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Regional Priority Setting in Queensland:
A multi-criteria evaluation framework

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Daintree River estuary at Cape Kimberley, QLD
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Report Summary

This report presents a framework for setting regional funding priorities in Queensland, which incorporates datasets from the National Land and Water Resources Audit and multiple criteria analysis. The framework can be used to help set priorities under programs such as the Natural Heritage Trust, the National Action Plan for Salinity and Water Quality and other State and/or Commonwealth environment programs. The framework is flexible allowing for the incorporation of additional data layers and decision maker preferences.

Multiple criteria analysis is a technique for evaluating a discrete set of alternative options against a set of multiple, and often conflicting, criteria. It allows decision makers to assign weights to the criteria, reflecting their relative importance. Criteria weights are a major factor influencing the results of a multiple criteria analysis model. The multiple criteria analysis model presented in this report can be used to assess regional funding priorities in Queensland.

Data have been compiled on Queensland's 13 funding regions: Cape York, Northern Gulf, Southern Gulf, Lake Eyre Basin, Wet Tropics, Burdekin, Desert Uplands, Burnett Mary, Fitzroy Basin, Southeast Moreton, Queensland Murray Darling, Mackay-Whitsunday and South West Strategy. The data, and priority-setting criteria, for each region relate to:

- Agricultural profits;
- Geographic extent (population, length of coastline, length of rivers, area);
- Degradation costs (acidity, sodicity and salinity[1]);
- Landscape value (number of historical, environmental and aboriginal heritage sites);
- Salinity area[1];
- Threatened species (marine, pelagic, plant and animal);
- Tree clearance (1990 to 1999);
- Water quality (turbidity, salinity, nutrient loads); and
- Water use.

The priority score assigned to each region varies widely depending on the criteria weights that are chosen. It is, therefore, advised that criteria weights be chosen with input from stakeholders. The Queensland Regional Natural Resource Management Group Collective and the Queensland State Assessment Panel would be appropriate forums for setting criteria weights.

An interactive spreadsheet model has been prepared, which allows users to view the impacts of alternative criteria weighting scenarios. The Microsoft Excel 2000™ Spreadsheet is provided with this document as an attachment and is called "*Regional Priorities.xls.*"

Whilst the modelling framework described in this report can help inform the process of regional priority setting, it cannot replace the need for decision maker judgements. There will be political and subjective issues important to setting regional priorities that will need to be handled by other means.

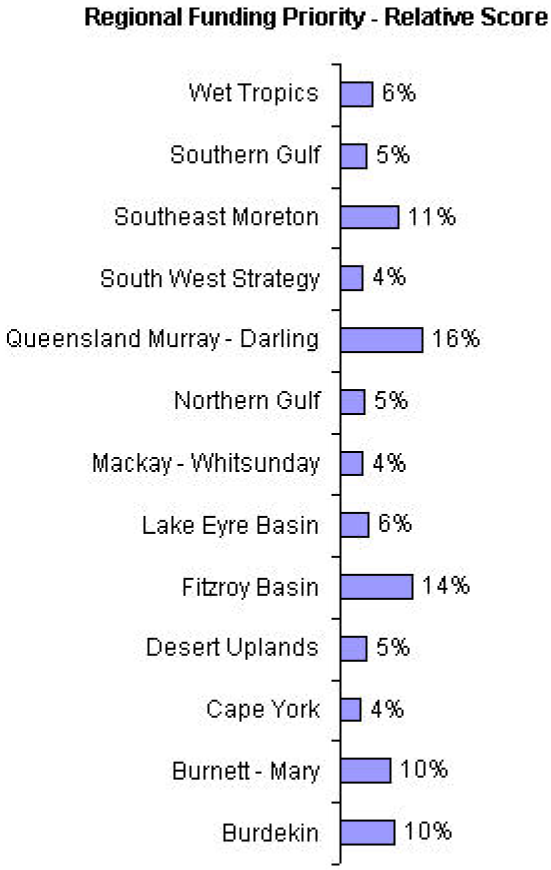
[1] The cost of salinity criterion relates only to the increase in agricultural profits if salinity were not present in the landscape. This contrasts to the salinity area criterion that can be used as a measure of all salinity impacts on biodiversity, landscape aesthetics, water etc, and the growth in salinity area from 2000 to 2020.

When the criteria are assigned equal weights, the multiple criteria analysis spreadsheet model will assign regional funding priorities as shown below. The percentage scores are indicative of the relative funding priority for the region, with a higher percentage score indicating a greater funding priority.

Criteria	Adjust	Weight
Agricultural profits		11%
Geographic extent		11%
Degradation Costs		11%
Landscape value		11%
Salinity area		11%
Threatened species		11%
Tree clearance		11%
Water quality		11%
Water use		11%
	1%	*100%*

Equal Wts | Hierarchy | Title Page

Region	**Score**
Burdekin	10%
Burnett - Mary	10%
Cape York	4%
Desert Uplands	5%
Fitzroy Basin	14%
Lake Eyre Basin	6%
Mackay - Whitsunday	4%
Northern Gulf	5%
Queensland Murray -	16%
South West Strategy	4%
Southeast Moreton	11%
Southern Gulf	5%
Wet Tropics	6%
Total	**100%**

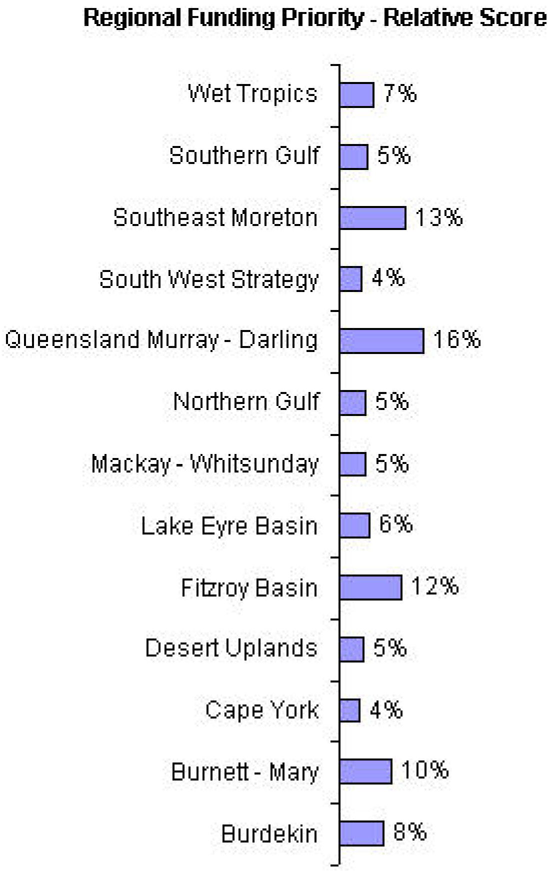


In the spreadsheet model shown below an alternative, and arbitrary, weighting scenario has been applied. It can be seen that this weighting scenario assigns different priorities to those given above. For example, the Southeast Moreton region receives a slightly higher priority than the Fitzroy Basin. Neither weighting scenario is 'correct' and the model allows decision makers to apply any set of weights considered appropriate.

Criteria	Adjust	Weight
Agricultural profits		20%
Geographic extent		4%
Degradation Costs		2%
Landscape value		20%
Salinity area		5%
Threatened species		15%
Tree clearance		15%
Water quality		15%
Water use		5%
	1%	100%

Equal Wts | Hierarchy | Title Page

Region	Score
Burdekin	8%
Burnett - Mary	10%
Cape York	4%
Desert Uplands	5%
Fitzroy Basin	12%
Lake Eyre Basin	6%
Mackay - Whitsunday	5%
Northern Gulf	5%
Queensland Murray -	16%
South West Strategy	4%
Southeast Moreton	13%
Southern Gulf	5%
Wet Tropics	7%
Total	**100%**



Acknowledgements

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- Brian Venz (QNRM) for offering guidance and assistance in how the priority-setting framework could be applied in a practical setting.
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- The Queensland Regional Natural Resource Management Group Collective who provided valuable feedback on the multiple criteria analysis framework and datasets at a meeting in Cairns in late June 2002.
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Report Contents

Introduction

Public funds allocated to environmental programs are seldom sufficient to comprehensively resolve land and water degradation problems in all regions. Typically, funding will need to be targeted on high priority regions and issues, where greatest return on investment is expected. Deciding where funding priorities lie is a complex problem depending on stakeholder preferences, scientific/economic data and administrative processes.

This report presents a framework and datasets to inform processes of regional priority setting in Queensland. There are thirteen regions competing for funds in Queensland, see Figure 1. The priority setting questions relates to inter (not intra) regional funding. The funds may be drawn from the Natural Heritage Trust, the National Action Plan for Salinity and Water Quality and other sources. The National Action Plan funds are limited to a subset of priority regions within Queensland, as shown in Figure 2.

Figure 1. Queensland's natural resource funding regions.

Alternative Approaches to Priority Setting

Setting regional funding priorities is an enduring problem, which is usually revisited each time a new environmental program is announced and/or at regular time intervals, e.g. annually. There are several main approaches to regional priority setting:

a) *Not to set priorities.* Under this approach each region is allocated the same level of funding regardless of need or likely impact. This is rarely done, as different regions will typically have different needs/impacts in different time periods. There is almost always some basis for discriminating between regions' funding needs.

b) *Setting priorities based on historical funding.* Through this approach a region's funding level is made proportional to its funding in the previous year, other time period or other program. Whilst simple to administer, this approach assumes that the initial fund allocation was correct. It fails to incorporate changing government objectives, societal values, scientific information, socio-economic conditions and physical landscape conditions.

c) *Setting priorities based on unstructured, but informed, negotiation processes.* This might be achieved by holding meetings with the objective of reaching consensus amongst participants on the most appropriate division of funds amongst the regions. The style of the meetings could range from *top-down* meetings attended mostly by government staff, through to *bottom-up* meetings attended by stakeholders. These meetings are not bound by a rigid structure or process for determining priorities and give attendees significant flexibility in making decisions.

d) *Setting priorities based on a formalised process.* A formalised process often involves a set of criteria and scoring system to determine a priority score for each region. Such processes may be relatively simple, relying upon subjective judgements and with all criteria evenly weighted, or they may be advanced, using natural resource datasets and multiple criteria analysis ranking procedures. Benefit cost analysis can also be used as a formalised process for regional priority setting. The benefits of a formalised processes is that it can help ensure full use of best available scientific data, clarify the subjective and normative[2] components of the decision and provide a formal avenue for incorporating stakeholder preferences.

A structured approach to priority setting using multiple criteria analysis, and datasets emerging under the National Land and Water Resources Audit, is applied here. Whilst this technique can help inform decision makers in setting regional priorities, it cannot replace the need for unstructured and subjective processes. No matter how accurate or robust the models or datasets, there will always remain a need to incorporate political and other issues that fall outside the realm of that which can be handled analytically.

[2] A normative issue is dependent on the value-systems held by stakeholders or decision makers for resolution. For example, the extent to which agricultural production is more important than biodiversity conservation (or vice versa!) is a normative issue.

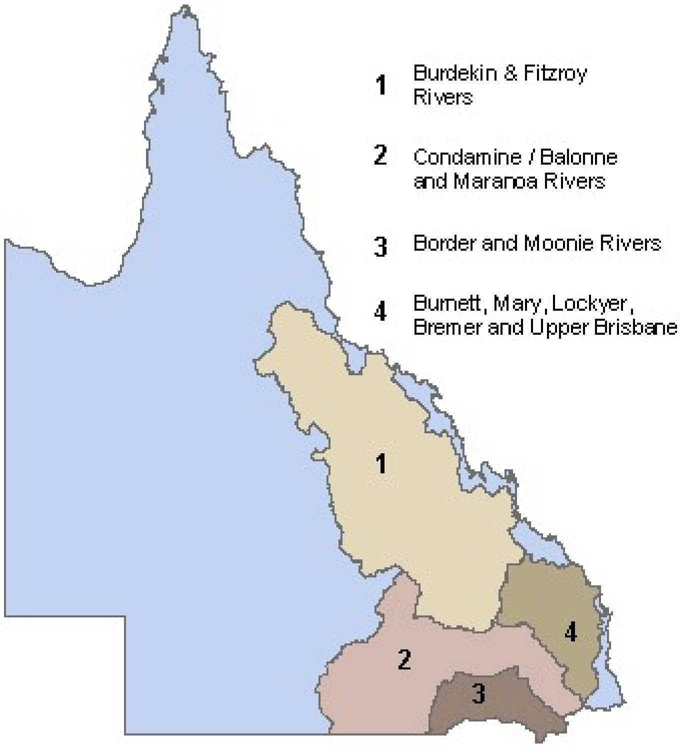

Figure 2. National Action Plan for Salinity And Water Quality priority regions in Queensland

Multiple Criteria Analysis

Multiple criteria analysis (MCA) is a structured framework for investigating, analysing and resolving decision problems constrained by multiple objectives[3]. It is used to appraise a discrete number of alternative options against a set of multiple criteria and conflicting objectives[4]. The MCA process is generally considered to involve the following stages:

- *Identify objectives.* These are statements relating to what decision makers seek to achieve in a particular circumstance. Objectives are distinct from criteria in that they are not necessarily measurable indicators of performance.
- *Identify options.* A discrete set of options represent the alternative choices available to the decision maker. Most MCA models will require "either-or" choices to be made, i.e. it is rarely possible to select combinations of options.
- *Identify criteria.* Criteria measure the performance of decision options against the decision objectives. For example, water salinity in units of electrical conductivity might be used to measure performance against a water quality objective.
- *Obtain performance measures.* A performance measure provides an assessment of an option's performance against a criterion. Performance measures are usually obtained from existing datasets, predictive models or expert judgements.
- *Weight the objectives and criteria.* Rarely are all objectives and criteria of equal importance in a decision problem. By assigning quantitative and qualitative weights to the objectives it is possible to make important criteria have a greater impact on the outcome than other criteria.
- *Rank the alternatives.* A great many algorithms can be applied to rank the options against the criteria. These algorithms make use of the performance measures and the criteria weights to obtain an overall performance score for each option.
- *Perform sensitivity analysis.* In this stage weights and/or performance measures in the model are systematically varied to see how they impact the results. This can help account for uncertainty. If a minor variation in one variable has a significant impact on the result, that variable should be subject to further validation.

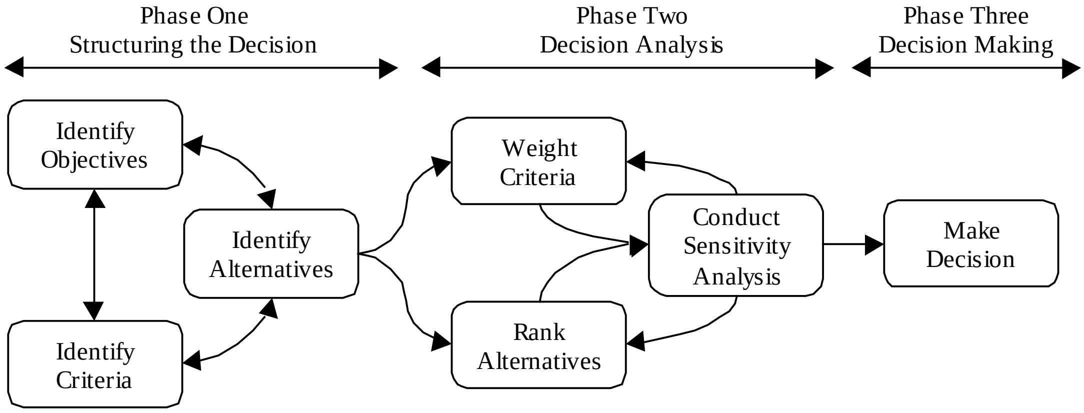

Figure 3. Multiple criteria analysis process

[3] Nijkamp *et al.* (1990)

[4] Voogd (1983)

The Effects Table

In its most basic form an MCA model is comprised of a set of evaluative criteria, a set of weights indicating the importance of those criteria, a set of alternatives, and a set of performance measures indicating the performance of each alternative against each criterion. These aspects of the MCA model are represented using an effects table[5]. An effects table is an $m \times n$ matrix with m criteria ($c_{j=1}$, $c_{j=2}$, $c_{j=3}$, … , $c_{j=m}$) and n alternatives ($a_{i=1}$, $a_{i=2}$, $a_{i=3}$, … , $a_{i=n}$). There is a corresponding weights vector W ($w_{j=1}$, $w_{j=2}$, $w_{j=3}$, … , $w_{j=m}$) of m weights which indicate the relative importance of each criterion. Typically, it holds that $\Sigma w_j = 1$ and $1 \geq w_j \geq 0$, for all j. That is, the weights sum to one and are non-negative. The weights can be expressed quantitatively or qualitatively depending on the particular MCA method that will be applied.

(Criteria - *j*)		c_1	c_2	c_3	…	c_m
(Weights - *j*)		w_1	w_2	w_3	…	w_m
(Alternatives - *i*)	a_1	$x_{1,1}$	$x_{2,1}$	$x_{3,1}$	…	$x_{m,1}$
	a_2	$x_{1,2}$	$x_{2,2}$	$x_{3,2}$	…	$x_{m,2}$
	a_3	$x_{1,3}$	$x_{2,3}$	$x_{3,3}$	…	$x_{m,3}$
	⋮	⋮	⋮	⋮		⋮
	a_n	$x_{1,n}$	$x_{2,n}$	$x_{3,n}$	…	$x_{m,n}$

Figure 4. An effects table used in multiple criteria analysis

Figure 4 shows the format of an effects table. The x_{ij} values are performance measures that represent the performance the i^{th} alternative against the j^{th} criterion. These can be expressed in different units although may need to be standardised to common units depending on the particular MCA method applied. Variations of the effects table represent alternatives as the columns, and criteria and weights as the rows.

Different decision making rules/methods can be applied to the data in the effects table in order to rank the desirability or suitability of the alternatives. The effects table represents the domain of factors, which the MCA model incorporates into its generation of solutions.

[5] Hipel 1992

Weighting the Criteria

There are many alternative techniques for assigning weights to criteria and objectives. Following is a brief description of some of the most commonly applied MCA weighting procedures:

- *Fixed Point Scoring.* In this technique the decision maker is required to distribute a fixed number of points amongst the criteria. A higher point score indicates that the criterion has greater importance. Often percentages are used as this is a measure with which many decision makers are familiar. The key advantage of fixed point scoring is that it forces decision makers to make trade-offs in a decision problem.

- *Rating.* The rating technique obtains a score from a decision maker to represent the importance of each criterion. It is similar to scales used on a Likert scale questionnaire. Often numbers 1-5, 1-7 or 1-10 are used to indicate importance (Nijkamp *et al* 1990). In this study rating weights were obtained on a ten point scale ranging from least important (1) to most important (10). These values were then normalised prior to application in a ranking algorithm.

- *Ordinal Ranking.* Ordinal ranking requires the decision maker to rank the criteria in order of importance. This method requires minimal information from the decision maker and is probably the easiest to handle conceptually. A drawback associated with ordinal ranking is that it will significantly limit the number of alternative ranking algorithms that can be applied. For example, weighted summation, one of the most commonly applied ranking algorithms, cannot be used when only ordinal weights information is available.

- *Paired Comparisons.* Paired comparisons involve the comparison of each criterion against every other criterion in pairs. It can be effective because it forces the decision maker to give thorough consideration to all elements of a decision problem. The number of comparisons can be determined by m(m-1) / 2. The decision maker can express the degree of difference in importance for each pair on a numeric scale.

- *Judgement Analysis.* To obtain weights in an implicit manner judgement analysis can be used. In this method the decision maker is presented with performance measures for a set of real or hypothetical alternatives. The decision maker is asked to assign a utility score to each of the alternatives. This represents the total utility a decision maker obtains from a particular alternative based only on information in the effects table. Multiple regression analysis is then conducted to determine the relative importance of each attribute in determining the decision maker's score. This means that if there is a very high correlation between the utility score and a particular criterion, then that criterion is likely to have greater importance.

In ideal situations it is desirable to apply some or all of these methods. However, practical constraints will limit the number that can be used in many situations. In the MCA model developed for this study percentage weights are entered into a spreadsheet.

Standardising Performance Measures

A key benefit of MCA is that it can handle performance measures in different units such as dollars, metres and degrees Celsius. However, most ranking algorithms require performance measures to be standardised into commensurable units. Several techniques are available for undertaking this standardisation. The most commonly adopted standardisation methods adjust criterion scores based on their distance to a maximum and/or minium value. For example, the top performing alternative for a given criterion is given a score of 1 and the worst performing alternative is given a score of 0. All intermediate alternatives are given adjusted scores between 1 and 0. The following approach to standardisation has been used in this study:

$$s_{ij} = \frac{x_{ij} - x_{j\,\min}}{x_{j\,\max} - x_{j\,\min}}$$ (where a higher criterion score indicates better performance)

$$s_{ij} = \frac{x_{j\,\max} - x_{ij}}{x_{j\,\max} - x_{j\,\min}}$$ (where a lower criterion score indicates better performance)

Where:

s_{ij} = the standardised performance measure for x_{ij}

x_{ij} = the performance of the i^{th} alternative against the j^{th} criterion in real units of any type

x_j max = the maximum performance score under the j^{th} criterion

x_j min = the minimum performance score under the j^{th} criterion

Ranking the Alternatives

A great many techniques exist to obtain a ranking of alternatives once the weights and performance measures have been entered into the effects table. The techniques primarily differ in how they handle qualitative and quantitative data, and decision maker preferences.

One of the most widely applied and most easily understood techniques is weighted summation. Using weighted summation the performance measures are multiplied by the weights, and then summed for each option to obtain an overall performance score. This is the approach taken here. The overall performance score can be calculated by:

$$v_i = \sum_{j=1}^{m} s_{ij} \cdot w_j$$

Where:

v_i = the value (or utility) of the i^{th} alternative relative to the other alternatives

s_{ij} = the standardised value of x_{ij} (the performance measure for the i^{th} alternative against the j^{th} criterion)

w_j = the weight of the j^{th} criterion.

Priority-Setting Criteria

A set of criteria are required to assess the funding priority of each region. Preferably these criteria will draw upon scientific measurements, minimising the need for subjective judgements. The criteria should also eliminate redundancy, i.e. no two criteria should provide same, or very similar, measures of objective-attainment.

This study has not permitted a stage where the decision makers are able to suggest criteria, due to timing and funding constraints. The approach taken, therefore, has involved identifying a wide range of potentially relevant criteria, which the decision makers can edit at a later stage. The criteria identified are shown in hierarchical form in Figure 5. This shows the overall objective at the far left, which is progressively broken up into more specific objectives and criteria, at the fingertips of the hierarchy.

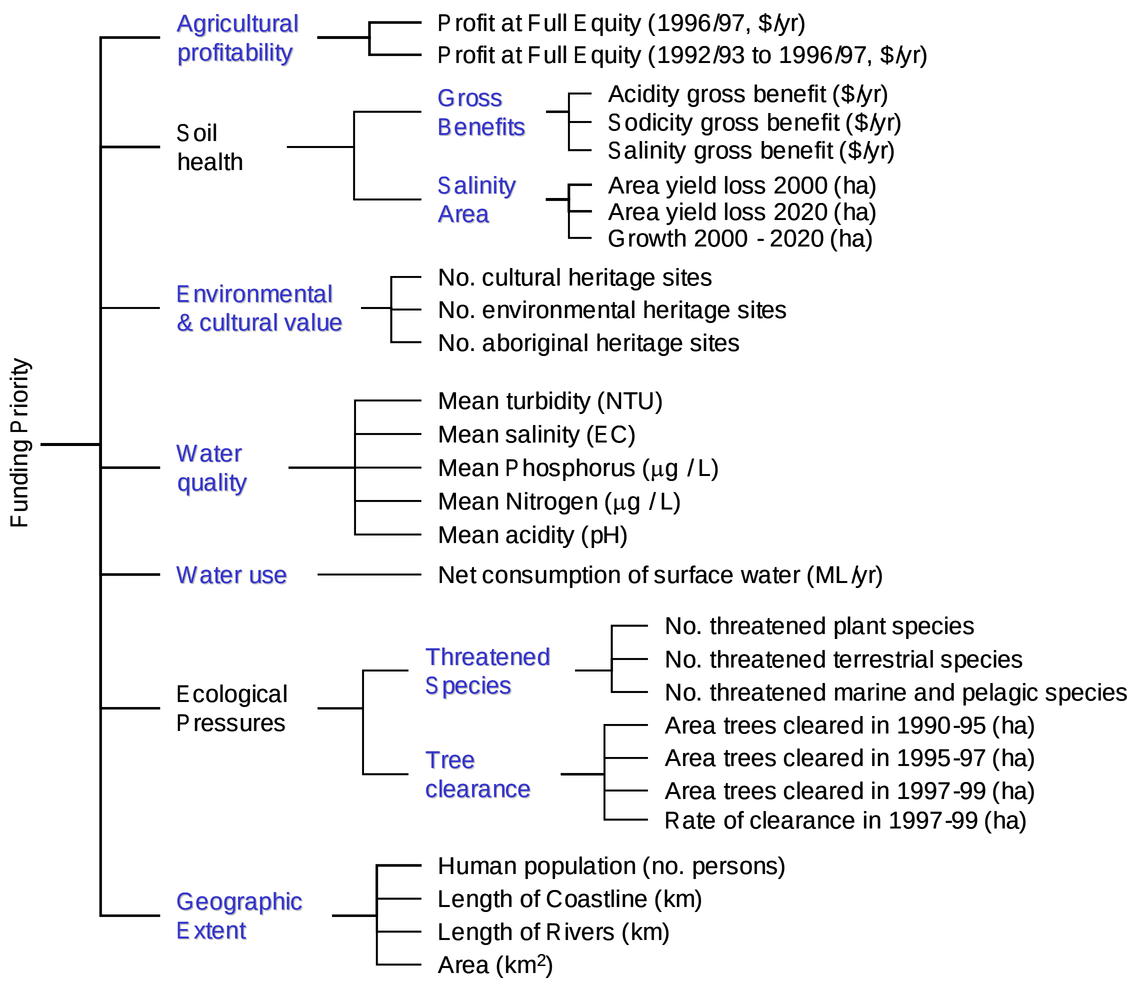

Figure 5. Criteria for regional priority setting

The criteria shown in blue (Figure 5) are weighted by decision makers in the MCA model. The total number has been limited to nine to ensure that weighting tasks faced by decision makers are manageable. The criteria at the fingertips of the hierarchy are sometimes referred to in later sections as attributes. The attributes measure the degree of criteria/objective attainment and are often assigned equal weight, although their weights can be adjusted by decision makers if desired. The following sections describe how data was obtained for each criterion and each funding region.

National Land and Water Resources Audit

Much of the data used in this priority-setting framework is derived from the National Land and Water Resources Audit (NLWRA). The NLWRA is a major project, which aims to provide information on ecological, social, economic and agricultural aspects of Australia's natural resources. It was set up in 1997 as a program of the Natural Heritage Trust and has a total worth of approximately $52 million. The first phase of the NLWRA concludes in 2002 and a recent meeting of the NLWRA advisory council has indicated how the program will be extended into the future. The bulk of NLWRA work has been conducted through inter-governmental partnerships:

"*The Audit is a partnership between all States, Territories and the Commonwealth, sharing and exchanging information and data on a vast array of topics to make the Audit one of the most ambitious programs on natural resources ever undertaken in Australia.*"[6]

By involving diverse organisations the NLWRA has sought to compile the best available data on Australia's natural resources. These data are intended to support natural resource policy in both public and private sector agencies. Regional priority setting is a key application anticipated for NLWRA datasets. The NLWRA data was developed through seven themes:

Theme 1	Water Quantity	Assessed ground and surface water use and availability. Also assessed groundwater quality.
Theme 2	Dryland Salinity	Mapped areas of dryland salinity risk across Australia, undertook benefit-cost analyses of remediation and assessed the economic consequences of dryland salinity.
Theme 3	Vegetation Condition &Use	Mapped the extent of different types of vegetation and rates of clearance in bioregions across Australia.
Theme 4	Rangelands Monitoring	Documented the nature and pressures of biophysical resources in Australia's rangelands[7]. This study also assessed socio-economic and institutional aspects of rangelands management.
Theme 5	Productivity and Sustainability	This theme covered a wide range of topics related to agriculture's natural resource base. Some key datasets include net primary productivity of soil resources, soil erosion rates and nutrient budgets.
Theme 6	Capacity for Change	Compiled socio-economic data relating to the use of Australia's natural resources. Some key datasets include agricultural profitability, costs of degradation (onsite & offsite) and community demographics.
Theme 7	Ecosystem Health	Compiled data on the health and integrity of Australia's ecosystems. This includes development of a water quality database and biodiversity assessment.

This project draws primarily upon themes 1, 2, 3, 6 and 7. There still exists considerable data under the other themes that could be useful in guiding regional priority setting decisions. In some cases, NLWRA data have been complemented by existing natural resource datasets.

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[6] Documentation on the National Land and Water Resources Audit available on the World Wide Web at http://www.nlwra.gov.au

[7] The rangelands of Australia are generally considered to be the low (>300mm/yr) rainfall sheep beef grazing regions of the arid interior.

Transferring Data

All of the data used in the multiple criteria analysis model was taken from regional frameworks, such as biogeographic regions or catchments, which overlap the funding regions. This made it necessary to transfer data from one set of regions to another. The process for transferring data between regions is shown in Figure 6. This process involves transferring the data from the source-regions to a 1km grid covering Queensland, then aggregating the grid data to the NRM funding regions.

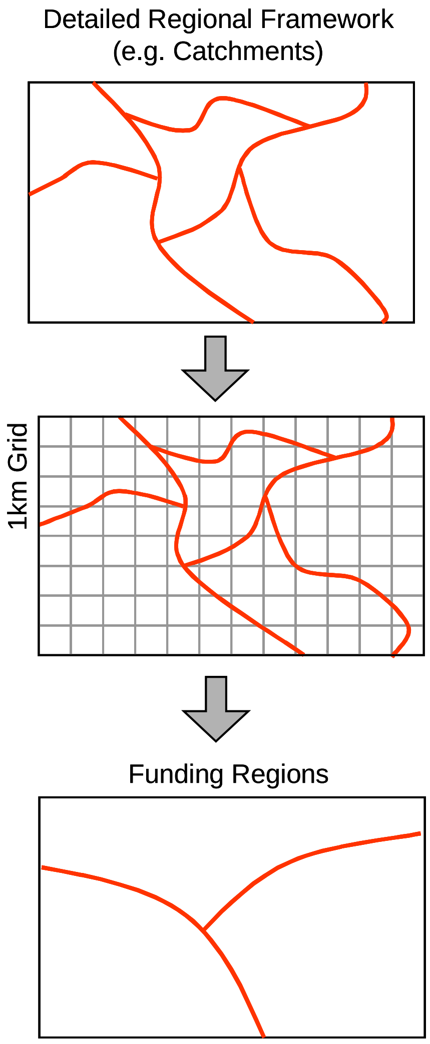

Figure 6. Process for transferring data between regions

To migrate from the detailed regions to a 1km grid regional values were either transferred to cells directly or divided by the number of cells in the region and then transferred. For example, mean water acidity, measured using pH, values were originally obtained by Catchment region. Each 1km grid cell within a catchment was given the pH value of its parent region. To get the mean pH of watercourses in a funding region the mean of all grid cell values was taken within that funding region.

A slightly different approach was taken for area-dependent data, expressed in hectares per region. For example, to determine the area of vegetation cleared per grid cell a slightly different approach was used. This required dividing the regional total (e.g. 400 ha) by the number of cells in the region (e.g. 200). With these example values the cell value for vegetation clearance would be 2ha/cell.

The 1km grids could then be aggregated back to funding regions by determining either mean or total values. Cell values were summed for all measures capable of being expressed in units/cell. Other measures, such as water quality and clearance trends, were aggregated by finding a mean value.

A difficult and important issue in setting regional priorities emerges when transboundary natural resource management issues are encountered. Projects addressing transboundary issues often will not fit neatly within the priority setting technique proposed in this report. A separate process for handling these projects may be required.

The Datasets

This section describes the datasets that were used to obtain performance measures for the priority setting criteria. Most of the data are represented spatially and were assigned to the funding regions using a geographic information system[8]. In general, the datasets either cover Queensland or the intensively used regions of Queensland, so that missing data is not a major source of bias.

Agricultural Profits

Agricultural profits were mapped across Queensland on a 1km grid for the National Land and Water Resources Audit. The datasets were made publicly available on 20 June 2002.

The measure of agricultural profit used was profit at full equity (PFE), which is roughly equivalent to Earnings Before Interest and Tax (EBIT). This provides a measure of returns to capital (natural and non natural) and managerial skill. The function used to determine PFE for a given landuse is as follows:

$$PFE = ((P1 \times Q1 \times TRN) + (P2 \times Q2 \times Q1)) - ((QC \times Q1 + AC) + (WR \times WP) + (FOC + FDC + FLC))$$

Where:

PFE = Profit at Full Equity ($/ha/yr)

P1 = Farm Gate Price ($/ha or $/DSE)

Q1 = Yield or Stocking Rate ($/ha or $/DSE)

TRN = Turn-off Rate (Ratio)

P2 =Price of secondary product ($/litre or $/kg)

Q2 = Yield of secondary product (litres/DSE or kg/DSE)

QC = Quantity Dependant Variable Costs ($/t or $/DSE)

AC = Area Dependant Variable Costs ($/ha)

WR = Water Requirement of Land Use (ML/ha)

WP = Water Price ($/ML)

FOC = Fixed Operating Costs ($/ha)

FDC = Fixed Depreciation Costs ($/ha)

FLC = Fixed Labour Costs ($/ha)

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[8] The Environmental Systems Research Institute's (ESRI) geographic information system product called "ArcGIS" was used in this project.

Profit at full equity, and all the variables used to derive it, have been produced for each 1km by 1km grid cell and relate to a single landuse. The source data was taken from the Australian Bureau of Statistics, the Australian Bureau of Agriculture and Resource Economics, State gross margin handbooks and expert advice. Yields in the profit function were also adjusted using satellite data, namely the normalised vegetation index, which is an index of vegetation greenness.

Two time periods were used to calculate PFE. The baseline time period was 1996/97, the year of an agricultural census. Profit at full equity was also calculated for the five years up to and including 1996/97, i.e. 1992/93 to 1996/97. For the five-year scenario prices and yields, for both the primary commodity and secondary commodity, were used in the profit function. Fixed and variable costs of production over the five years were held constant at their 1996/97 values. All dollars are given in 1996/97 Australian dollars.

The total profit at full equity for each funding region was determined by adding the PFE for each 1km pixel across the region (see Table 1). It is worth noting that some commodity prices have changed substantially since 1996/97, for example beef prices have risen considerably. Changes in commodity prices will significantly change profits. It would be possible to change the prices and associated costs to reflect current or alternative price scenarios.

Table 1. Total agricultural profits per funding region[1]

Region	Five Year	1996/97
Burdekin	$90,229,400	$71,238
Burnett - Mary	$243,172,000	$176,390,000
Cape York	$7,667,780	-$2,776,400
Desert Uplands	$7,886,430	-$35,185,800
Fitzroy Basin	$207,191,000	$78,873,800
Lake Eyre Basin	-$3,350,870	-$52,521,800
Mackay - Whitsunday	$93,624,200	$66,331,800
Northern Gulf	$35,497,600	-$46,392,000
Queensland Murray - Darling	$613,043,000	$750,939,000
South West Strategy	-$24,556,300	-$29,816,800
Southeast Moreton	$294,105,000	$292,279,000
Southern Gulf	$70,423,900	-$11,540,600
Wet Tropics	$165,502,000	$124,204,000
Totals	$1,800,435,140	$1,310,855,438

1. Dollar values in red are negative, regions in red are negative for both time periods

Rationale for Inclusion: Regions with higher profit levels are likely to contain agriculture of more economic value to Queensland, ceteris paribus[9]. Degradation or improvement of natural resources in these regions, upon which agriculture depends, will have a greater impact on Queensland's total agricultural profits than in other regions. For this reason agricultural profitability can be considered a criterion for targeting public land and water management funds. In the multiple criteria analysis model a higher level of agricultural profit implies a higher funding priority. Two attributes are used to measure agricultural profits: profit at full equity in 1996/97 ($/yr) and mean profit at full equity over the five year period 1992/93 to 1996/97 ($/yr).

[9] Ceteris paribus is Latin for "all other things being equal". The phrase is often employed in scientific and economic literature to highlight the effect of changing one variable in a model whilst all others are held constant.

An alternative perspective on agricultural profitability could involve a contrary stance, where lower profits mean the funding-priority is higher, i.e. the criterion is linear and negative. The logic for this approach might be based on the notion that where profits are low, there is a need to assist regional communities and boost profits. If this approach were taken it would be important to consider that agricultural profits are sometimes low because of unchangeable environmental characteristics, e.g. low rainfall, inherently poor soil and inaccessibility to markets. Targeting these areas for expenditure may results in very poor economic returns on investment.

Tree Clearing

The vegetation clearing data were taken from the NLWRA's Landscape Health project. This project estimated the area of vegetation clearance in each biogeographic region for the periods 1990-95, 1995-97 and 1997 to 1999. The biogeographic regions are defined by the Interim Biogeographic Regionalisation of Australia (IBRA) version 5.1 (Figure 7). Queensland is covered by 128 IBRA regions.

Vegetation cleared per 1km pixel was determined by dividing the total area (ha) cleared per IBRA sub region by the number of pixels in the IBRA sub-region. The total area cleared per funding region was then determined by summing the values for all pixels within that region. This gives clearance values per region as shown in Table 1. A mean rate of tree clearance was determined from the areas cleared over 1990 to 1999. The mean rate is equal to the 1997-99 area cleared minus the 1990-95 area cleared.

Table 2. Vegetation clearance in Queensland by funding region.

Region	Area trees cleared in 1990-95 (ha)	Area trees cleared in 1995-97 (ha)	Area trees cleared in 1997-99 (ha)	Mean rate tree clearance 1990-99 (ha/yr)
Burdekin	34,097	35,448	29,139	-550.84
Burnett - Mary	6,277	11,993	14,952	963.86
Cape York	228	370	206	-2.39
Desert Uplands	42,623	40,617	48,865	693.56
Fitzroy Basin	64,439	69,832	80,485	1,782.91
Lake Eyre Basin	14,874	13,213	15,984	123.34
Mackay - Whitsunday	1,405	4,169	2,152	82.97
Northern Gulf	1,132	1,985	1,301	18.80
Queensland Murray - Darling	45,715	100,674	160,935	12,802.20
South West Strategy	61,739	52,139	82,307	2,285.27
Southeast Moreton	5,145	5,837	5,510	40.60
Southern Gulf	1,181	1,513	2,103	102.50
Wet Tropics	193	352	318	13.90
Totals	279,047	338,144	444,257	-

Rationale: Regions with higher rates of vegetation clearance are likely to be placed under greater environmental stress than regions with low rates of vegetation clearance. In such regions, there would be a greater risk of loosing biodiversity and other problems related to tree clearing such as salinity. In the multiple criteria analysis model, higher rates of tree clearance imply greater funding priority. Four attributes are used to measure the tree clearance criterion: Area Cleared in 1990-95 (ha), Area Cleared in 1995-97 (ha), Area Cleared in 1997-99 (ha) and clearing trend (qualitative score, 1 = highest to 4 = lowest).

Figure 7. Interim biogeographic sub-regions of Queensland (128 in total), version 5.1. Source: Queensland Environmental Protection Agency.

Costs of Degradation

The costs of degradation data were taken from theme 6.1 of the NLWRA – "*Economic Returns to the Natural Resource Base and Costs of Degradation*" [10]. The source datasets are available as 1km grids covering intensively used regions of Australia. The grids give the additional profit at full equity attainable, in dollars per hectare per year, if the yield constraints associated with soil salinity, acidity and sodicity were removed without cost.

The cost of degradation data were referred to in the NLWRA as the "Gross Benefits" of soil amelioration – as they represent only the benefit side of a benefit-cost analysis. The values make

[10] The data and reports are available on the NLWRA web site at www.nlwra.gov.au

no distinction between naturally occurring and human induced soil constraints[11]. They merely identify the profit opportunity were the constraint removed.

Gross benefits were compiled for the 1996/97 financial year. In this study, values were obtained for funding regions by adding the pixel values, expressed in $/pixel/yr, within the funding region (see Table 3).

Table 3. Gross benefits[1] (costs) of salinity, sodicity and acidity per funding region ($000).

Region	Salinity	Sodicity	Acidity	Limiting Factor[2]
Burdekin	743	11,336	3,873	14,294
Burnett - Mary	2,571	11,883	25,290	35,247
Cape York	0	151	9,351	9,362
Desert Uplands	1	1,448	60	1,503
Fitzroy Basin	4,519	29,176	3,648	34,851
Lake Eyre Basin	0	9,131	0	9,131
Mackay - Whitsunday	5	6,075	15,265	17,601
Northern Gulf	0	708	22,197	22,641
Queensland Murray - Darling	1,687	86,374	19,881	101,415
South West Strategy	1	2,655	103	2,745
Southeast Moreton	499	17,168	51,828	60,380
Southern Gulf	10	2,463	0	2,468
Wet Tropics	192	1,672	80,961	81,266
Totals	10,228	180,238	232,455	392,903

1. The gross benefit is the additional agricultural profit attainable if the crop/pasture yield constraint were costlessly removed.
2. The limiting factor is the combined gross benefit of ameliorating sodic, saline and acidic soils. It is considerably less than the sum of gross benefits for the three factors.

Rationale: Salinity, acidity and sodicity are three soil factors that commonly limit crop and pasture yields. Ameliorating these soil constraints can increase productivity and profitability of agriculture. Regions where profitability increases are likely to be greatest, i.e. they have higher gross benefits, could be considered a higher priority for remedial actions. In the MCA model higher degradation costs create a higher priority score. Four attributes are used to measure the degradation costs criterion: gross benefit of salinity ($/yr), gross benefit of acidity ($/yr), gross benefit of sodicity ($/yr) and limiting factor gross benefit ($/yr).

Water Use

Water use data was taken from theme 1 of the NLWRA, namely the *Australian Water Resources Assessment* project. This project compiled data on surface water use rates per river basin, expressed in megalitres per year. These data were supplied by the relevant State and Territory agencies across Australia.

[11] Soil salinity, salinity and sodicity in Australia have both natural and human induced causes. Soil sodicity is primarily a natural feature of the Australian landscape. Measures of gross benefit used in this study make no distinction between naturally occurring and human induced soil constraints – assessing only the increase in profit were the constraint removed.

Catchment water use was translated into water use per 1km pixel by dividing the total catchment water use by the number of pixels in the catchment. Pixel values could then be added by the funding regions. The results are shown in Table 4.

Rationale: Improvements to water quality and availability in regions with high surface water use rates are likely to hold greater benefits to society than equal changes in regions with low surface water use rates. In the multiple criteria analysis model higher rates of water use imply a higher priority score. Only one attribute is used to measure water use: surface water use in megalitres per year.

Table 4. Surface water use rates for the funding regions.

Region	Surface Water Use (ML/yr)
Burdekin	525,708
Burnett - Mary	158,160
Cape York	487
Desert Uplands	265,578
Fitzroy Basin	265,317
Lake Eyre Basin	3,093
Mackay - Whitsunday	26,219
Northern Gulf	22,108
Queensland Murray - Darling	415,625
South West Strategy	161,428
Southeast Moreton	166,411
Southern Gulf	8,130
Wet Tropics	32,667
Total	2,050,932

Salinity Area

The estimates of salinity area have been taken from theme 6.1 of the NLWRA – "*Economic Returns to the Natural Resource Base and Costs of Degradation*" with original data being accessed from theme 2 of the NLWRA – "*Australian Dryland Salinity Assessment*".

The original theme two salinity data estimated the areas at risk. Maps of dryland salinity risk are based on groundwater trends, known incidences of salinity, soil characteristics and topography (NLWRA 2001). For Queensland, the area of dryland salinity risk was assessed for 2050, but not for the year 2000.

Under Theme 6.1 the risk maps were reinterpreted as extent maps, i.e. locations of regions where salinity was causing appreciable yield loss or landscape damage. This was done through consultation with the scientists that constructed the original risk maps. Information was obtained on the area of land within an "at-risk" region that was actually subject to physical salinity damage. The Queensland 2050 salinity risk map was used to create a 2000 risk map by contracting salinity regions with likely rates of salinity growth over the 50-year time period. The Burdekin, Fitzroy and Murray Darling Basin regions have the largest areas of salinity extent.

Table 5. Areas of salinity extent by funding region.

	Estimated Salinity Extent (ha)	
Region	2000	2020
Burdekin	12,330	29,673
Burnett - Mary	5,379	13,492
Cape York	344	783
Desert Uplands	532	3,581
Fitzroy Basin	24,702	52,932
Lake Eyre Basin	19	19
Mackay - Whitsunday	142	904
Northern Gulf	122	3,070
Queensland Murray - Darling	11,079	24,200
South West Strategy	199	202
Southeast Moreton	1,464	1,941
Southern Gulf	4,975	10,890
Wet Tropics	924	3,557
Total	64,211	147,263

Rationale: Funding regions with larger areas of salinity extent are also likely to have more severe salinity problems, ceteris paribus. These may be areas where funds should be targeted, especially if the region also has high biodiversity and agricultural productivity values. In the multiple criteria analysis model a larger salt area implies a higher priority for funding. Two attributes are used to measure salinity: salinity extent 2000 and salinity extent 2020.

Water Quality

Water quality data was taken from theme 1 of the NLWRA - "*Australian Water Resources Assessment*". This project compiled data on surface water quality by river basin. Some of the key water quality parameters for which data was supplied include:

- Acidity (pH)
- Turbidity (NTU – National Turbidity Units)
- Salinity (EC – Electrical Conductivity)
- Phosphorus load (mg/L – milligrams per litre)
- Nitrogen load (mg/L – milligrams per litre)

For each river basin a mean, median, max, minimum, count and standard deviation is given for the water quality parameters as measured from gauging stations. The measures are more reliable in catchments with a larger number of gauging stations. In the MCA model mean values were used. It is worth noting that the means may overlook some significant within-catchment variability in water quality. However, data at a finer level of spatial detail is not available.

Each 1km grid cell within a river basin was assigned the mean water quality parameter for that basin. The grid cells were then aggregated by taking the zonal mean of all cells within each funding region. The resulting water quality values are shown in Table 6. The table is colour coded to show good, fair and poor water quality classifications. The cut-offs for different water quality classes are listed in Appendix A.

Table 6. Average water quality values for funding regions[1].

Region	Salinity (EC)	Nitrogen (mg/L)	Phosphorus (mg/L)	Acidity (pH)	Turbidity (NTU)
Burdekin	207.8	0.7	0.2	8.0	86.7
Burnett - Mary	515.1	0.5	0.1	7.7	24.7
Cape York	101.5	0.2	0.0	6.6	7.8
Desert Uplands	184.3	1.8	0.5	7.8	332.8
Fitzroy Basin	235.1	0.9	3.9	7.6	337.4
Lake Eyre Basin	165.5	2.8	0.8	7.5	529.2
Mackay - Whitsunday	723.3	0.7	0.2	7.5	11.7
Northern Gulf	165.0	0.4	0.0	7.6	48.4
Queensland Murray-Darling	376.0	0.9	0.2	7.7	85.9
South West Strategy	413.3	1.0	0.3	7.7	104.1
Southeast Moreton	400.2	0.9	0.1	7.6	78.0
Southern Gulf	176.8	2.2	0.6	7.7	411.0
Wet Tropics	96.9	0.3	0.0	7.2	19.3

1. This table is colour coded according to Queensland water quality guidelines (see Appendix A):

Good quality
Fair quality
Poor quality

Rationale: Regions with severe water quality problems are likely to have higher priority for funding, with all other factors being equal. In the multiple criteria analysis model poorer water quality implies a higher funding priority. Five attributes are grouped under the water quality criterion: acidity (pH), turbidity (NTU), salinity (EC), nitrogen (mg/L) and phosphorus (mg/L).

Threatened Species

Data on threatened species were derived from the NLWRA's *Landscape Health* project. For each interim-biogeographic sub-region, the Landscape Health project estimated the number of threatened:

- plant species;
- terrestrial vertebrate species; and
- marine and pelagic vertebrate species.

Regions could have large numbers of threatened species for two reasons. Firstly, a region may have very high biodiversity and by virtue of containing many species is likely to hold more threatened species than other regions. Secondly, a region may be under high levels of environmental stress (e.g. tree clearing or pollution), which is placing species within that region under risk.

The threatened species data were transferred from biogeographic regions to a 1km grid, and then aggregated back to funding regions. The results are shown in Table 7.

Table 7. Threatened species per funding region

	Number of Threatened Species		
Region	Plant	Marine and Pelagic	Terrestrial Animals
Burdekin	8	10	9
Burnett - Mary	26	6	15
Cape York	21	10	8
Desert Uplands	5	-	7
Fitzroy Basin	12	11	10
Lake Eyre Basin	3	-	4
Mackay - Whitsunday	8	12	10
Northern Gulf	8	11	8
Queensland Murray - Darling	13	13	10
South West Strategy	4	-	2
Southeast Moreton	41	12	17
Southern Gulf	1	11	5
Wet Tropics	25	10	14
Total	175	108	120

Rationale: Regions with higher numbers of threatened species are likely to hold greater risks of species extinction. Investments in these regions will have greater chances of preventing species extinction, holding all other factors constant. In the multiple criteria analysis model a larger number of threatened species implies a higher funding priority. Three attributes are used to measure threatened species, the number of threatened plant; marine/pelagic and terrestrial animal species.

Cultural and Environmental Value

Data that could be used to measure a funding region's cultural and environmental value were relatively scarce. The NLWRA intends to release data relating to the significance of a biogeographic region's biodiversity, under the Australian Biodiversity Assessment 2002. However, this dataset is not yet available.

A region's cultural and environmental value was measured in this study using datasets from the Australian Heritage Commission. These datasets list the latitude and longitude of significant historical, cultural or environmental features in Australia[12]. Using a geographic information system it was possible to determine the number of features in each funding region. The results are shown in Table 8.

[12] The datasets are publicly available from the Australian Heritage Commission on the Web at: www.ahc.gov.au

Table 8. Number of heritage listed sites per region

Region	Aboriginal	Historical	Natural	Total
Burdekin	2	6	34	42
Burnett Mary	9	23	27	59
Cape York	6	4	8	18
Desert Uplands	1	2	4	7
Fitzroy	4	8	29	41
Lake Eyre	23	11	5	39
Mackay Whitsunday	-	1	10	11
Murray Darling	7	1	1	9
Northern Gulf	8	16	9	33
Queensland Murray-Darling	7	15	10	32
South East	23	21	40	84
South West Strategy	4	-	1	5
Southern Gulf	10	1	8	19
Wet Tropics	1	8	31	40
Total	105	117	217	439

Rationale: There is likely to be greater social benefit from protecting regions with high cultural and environmental value, other things being equal. These regions contain assets valued by people, and protection of high value assets is a higher priority than protection of low value assets. In the multiple criteria analysis model higher cultural/environmental value implies higher priority.

Geographic Extent

Data were obtained on each funding region's area (km^2), length of coastline (km), length of rivers/streams (km) and population (number of people) – as shown in Table 9. These calculations were made using standard overlay functions of a geographic information system and topographic data obtained from Geoscience Australia – National Mapping[13].

Population data was taken from the Australian Bureau of Statistic's 1996 Census. The census records the number of persons per collection district. Using population density estimates, the number of persons per 1km pixel within a census district was determined. The population of each funding region was determined by summing the pixel values.

Rationale: A larger population and physical size of a funding region implies a greater need for funding, other things being equal. These characteristics could suggest that the region is more heavily used, and therefore has higher use-value, and contains a larger physical extent of natural resources requiring management and conservation. In the multiple criteria analysis model geographic size is defined by area (km^2), length of coastline (km), length of rivers/streams (km) and population (number of people).

[13] Formerly known as AUSLIG, the Australian Land Information Group.

Table 9. Geographic extent of funding regions

Region	Area (km^2)	Length Rivers (km)	Length Coastline (km)	Population (Number of Persons)
Burdekin	101,382	17,048	464	168,504
Burnett - Mary	54,277	10,828	1,091	238,370
Cape York	107,446	13,384	2,549	7,641
Desert Uplands	87,394	12,131	0	4,961
Fitzroy Basin	155,624	32,513	1,263	206,841
Lake Eyre Basin	463,371	100,617	0	34,834
Mackay - Whitsunday	9,053	2,129	787	106,426
Northern Gulf	194,064	28,883	354	9,316
Queensland Murray - Darling	127,026	18,310	0	191,645
South West Strategy	187,387	21,188	0	9,729
Southeast Moreton	22,599	4,149	665	2,133,720
Southern Gulf	192,367	38,111	720	9,537
Wet Tropics	21,093	2,539	493	213,435
Totals	1,723,083	301,831	8,387	3,334,959

Applying the Model

The multiple criteria analysis model developed in this project is intended for application in a wide variety of regional priority setting exercises in Queensland. The data assembled have broad applicability to many government programs such as the National Action Plan for Salinity and Water Quality and the Natural Heritage Trust.

The criteria weights will dictate the multiple criteria analysis model's results. It is therefore suggested that stakeholder preferences be used to guide the weighting process. This could be achieved by holding meetings attended by stakeholders or representatives of stakeholder groups. The Queensland Regional Natural Resource Management Group Collective is an example of a stakeholder group that could guide the weighting process. The Queensland State Assessment Panel could also fulfil this purpose.

With the exception of water quality, National Land and Water Resource Audit data with statewide coverage of Queensland are used in the model. The water quality data covers the south-eastern regions of Queensland in more detail, although all regions have at least some coverage. The bias associated with data availability is most likely negligible. The accuracy of the underlying datasets is discussed above and more detail can be obtained by accessing the full metadata documents held by the National Land and Water Resources Audit.

Whilst the model can inform the process of priority setting it is worth noting that there will always exist a strong role for the decision maker's subjective judgements. Priority setting is a task dependent on people's value systems and complex political pressures. A model cannot hope to simulate all these factors. It is also possible that the model, as it currently stands, may not incorporate all the relevant scientific measures relevant to a region's funding priority. For example, there may be complex interplay between water quality and water use that is not explicitly handled in the multiple criteria analysis weighted summation technique. These factors highlight the need for this model to be used within a broader decision making framework.

Spreadsheet Model

A spreadsheet model was developed for this project using Microsoft Excel 2000™ with Microsoft Visual Basic™ for Applications. It can be used to view relative funding priority for each region under alternative weighting scenarios. The spreadsheet model is supplied as an attachment to this report, on disc, and is called "*Regional Priorities.xls*".

The main page of the spreadsheet contains a tool to facilitate interactive specification of criteria weights, see Figure 8. The user can either enter weights manually, or change weights by using the 'spinbuttons'. As the weights are changed the user is given instant feedback on the relative funding priorities for the regions in the form of a bar graph and table.

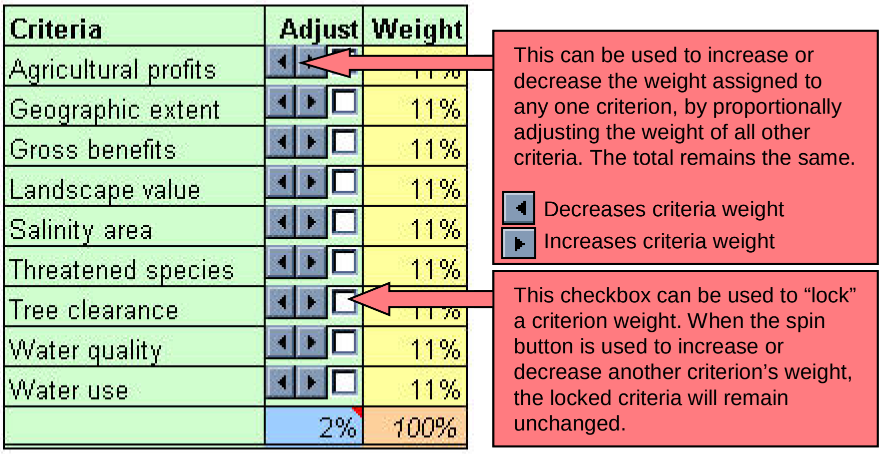

Figure 8. Spreadsheet tool for interactive specification of criteria weights

The user also has the option of adjusting the extent to which the attributes, or lower order criteria, influence the nine main criteria. This can be done by using the criteria hierarchy page, as shown in Figure 9. This is achieved by changing the values in the yellow boxes. It is necessary to ensure that the yellow-box values add to 100% at every fork in the hierarchy.

Figure 9. Criteria hierarchy used in the spreadsheet model. Cells coloured in yellow can be used to adjust the relative contribution of attributes to their parent objective – they should add to 100% at each branch of the hierarchy, in blue.

In addition to these tools the spreadsheet contains the base data, as derived from the geographic information system. This can be accessed under the "data view". The values for each criterion are given for each funding region in an effects table. The data view also contains the standardised performance measures and the overall performance score for each region. The relative priority scores given on the main view are the normalised performance scores.

References

Voogd, H. (1983) *Multicriteria evaluation for urban and regional planning*, Pion, London.

Nijkamp, P., P. Rietveld and H. Voogd (1990) *Multicriteria evaluation in physical planning*, North Holland, Amsterdam.

Hipel, K.W. (1992) *Multiple objective decision making in water resources*, Water Resources Bulletin, 28(1): 3-12.

Appendix A: Water Quality Thresholds

Sourced from the National Land and Water Resources Audit, Metadata documents supplied relating to Theme 1 – Water Quality and Availability. Classes indicate good, fair and poor water quality.

	Turbidity (NTU)	Salinity (EC)	Total Phosphorous (mg/l)	Total Nitrogen (mg/l)	Acidity[1] (pH)
Good	<5	<500	<0.05	<0.375	6.5-9
Fair	5-50	500 - 1500	0.05 – 0.10	0.35 – 0.75	
Poor	>50	>1500	>0.10	>0.75	<6.5 & >9

1. Taken from South Australia, as acidity water quality classes were not available for Queensland.