390	390	468	468	400	100	26694	3603	13.50
49	953	953	1175	1175	950	250	7620	6612	86.77
50	525	525	550	550	525	50	2974	2149	72.28
							1058684	671580	

Definitions: Grp = Number of the environmental group, Sol = Conservation Options Solution,
km = kilometre square, PA = protected areas, nat = Natural vegetation,
ROTAP = Rare and Threatened Australian Plants,
E&Vs = Endangered and vulnerable vertebrates in the MDB.

Table 4: Differences between solutions 1 and 2 and solutions 3 and 4

Group	Solutions 1 & 2 Difference from 5% - 10%	Solutions 3 & 4 Difference from 5% - 10%	Differences from Sols 1&2 to sols 3&4
1	N	N	
2	N	N	
3	N	N	
4	D	M	*
5	M	N	*
6	M	N	*
7	N	N	
8	N	N	
9	N	N	
10	N	N	
11	M	M	
12	N	N	
13	M	M	
14	D	N	*
15	N	N	
16	N	N	
17	N	N	
18	N	N	
19	D	D	
20	N	N	
21	N	N	
22	M	M	
23	D	D	
24	N	N	
25	M	N	*
26	N	N	
27	N	N	
28	N	N	
29	N	N	
30	N	N	
31	N	N	
32	N	N	
33	D	D	
34	D	D	
35	D	D	
36	M	M	*
37	M	N	*
38	D	D	
39	D	D	
40	D	D	
41	M	M	
42	D	D	
43	M	M	
44	N	N	
45	N	N	
46	D	N	*
47	N	N	
48	N	N	
49	N	N	
50	N	N	

Key: N = Nil change in the area required between 5% and 10% solutions
M = Medium change in the area required between 5% and 10% solutions
D = Doubling in the area required between 5% and 10% solutions
* = Decrease in the area required from Solutions 1&2 to solutions 3&4

Data used to create this table were derived from Table 3.

Table 5: : Area of the Murray-Darling Basin Encompassed in the four solutions obtained from the conservation options exercise

Solution No.	Area (Ha)	Percentage Area of MDB
1	4957856	4.7
2	7595408	7.2
3	6644995	6.3
4	8879499	8.4

Solution 1: Includes records of ROTAP species, endangered and vulnerable animals plus 5% of each of the 50 environmental groups.

Solution 2: Includes records of ROTAP species, endangered and vulnerable animals plus 10% of each of the 50 environmental groups.

Solution 3: Includes existing protected areas, records of ROTAP species, endangered and vulnerable animals plus 5% of each of the 50 environmental groups.

Solution 4: Includes existing protected areas, records of ROTAP species, endangered and vulnerable animals plus 10% of each of the 50 environmental groups.

4.0 DISCUSSION

4.1 The conservation options exercise for the Murray-Darling Basin

4•1•1 Overall results of the exercise

Consistent with the complementary nature of this project concerning the identification of gaps in ecosystems and vulnerable and endangered species within protected areas, the conservation options algorithm proceeded initially to identify all sites for species and then identified additional sites within each environmental group up to the thresholds of 5 and 10% respectively. Hence the rationale for this approach weights vulnerable and endangered species more highly than ecosystems. In most instances the actual levels were primarily determined by the numbers of seed grid cells, that is the number of ROTAPs, endangered and vulnerable fauna and protected areas in each of the groups.

The vulnerable and endangered species records compiled in Phase I and environmental regionalisations developed in Phase II have been used as a framework for identification of candidate protected area networks

Environmental groups were chosen as the principal units for conservation assessment for the MDB project. In the absence of detailed biological data it is possible to use such groups to assess the adequacy of and draw conclusions about the effectiveness of the protected area network with respect to protecting these groups. The assumption underlying the identification of percentage area within each environmental group is that the environmental groups are representative of ecosystems. This project has adopted the 10% level of representation of each ecosystem recommended by IUCN, as well as investigating a 5% level for the purposes of completeness.

The algorithm has identified a number of relatively large areas in the Western part of the Basin, particularly the north western group. This reflects the present lack of reservation of the environments which occur in the arid and semi-arid areas. With respect to the identified areas in southern Queensland, the coverage of protected areas used for this analysis is known to be out of date, particularly in Queensland, where the National Park Estate is in the process of being doubled. A number of acquisitions for the purpose of creating new protected areas have been carried out in this area, which coincides with the Mulga Lands biogeographic region (Stanton and Morgan, 1977).

The results fully support the conclusions of previous analyses which indicate that for many areas of the Basin the present protected area network is inadequate in representing the range of environments found there. This conclusion applies more to the Westem portion of the Basin and less to the south-eastern groups.

4•1•2 Level of representation of the 50 environmental groups in the solutions

Analysis of the results presented in Table 3 indicates that not all groups appear to have been reserved at the minimum required levels of 5 and 10 percent, for example groups 35 and 42. The reason for this apparent discrepancy is that the algorithm was identifying proportions of grid cells which were approximately 5km^2 rather than percentage areas. The algorithm identified a number of grid cells until the proportion reserved was 5 or 10 percent, however, because the grid cell size actually differs slightly over the extent of the Basin, when the figures are converted to actual areas the results may vary slightly as has happened with some groups. This effect tends to be more marked with larger groups within which the actual area of the grid cells would have more variation.

Groups 9 and 45 contained no biological records or existing protected areas, and therefore no seed grid cells. For each of these groups, however, it was only necessary for the algorithm to choose a single grid cell to satisfy the minimum requirement, and the first grid cell encountered was chosen. Both of these groups consist of only a very small number of grid cells and are located close to the south-western boundary of the Basin. As such, these groups are probably more representative of environmental groups which occur outside the Basin boundary.

4•1•3 Comparison of the results with and without existing protected areas

Figures 6 and 7 show that the two sets of solutions are remarkably similar, because they are based on the inclusion of grid cells containing biological records. The most obvious differences between the two sets of solutions involve several relatively large protected areas occurring in the western portion of the Basin which are not included in solutions 1 and 2 which are based on biological records only. Both the solutions which included the protected areas (3 and 4) require more area to be reserved than their corresponding solutions (1 and 2). The most obvious reason for this is that the protected areas do not coincide with the records of ROTAPs and endangered and vulnerable species held in the database. This is not meant to imply that these species do not occur within these areas.

This point leads us to reconsider what the aim of a protected area network is. If the aim of having a protected area network is to conserve biodiversity in the most efficient possible way, then the inclusion of existing protected areas can result in a loss in the efficiency of this process. Protected areas as they now exist have often been chosen for reservation for aesthetic reasons or for other reasons which may have little to do with the contribution of the area to the maintenance of biodiversity.

To further illustrate this point, environmental groups for which there was nil change between solutions 1 and 2 (28 groups) in all cases also required nil change between solutions 3 and 4. This occurs because there were enough records of endangered and vulnerable species and ROTAPs from the initial stage to account for 10% of the area of the group. Generally these were small groups, or groups which were effectively small because areas of extant natural vegetation were decreased due to much of their area being cropped land and/or sown pasture, and therefore unavailable for selection even if identified by the algorithm. If one considers for the purposes of this exercise that the species records are in some way representative of biodiversity, then the addition of the existing protected areas to the solution then appears to add nothing in the way of increased protection for biodiversity.

There are, of course, major limitations on this conclusion given the incomplete nature of the data, and in particular the species data. One could not claim species records alone to be representative of biodiversity. This exercise, does, however, illustrate the point that the existing system of reserves may not only be inadequate to preserve biodiversity, but that in some cases we may be maintaining large areas of land which contribute very little to the conservation of biological diversity. It must be stressed however, that due to the incomplete nature of the data this point is made with reservations. For example, there has been no consideration of invertebrate, microbiological or genetic diversity, nor would this be possible at present.

4•1•4 How feasible is the result in terms of implementation?

The fact that the algorithm identifies clusters of cells wherever possible, and particularly the ability to "add on" to existing protected areas, has important practical implications for management. Large clustered areas are much more likely to be viable and are more practical to manage than small widely scattered areas. This is particularly true in the case of existing protected areas. Increasing the representativeness of the existing protected area system by adding on to existing protected areas, would seem to be the most practical solution as in many cases the management infrastructure and experience is already in place.

These algorithms do not necessarily find the optimum solution, however, and it should be stressed that the solutions presented here are only examples which would change if any step of the algorithm was altered. For example, step 1 allows the inclusion of initially identified sites which may be of particular significance. One of the solutions presented here was derived by initial inclusion of existing nature conservation protected areas with IUCN codes I - IV. It is possible to include any other set of sites which are considered worthy of inclusion into the final identified set. The availability of additional data introduces a greater level of flexibility into the methodology.

4.2 Explicit protected area identification techniques

4•2•1 Advantages of explicit reserve identification techniques

The results are illustrative of what it is possible to achieve by applying a particular conservation option algorithm to a particular set of data. This result represents only one of a number of possible solutions. In fact, the major advantage of using these "fit" procedures is that they are explicit, efficient and flexible. (Nicholls and Margules, 1992). They are explicit in that each step of the procedure can be traced and the derivation of the result can be understood by others. Efficiency is achieved by the identification of potential sites in a step wise manner such that at each step the new area is the most complementary site to existing areas or previous choices in terms of representing features not included elsewhere. This provides for the most efficient representation of natural features, ecosystems, habitats or species. This approach can be more difficult to justify on ecological grounds as the minimum may not be sufficient to maintain the species or the ecological integrity of the group. From a practical viewpoint, however, efficiency and the ability to identify associated minimum sets will be a necessity for the foreseeable future.

The concept of flexibility, when applied to these algorithms, recognises that within a bioregion, several different combinations of sites may be available to collectively form a representative protected area network. The larger the number of alternative networks available, the more likely the planner is to find one that is representative, maximises values of design/area suitability; maximises linkages or contiguity (and therefore viability; and.or minimises costs; as well as reflects the wishes and aspirations of the human communities within the bioregion. A further level of flexibility is possible as the algorithm can be altered depending on the available information and the desired result, for example steps can be altered to choose the largest or smallest site where there is a choice. In addition, as the databases underneath the algorithms are updated and more information becomes available the algorithms can be rerun. This will obviously affect the results obtained, and different solutions can be compared.

4•2•2 Limitations of explicit protected area identification techniques

One criticism of conservation options algorithms is that they result in "spotty" solutions (Bedward *et al*, 1992). This occurs because species and environments have an unequal distribution across the landscape, with the result that the minimum set of sites may be small and widely dispersed. The algorithm used in this exercise aims to overcome this problem by including an early decision to choose the nearest site if there is a choice between sites, and minimises the risk of order dependency by including more rules for choosing between equally qualified sites (Nicholls and Margules, 1992). This can be seen in the solutions in that to a large extent the identified grid cells are clustered in groups, and in the case where the existing protected areas were included, identified cells tend to be clustered around the boundaries of the protected area.

The major limitation restricting application of explicit protected area identification techniques remains the requirement for data at different scales. Techniques such as that demonstrated in this report are essentially scaleless, and could be applied at finer scales than that used here if the supporting data was available. What is necessary is to have a consistent level of data for the entire region under consideration, as the technique is based on complementarity (or efficiency) and comparison, i.e. in order to identify a representative set it is necessary to know what is "next door".

The lack of appropriate data is a very significant problem with most decisions for informed decision making for conservation and land use planning. However, it is important that technologies for identification of potential protected area networks are available to maximise the probability that decisions made now are the best ones possible with the available information. Meanwhile, the databases and the technologies to utilise them will continue to improve and this in turn will increase the value of techniques such as that demonstrated in this report.

Past experience has demonstrated that it is usually only after a particular area is under direct threat that it is examined with a view to purchase for the purposes of creating a protected area, if such a course of action is deemed appropriate. This fact, however, should not prevent individuals and agencies concerned with nature conservation from taking the most systematic approach to protected area identification using the latest available technology. A more pro-active approach will ensure that the technology is readily available as it is required, in order that it can be quickly applied as opportunities arise or when a reaction to a threat is required within a short time frame.

4.3 Targets for reservation - how valid are they?

A further consequence of the potential of explicit reserve identification techniques to provide a solution which satisfies targets for reservation is that these targets need to be both clear and meaningful in terms of what is to be achieved. Setting targets for reservation has become an accepted policy initiative at all levels of government. Whilst procedures and methodologies for implementing such strategies are a available, the greatest problem hindering both the implementation and the assessment of the effectiveness of these approaches is a lack of detailed ecological data.

It is all very well to aim to reserve 5 or 10% of ecosystems, however there is no particular scientific basis for a figure of 10 percent and no evidence to demonstrate that this figure is effective. In terms of conservation of biodiversity, any areal target ignores the fact that there is considerable variation in both the distribution and abundance of species among various environments.

The appropriate proportion of a particular environment that it is desirable to reserve will thus vary significantly among environments. For some environments 10 percent may be grossly inadequate, while for others it may be generous. A further difficulty with areal targets is that once reached, they may impose an artificial ceiling to further reservations which may be required in the light of new knowledge. Targets based on levels of ecological representation in protected areas have a much greater validity. The proportion of regional ecosystems and the proportion of vegetation associations included in protected areas are among ecological measures which have been applied. Nevertheless, there are also limitations to the general applicability of these measures of representativeness. For example, there are considerable definitional problems with the identification of ecosystems and the extent to which vegetation assemblages serve as an effective surrogate measure for the various fauna groups is unclear.

The problem, therefore, comes back to how accurately we can define "representative" and "comprehensive". To be both fully representative and comprehensive in terms of protecting biodiversity the reserves system would need to encompass all species, with some predefined levels of replications of each. Such a target is not achievable in a practical sense, as indeed even for the two most well studied categories of biota, vascular plants and vertebrates, the level of knowledge for Australia is insufficient. This lack of data does not mean that we should shy away from setting the highest possible ideal, but rather that we acknowledge these deficiencies and explicitly state the assumptions made as we attempt to fulfil these aims.

5.0 CONCLUSIONS

The project "An assessment of the major ecosystems in parks and reserves of the Murray-Darling Basin" has addressed two main questions concerning the conservation of major ecosystems and vulnerable and endangered species in the Basin:

1. what are the gaps in the system of protected areas, in relation to major ecosystems and vulnerable and endangered species?, and

2. how should candidate areas for potential reserves be identified and where should these be located to fill the gaps in our representation of major ecosystems and populations of vulnerable and endangered species?

Phases 1 and 2 have addressed question one, and this report on Phase 3 has addressed the second question.

The development of a strategy for the conservation of ecosystems and vulnerable and endangered species in the Basin has involved the development and application of a heuristic algorithm to enable a series of four scenarios to be investigated and interpreted. The philosophy of approach discussed in the report is that conservation options analyses do not produce a single best result but rather provide the decision maker with a range of alternatives or solutions. Three elements underlie this approach i.e. efficiency (with respect to the total area of land required), flexibility (adaptability in the face of competing land uses and new data becoming available) and ecological integrity (The probability that ecosystems and species within nominated protected areas will persist in the future).

The results of four scenarios provide a preliminary conservation options analysis. The value of this result is the inherently flexible in the methodology, rather than in the results themselves. As new data or a different set of requirements are formulated then the algorithm is rerun and interpreted.

The analyses show that if the goal of conservation management is to develop a system of protected areas to conserve as much biological diversity as possible, then the inclusion of existing protected areas can result in a loss of efficiency in this process. This is due to the fact that existing protected areas have often been chosen for reasons other than the conservation of biodiversity.

The question of how should candidate areas for potential reserves be identified and where should these be located to fill the gaps in our representation of major ecosystems and populations of vulnerable and endangered species has been examined using the best available data sets for the Basin. The results presented in this report are by no means definitive.

There are a number of limitations to the results given the coarse nature of the ecosystem and biological data available. The species records used in this analysis could not be claimed to be representative of biodiversity. This exercise, however, does demonstrate that the existing system of reserves may be inefficient with respect to the maintenance of biodiversity. This is not to say that there should be no areas which are protected for aesthetic or other reasons, but rather that if we aim to protect our biodiversity, then a more strategic approach to the identification of protected areas is required. In turn, this will require access to better quality data sets in order that we have more knowledge of exactly what we are trying to conserve, and the most efficient ways of achieving this aim.

Applications of conservation options algorithms provide a useful tool to locate potential candidate areas for protected areas. The outputs should be viewed as approximations given the "fuzzy" nature of the data. More work would be required to refine and revise the methodology and results at finer scales. Additional data sets at better resolution would improve the quality of the results. Further investigations at finer scales should be conducted as cooperative project between the Commonwealth and relevant State and Territory jurisdiction.

Issues relating to the acquisition of land are beyond the scope of this report. Indeed this involves issues of a local scale which are more appropriately the domain of the relevant State and Territory nature conservation and land management jurisdictions.

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7.0 ACKNOWLEDGEMENTS

Funding for this project was provided by a grant received from the Murray-Darling Basin Ministerial Counci in 1989 to commence Phase 1 of a 3 phase project. Funding was approved under the Natural Resources Management Strategy, project number M008. Phase 2 of the project was funded by the MDBC in 1990/1991, and further funding in 1991/1992 has been provided for the completion of Phases 2 and 3. Access to these external funds enabled the ANPWS ERIN unit, under its National Index of Ecosystems project to demonstrate the methods and concepts developed under that project.

We would particularly like to thank Nick Nicholls and Chris Margules of the CSIRO Division of Wildlife and Ecology who provided significant input into this project with the development and application of the conservation options algorithm.

Numerous people in ERIN, NRIC, the Centre for Resource and Environmental Studies, Australian National University (ANU), CSIRO and other State and Territory nature conservation agencies and museums and herbaria have contributed to the development of the data sets used in this analysis of environmental groups of the Murray-Darling Basin.

Appendix 1:Table of four solutions to the conservation option analyses. Table is sorted by the relative difference between 5% and 10% area required for solutions 1 and 2.

50 Grp	5% nil_PA sol1_km	10% nil_PA sol2_km	5% with_PA sol3_km	10% with_PA sol4_km	ROTAP & E&Vs	Area of PAs	Rel difference between sols1-2 from 5% to 10%	Rel difference between sols 3-4 from 5% to 10%
38	3539	7050	3533	7041	275	625	D	D
33	3150	6273	3150	6273	200	0	D	D
40	2184	4342	2164	4302	125	150	D	D
35	1168	2337	1167	2335	600	75	D	D
42	1352	2705	1352	2705	375	0	D	D
34	1413	2826	1413	2826	250	75	D	D
19	4435	8898	4456	8852	1225	3150	D	D
23	1554	3111	1543	3094	575	500	D	D
39	2174	4320	2165	4304	225	225	D	D
04	981	1938	1451	1940	575	900	D	M
46	251	503	615	615	225	400	D	N
14	2215	3890	4235	4235	2225	2225	D	N
43	968	1555	1339	1550	925	375	D	N
22	127	152	127	152	175	0	M	M
41	586	1010	718	1008	550	150	M	M
36	2373	3033	2906	3032	2350	700	M	M
13	336	646	335	646	225	0	M	M
05	285	466	568	568	275	350	M	N
37	464	515	670	670	500	225	M	N
11	400	506	400	506	375	0	M	M
06	2438	2544	2729	2729	2275	300	M	N
25	367	496	752	752	350	375	M	N
07	391	415	595	595	400	300	M	N
20	629	629	902	902	675	400	N	N
01	576	576	1320	1320	625	1050	N	N
02	536	536	562	562	500	75	N	N
03	247	247	322	322	325	300	N	N
28	1178	1178	1909	1909	1175	1300	N	N
29	810	810	945	945	800	125	N	N
30	738	738	789	789	875	75	N	N
31	274	274	372	372	325	225	N	N
32	307	307	385	385	300	175	N	N
08	429	429	529	529	450	125	N	N
09	25	25	25	25	0	0	N	N
10	276	276	850	850	300	725	N	N
24	1759	1759	2380	2380	2150	975	N	N
12	543	543	1517	1517	575	1100	N	N
26	761	761	1741	1741	775	1225	N	N
27	944	944	1665	1665	1150	1600	N	N
15	300	300	473	473	300	200	N	N
16	510	510	586	586	525	100	N	N
17	1857	1857	5027	5027	1950	3575	N	N
18	272	272	594	594	300	450	N	N
44	649	649	1550	1550	675	1400	N	N
45	26	26	26	26	0	0	N	N
21	346	346	593	593	425	375	N	N
47	572	572	819	819	650	300	N	N
48	390	390	468	468	400	100	N	N
49	953	953	1175	1175	950	250	N	N
50	525	525	550	550	525	50	N	N

Key: N = Nil change in the area required between 5% and 10% solutions
M = Medium change in the area required between 5% and 10% solutions
D = Doubling in the area required between 5% and 10% solutions

See Table 3 in the body of the report for unsorted version of this table.

Appendix 2:Table of four solutions to the conservation option analyses. Table is sorted by the relative difference between 5% and 10% area required for solutions 3 and 4.

50 Grp	5% nil_PA sol1_km	10% nil_PA sol2_km	5% with_PA sol3_km	10% with_PA sol4_km	ROTAP & E&Vs	Area of PAs	Rel difference between sols1-2 from 5% to 10%	Rel difference betw'n sols 3-4 from 5% to 10%
38	3539	7050	3533	7041	275	625	D	D
33	3150	6273	3150	6273	200	0	D	D
40	2184	4342	2164	4302	125	150	D	D
35	1168	2337	1167	2335	600	75	D	D
42	1352	2705	1352	2705	375	0	D	D
34	1413	2826	1413	2826	250	75	D	D
19	4435	8898	4456	8852	1225	3150	D	D
23	1554	3111	1543	3094	575	500	D	D
39	2174	4320	2165	4304	225	225	D	D
04	981	1938	1451	1940	575	900	D	M
13	336	646	335	646	225	0	M	M
43	968	1555	1339	1550	925	375	M	M
22	127	152	127	152	175	0	M	M
11	400	506	400	506	375	0	M	M
41	586	1010	718	1008	550	150	M	M
36	2373	3033	2906	3032	2350	700	M	M
46	251	503	615	615	225	400	D	N
05	285	466	568	568	275	350	M	N
37	464	515	670	670	500	225	M	N
14	2215	3890	4235	4235	2225	2225	D	N
06	2438	2544	2729	2729	2275	300	M	N
25	367	496	752	752	350	375	M	N
07	391	415	595	595	400	300	N	N
20	629	629	902	902	675	400	N	N
01	576	576	1320	1320	625	1050	N	N
02	536	536	562	562	500	75	N	N
03	247	247	322	322	325	300	N	N
28	1178	1178	1909	1909	1175	1300	N	N
29	810	810	945	945	800	125	N	N
30	738	738	789	789	875	75	N	N
31	274	274	372	372	325	225	N	N
32	307	307	385	385	300	175	N	N
08	429	429	529	529	450	125	N	N
09	25	25	25	25	0	0	N	N
10	276	276	850	850	300	725	N	N
24	1759	1759	2380	2380	2150	975	N	N
12	543	543	1517	1517	575	1100	N	N
26	761	761	1741	1741	775	1225	N	N
27	944	944	1665	1665	1150	1600	N	N
15	300	300	473	473	300	200	N	N
16	510	510	586	586	525	100	N	N
17	1857	1857	5027	5027	1950	3575	N	N
18	272	272	594	594	300	450	N	N
44	649	649	1550	1550	675	1400	N	N
45	26	26	26	26	0	0	N	N
21	346	346	593	593	425	375	N	N
47	572	572	819	819	650	300	N	N
48	390	390	468	468	400	100	N	N
49	953	953	1175	1175	950	250	N	N
50	525	525	550	550	525	50	N	N

Key: N = Nil change in the area required between 5% and 10% solutions
M = Medium change in the area required between 5% and 10% solutions
D = Doubling in the area required between 5% and 10% solutions

See Table 3 in the body of the report for unsorted version of this table.