The montage of press statements on page two highlights the nature of public debate on land use conflicts in Western Australia. The article to which it relates describes a rational and objective approach to the resolution of such conflicts, and is worthy of close study.

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Erratum to Forest Focus 24.
The photograph on page 7 attributed to P. Cheney, was in fact taken by M. Tanton.

Contents

Front cover

An aerial photograph of experimental plantations in the eastern part of the Murray Catchment near Popanyinning. Below the plantation is a salt seep that is being monitored to determine whether the plantation has any effect on it. Above the plantation is a dam used for supplying drinking water to farm animals with a roaded catchment to enhance runoff into it. *(Photo courtesy of the Department of Administrative Services.)*

"ON RATIONAL GROUNDS..."

a precis of a study on the Western Australian Murray River.

On Rational Grounds is a recently published book that describes a management tool designed to help decision makers plan land and water use in river catchments. The example used is the salt-affected Murray River catchment, south of Perth.

The book outlines a comprehensive approach, employing economics and systems analysis to the problem of increasing conflict between land uses in this water catchment area in the Darling Range. This approach requires highly specialized skills. Because of this, much of On Rational Grounds *appears inaccessible to the general public and decision makers, many of whom have not been trained in economics and mathematics. But this report is valuable and pertinent, addressing a problem which affects many people in Western Australia.*

A politically conservative document, On Rational Grounds *points to the need for 'rational' planning (defined as involving objective assessment of all alternatives) within an area where rational planning has not been the case in the past. It reasserts some fundamental philosophies behind our political system — a system that is based on freedom of thought and expression, and decentralization of decision making. It points out the need for greater communication between government bodies, analysts of resource management problems, and citizens, and an opening up of administrative procedures in Western Australia. We are presented with a case example of the place that objective planning could hold in our society — a society that has favoured experienced but unsystematic judgements, or has been swayed by the arguments of vested interests. The Murray catchment is changing. This document shows how that change might be approached in a way that makes optimum use of current information and modern decision aids, while retaining traditional democratic and scientific values.* "Rational planning should ideally be viewed, not as an attempt to enforce reason on an unreasonable world, but as the improvement of decision makers' ability to decide rationally". *The following is a brief resume of the method used, described in detail in* On Rational Grounds. *Further enquiries may be addressed to Dr David Bennett and Mr John Thomas from the CSIRO Land Resources Management Division, Perth or Mr Joe Havel and Mr Frank Batini, Forests Department, Como.*

The Problem

Timber, water, recreation, conservation or mining? Which of

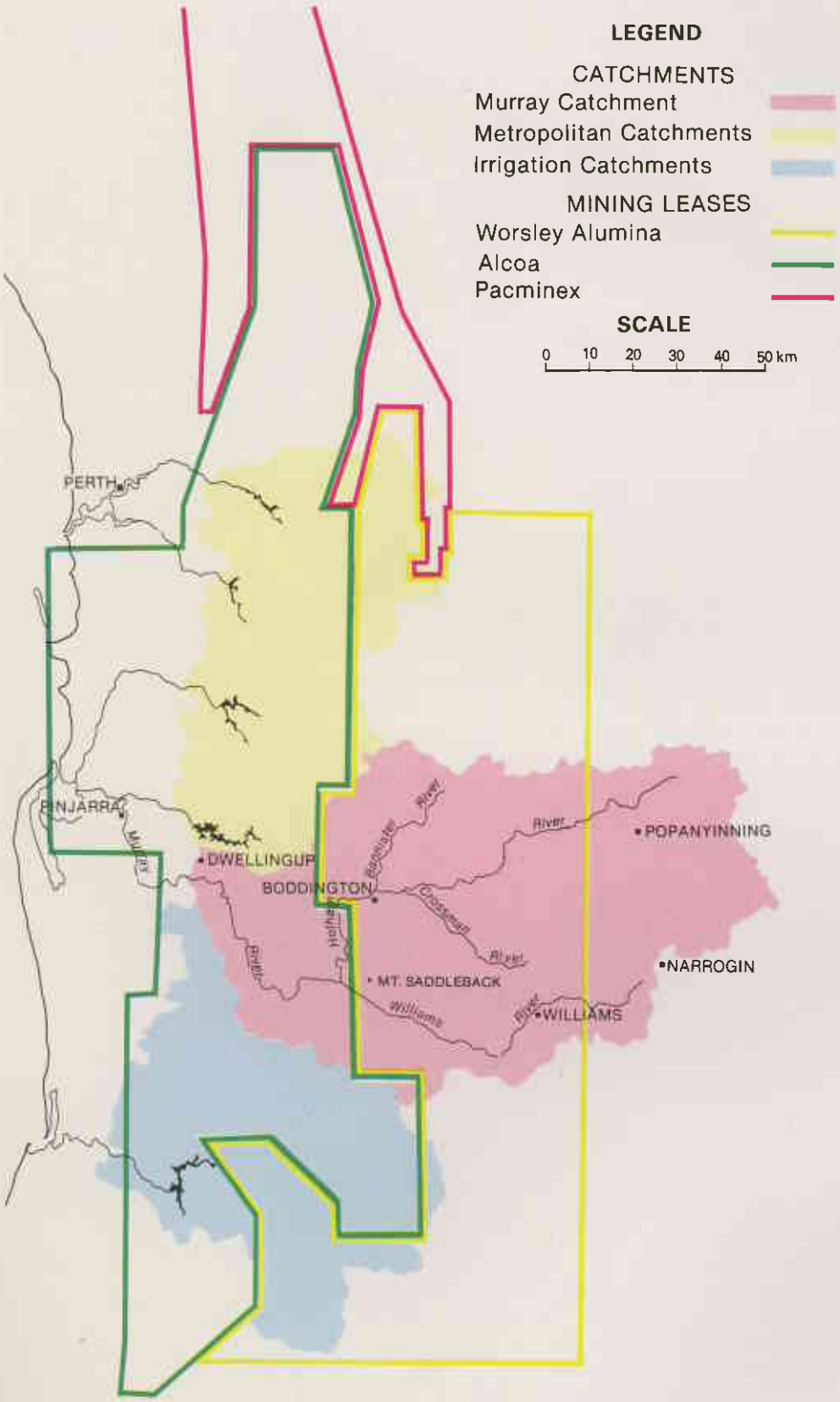


Fig. 1.

these or several other uses should take priority? What forms of land use are best in the short and long term interests of this State?

In the northern jarrah forest in Western Australia, competing land uses are vying for preference. In view of the value of this resource to the community, and its proximity to the State's capital and main centre of population, a considerable number of people will eventually be affected by land use decisions made here.

The resources of the northern jarrah forest provide both wood and agriculture products, minerals (bauxite, gravel and blue metal) and various recreational and conservational values. Of paramount importance is its use as a catchment for domestic and industrial water supply and for irrigation. The bulk of the land still under forest is held as dedicated State forest and managed by the Forests Department of Western Australia. However, much of the region is privately owned and cleared for either pasture or crops, so that resource utilization involves other Government Departments, private companies and individual landowners.

The Murray is the largest undammed stream in the region. Its catchment is located some 100km to the south of Perth, has an area of 660,000 ha and extends eastwards well into the Agricultural belt. It lies between existing metropolitan and irrigation catchments (see fig. 1). Rainfall varies from less than 500mm to 1 300 mm per annum. Some 45 per cent of the catchment has already been cleared, causing severe salinity problems from salt seepages on farms and salination of the major waterways. It is possible that the Murray will be used for metropolitan water supplies by the end of the century and this would drastically affect the current recreational and conservational values of the main valley.

Within the catchment are some of the finest young regrowth stands of jarrah as well as some high quality bauxite deposits. Conflict in

resource management and development in the Darling Range is obvious. Now with damming proposals for the Murray River critical decisions must be made for the future of the catchment. How best to make decision for this and other catchments in the future?

The Murray River Supply

The Murray could supply a large volume of water, probably 250 million cubic metres per year, given full utilization in its brackish state. Metropolitan consumption of water is currently 149 million cubic metres per year. The cost of delivering water from the Murray to the consumer in Perth would be lower than that for more southerly rivers, and similar to the cost of delivering underground water from an area near the Moore River, north of Perth.

The major problem with using the Murray is that its average salinity (approximately 1200 milligrams per litre total dissolved salts) is very much higher than existing metropolitan supply (approximately 350 milligrams per litre). Nevertheless, water from the Murray River could possibly be used in Perth's metropolitan supply system in a number of ways. The following have been suggested:

- direct use, using one dam, with reforestation in the catchment's agricultural areas to reduce current salinity levels;
- mixing with less saline supplies;
- construction of a secondary dam to divert saline headwaters;
- construction of small dams on the fresh tributaries in the forested area;

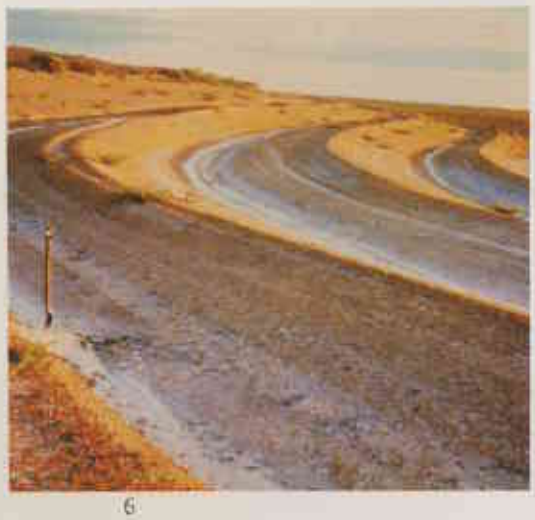
In the eastern half of the catchment mixed farming predominates, sheep grazing ▲ alternating with cereal cropping. It is from here that most of the salt flow originates. *G. Pead*

The Hotham River Gauging Station is a v-notch weir where stream flow and salinity measures are taken. It is pictured during a period of winter flow. *(Photo courtesy of the Public Works Department.)* ▼

The visible expression of salinity in the ► Murray Catchment is the death of vegetation in the lower parts of the landscape in the east. *G. Pead*

▲ A prosperous looking farm in the eastern part of the catchment. Note that clearing of the area has not been total. *G. Pead*

Canoeing and rafting are popular forms of recreation on the free-flowing waters ▼ of the Murray River. *J. Carey*



- installation of desalination plants utilizing reverse osmosis technology.

Reforestation would involve a considerable amount of social disruption and effort to achieve the desired effect, and its capacity to do this is uncertain. It would increase transpiration and therefore reduce streamflow by perhaps 30 per cent, but it would still leave enough runoff to supply approximately 200 million cubic metres per year. Mixing with less saline supplies would involve fairly severe engineering problems to achieve an adequate mix of saline and fresh waters within the supply system. In the absence of special measures to increase runoff, the building of two dams would involve a lower yield of water for the metropolitan system (an approximate total of 100 million cubic metres per year), and would also more than double the cost of dams and pipes. But it would almost certainly involve less social disruption and less environmental effect than reforestation. The strategy of building small dams on fresh tributaries would yield less water (an approximate total of 30 million cubic metres per year) but it would possibly have lesser effects on other land uses. Physical desalination by reverse osmosis could produce a large volume of water (approximately 200 million cubic metres per year), with little social disruption, but at a high cost.

The complexities of the decisions required for future planning of this catchment become obvious when all of the variables are assessed.

The Study Team

A number of experts from the CSIRO's Division of Land Resources Management, the Department of Agriculture and the Forests Department came together to propose a systematic and economic plan for the catchment. Members of other Government Departments and private companies assisted the group as advisers in more specialized fields. Public opinion on recreational use of the catchment was obtained through surveys and questionnaires administered by the Forests Department.

◄ The landscape of a roaded catchment. For efficient water collection the surface has to be free of plants, eradication of which causes high annual maintenance costs. *(Photo courtesy of the W.A. Department of Agriculture.)*

The Model

A mathematical model was used to allocate land uses in the Murray catchment, under various scenarios of water planning, including the option of not to dam. The catchment was divided into 41 zones according to land form types, rainfall and vegetation coverage, and all probable land use activities were considered for each zone. A computer programme was written that would account for all combinations of the activities in the zones. Eleven land uses were considered, including flora and fauna reserves, national parks, eucalypt hardwood forestry, plantation forests, agriculture (as adapted to different zones), agroforestry, streamline plantations, water runoff enhancement by surface sealing land surfaces (''roading''), bauxite mining (followed by forestry, agriculture or roaded sub-catchments), and water storage. The task was to assess the economic value of each activity in each zone and work out which would be the most efficient land use, according to three basic water development options (no water using development, one dam with reforestation, two dams diverting saline headwaters).

Landform mapping, a technique developed by the CSIRO has now been applied to large areas of the south-west of Western Australia. The main reason for this is that land forms can be mapped from the air over very large areas, where as quite significant differences in soils and vegetation can often be seen only from the ground, and can therefore

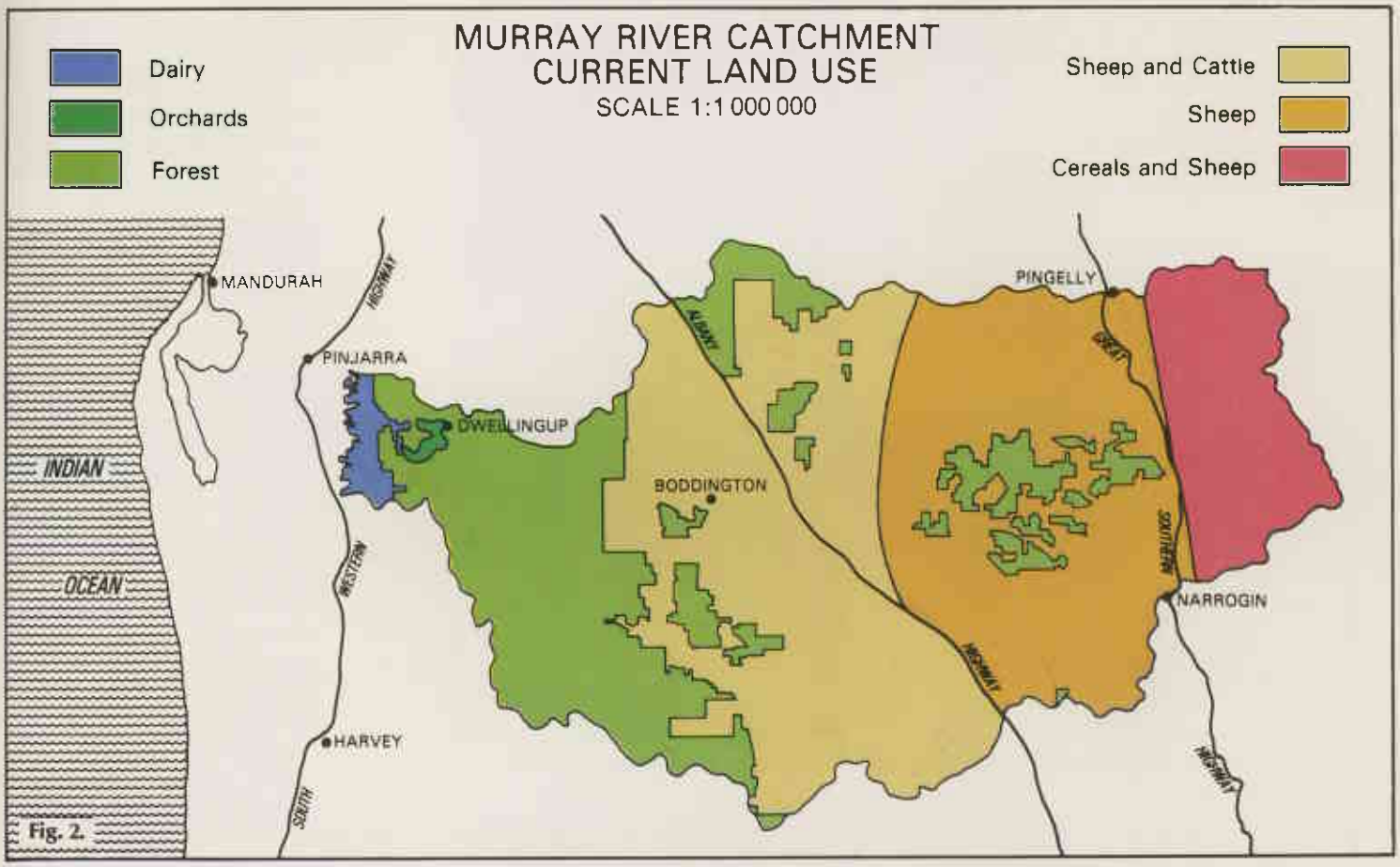
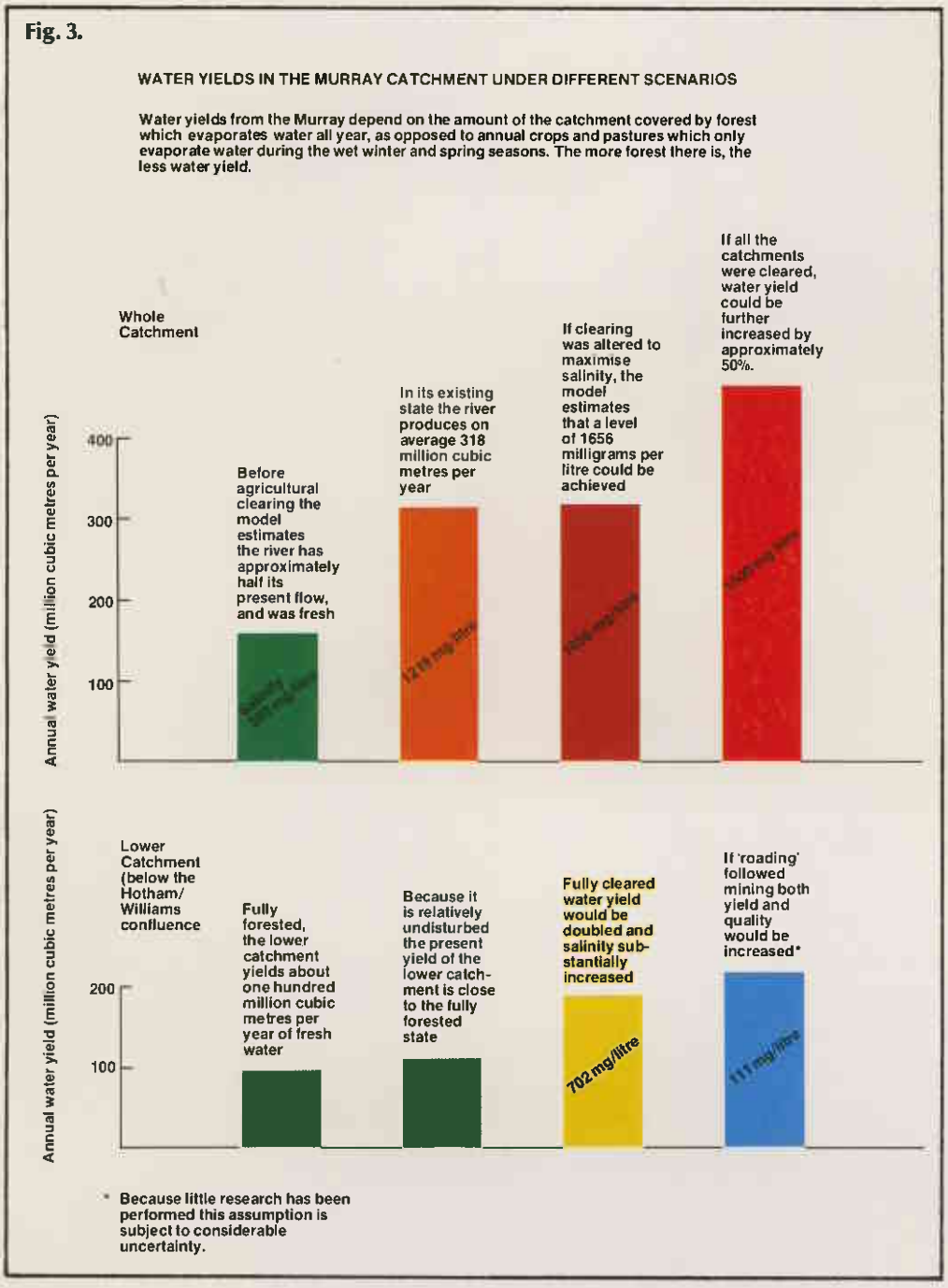


Fig. 2.

In the better vegetated parts of the catchment, beekeeping is carried out seasonally. *G Pead*

This picture shows a harmonious combination of land uses in the catchment - water supply, farming, private pine plantation forestry, with the hardwood jarrah forest in the background. *G. Pead*

Fig. 3.



only be mapped very laboriously. There are now several studies within State forests that successfully relate land forms to vegetation and soils. It is therefore possible to interpret landform maps in terms of vegetation and soils, and thus utilize them as a basis for land use planning. For example, the allocation of parts of the State forest to various land uses such as catchment protection, recreation, flora and fauna conservation and timber production, is to a considerable degree based on land forms, though economic and social factors also have a strong influence.

Budgets

The economic value of each possible land use activity in each zone was calculated on the basis of five 'budgets'.

(1) An overall economic cost/benefit comparison of the activities themselves in each zone. For example, the cost of planting pines and the profit made in logging these pines, compared with direct cost/benefit of all other activities.

(2) A water budget — how each activity in each zone would affect the amount of potable water released into the river, and how much this water would be worth.

(3) A salinity budget — how each activity in each zone would affect the amount of salt released into the Murray River, and what economic costs would be incurred as a result.

(4) A recreation budget — how much each activity, for example bauxite mining, would affect recreation in each zone. Numbers of visitors to the area were estimated and then valued.

(5) A conservation budget. This was difficult to assess because the values of conservation cannot be directly incorporated into the model. Therefore, it was used as a constraint. By using conservation as a constraint an indirect value was gained in dollars as to how much it cost to allocate land to this purpose. This is called an opportunity cost, or the value foregone. Activities were assessed both with and without conservation constaints.

Overall then, the model accounted for 41 zones, 11 activities per zone, 5 budgets per activity per zone. The task then posed was to simulate the catchment under proposed water supply schemes and optimize land use activities. The overall economic return of each scheme could then be assessed.

York gums *(Eucalyptus loxophleba)* grow naturally in the low rainfall area of the eastern catchment, but have been largely cleared from the area to facilitate wheat and sheep farming. Note the experimental plantation in the background established by the CSIRO to monitor the effect on salinity levels of large-scale re-planting in agricultural areas. *(Photo courtesy of CSIRO.)*

Results of the Study

A large number of different assumptions about data value, land use options and water exploitation strategies were examined in the book, only the most salient results are recorded here. In the absence of water resource development, present land use is close to the optimal allocation of agriculture and forestry.

Given the estimated values of water used in the study, the net benefits to the community from extensive reforestation in agricultural areas or large-scale diversion of saline tributaries (using two dams), or physical desalination would be either small or negative. Even at 45 per cent of estimated costs desalination plants would not be worthwhile. In these schemes, benefits from water resource development would be offset by the resource costs.

The model suggests that the two dam scenario will halve the yield and salinity, as compared with the one dam scenario of 250 million cubic metres yield and about 1200 milligrams per litre salinity. Within this major option, further variation will result from mining rehabilitation. If mining is followed by forestry rather than agriculture, the value of the catchment products will decrease by $13 million, water yield by 28 million cubic metres, but salinity will further drop from 473 to 301 milligrams per litre. Under certain conditions, the two dam option might be justifiable, particularly if extensive recreational use were made of the upper diversionary dam.

Overall, however, it was concluded that unless a very efficient method of reducing stream salinity were to be found for this catchment, other methods of coping with Perth's water demand should be considered. The inclusion and optimal allocation of bauxite mining increases the overall net value, but does not alter the relative merits of the water development projects, compared with no development.

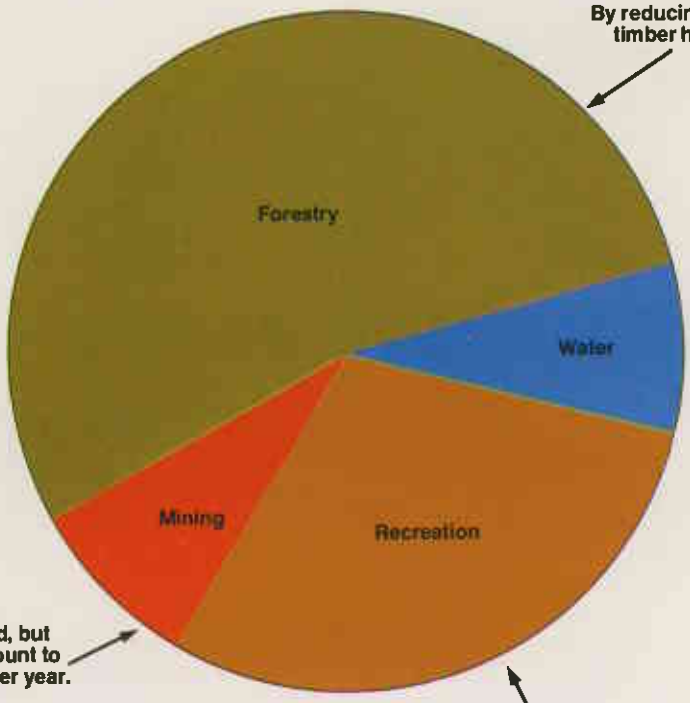
In addition to the conventional land uses discussed above, the impact of new forms of land use designed to improve water quality such as agroforestry, streamline plantations, and strategic enhancement of runoff by roading were investigated. In these analyses, considerable reductions in salinity were assumed to be achieved by relatively minor changes in land use. On these assumptions, water resource development appears much more economically viable. Again for a two dam scenario, introducing roading after mining instead of agriculture would virtually double water yield and reduce salinity to a quarter. This solution produces the best quality water but its implementation could well cause turbidity, bacteriological, and engineering problems.

The results of the case study also serve to emphasize two more general principles for management of this catchment. Firstly, the main land use conflict affecting water quality is that between clearing for agriculture and the alternative uses of agricultural land. The release of salt from agricultural land far exceeds that from any possible amount of bauxite mining, even if mining contributes substantially to the spread of jarrah dieback disease (though this would probably not be true in some other local catchments in which there is little agricultural clearing). Thus, measures to improve water quality by choice of land use must concentrate on agricultural land.

A second principle relates to the less extensive, though more intense, conflict between bauxite mining, conservation and recreation areas in the western forested part of the catchment. The area to be mined for bauxite is, on present projections, small compared with the total area where bauxite is found. Thus there is considerable freedom for allocating the areas to be mined so as to respect recreation and conservation areas. The resulting additional cost is not only small compared with the value of the

THE COSTS OF CONSERVATION IN THE MURRAY VALLEY

The model estimates that the overall cost of implementing proposed conservation areas amounts to a discounted cost of $24 million at 1976 prices, equivalent to an annual cost of $1.68 million. The distribution of this cost between the affected land uses is shown in this diagram for the case of a single dam and 200 km² of mining.



By reducing the area available for timber harvesting conservation cuts forestry value by $910,000 per year.

Because there is 10 km² less agriculture, and less run off, water supplies are reduced in value by $140,000 per year.

The area mined is not reduced, but increased transport costs amount to $140,000 per year.

Flora and fauna conservation reduces recreation values by $490,000 per year by excluding recreational activities from reserved areas.

Fig. 4.

bauxite, but may well be exceeded by the value of recreation alone. Therefore, taking advantage of the potential mobility of mining is an important principle of efficient land use management in this and similar catchments.

Discussion of the Study

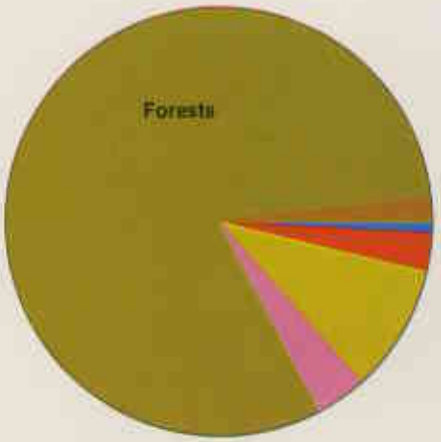
On Rational Grounds *includes an evaluation of the methods that were used in the case study. This evaluation illuminates some of the problems that affect the viability of 'rational' planning in our society. The available physical data is always far from perfect, so that some predictions will be in error. In addition, analysts and decision makers always have their own assumptions about what is good for society: about what environmental factors are important for instance, and about the evaluation of social welfare and benefit. Economic assumptions, though necessary, are always questionable. For instance, the task of ascribing values to recreation potential and conservation, both of which carry much 'intangible' though real value, leads to a fundamental questioning of economic concepts, and makes great demand on logical reasoning. But if problems such as these are not tackled, much well-intentioned scientific data gathering may be fruitless.*

The study highlighted several areas where collection of more information would reduce, but not eliminate, the uncertainties of planning in the Murray study.

At the time of the study there was only a limited amount of data on

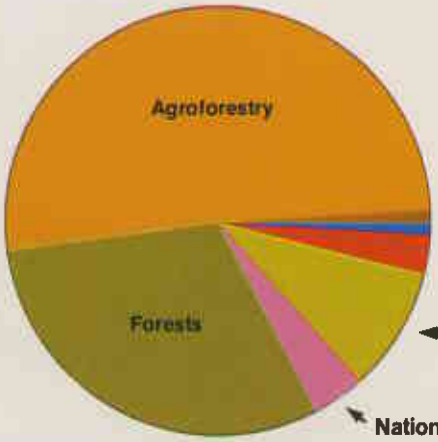
ONE DAM BELOW NANGA BRIDGE WITH LAND USES DESIGNED TO MEET WORLD HEALTH ORGANIZATION'S STANDARD OF 500 mg L^{-1} TOTAL DISSOLVED SOLIDS

(a) Pessimistic assumption about land use/water quality interactions*



To meet the salinity standard nearly all the agricultural land has to be planted to plantations which lose money. Annual value of the catchment products falls to $25 million. Dam supplies, on average, 177 million cubic metres of water per year to Perth at 500 mg L^{-1} Total Dissolved Solids.

(b) Optimistic assumption about land use/water quality interactions*



Agroforestry replaces money losing plantations. Annual value of the catchments products rises to $31 million. Dam supplies the same amount of water at the same quality standard.

Agriculture
Reservoirs
Mining
Mining area does not change unless refinery capacity changes
Flora and Fauna Reserves
National Parks
Flora and fauna reserves are held at this allocation

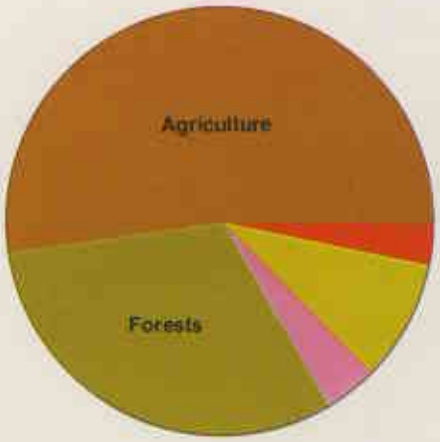
*The 'optimistic' assumption is that limited tree planting in agroforestry schemes would be effective in reducing salt flow from agricultural areas; the 'pessimistic' assumption is that it is not possible to find land management schemes which achieve this, other than full reforestation of agricultural areas.

Fig. 5.

Fig. 6.

COMPARISON OF LAND USE ALLOCATION FOR NO DAM AND TWO DAM OPTIONS

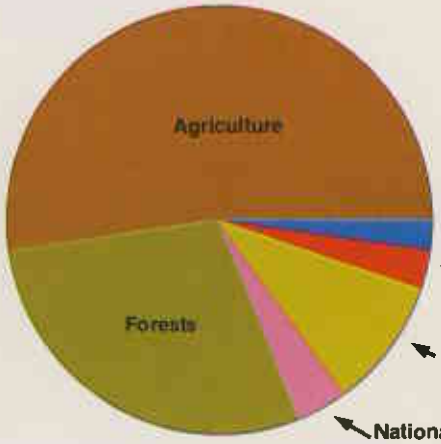
NO DAM



Very little change from the existing land use is suggested. Annual value of the catchments products is $28.7 million; the river flows at 294 million cubic metres per year at a salinity of approx. 1200 mg L^{-1} Total Dissolved Solids.

TWO DAMS

(One below Nanga Bridge and the upper dam to divert saline headwaters just below the junction of the Hotham and Williams Rivers)



Some land is flooded by the upper and lower dams. Annual value of the catchment products rises only $0.3 million. Lower dam supplies on average, 126 million cubic metres of water per year to Perth at 450 mg L^{-1} Total Dissolved Solids.

Reservoirs
Mining
Mining area does not change unless refinery capacity changes
Flora and Fauna Reserves
National Parks
Flora and fauna reserves are held at this allocation

▲ Bauxite mining in the western part of the catchment. *G. Pead*

▼ Part of the jarrah forest devastated by dieback disease in the western part of the catchment. *G. Pead*

recreational activities. Subsequent Forests Department surveys have added considerably to the available information, however, data on the recreational use of streams, rivers and open bodies of water in the south-west is still relatively sparse and unco-ordinated. Surveys aimed specifically at the economic aspects of recreational activity have not been undertaken.

Another data deficiency noted in the study was the lack of reliable estimates of the way changes in price will change the demand for water. These are important for calculating growth in Perth's demand for water, the growth rate in the utilization of a particular water resource development, and thus, the estimation of benefits from building dams. Currently the Perth Metropolitan Water Supply Sewerage and Drainage Board is undertaking a major study of social and economic factors influencing water use that will yield data relevant to these purposes.

There is even less available information on the economic costs which result from salinity in water supplies. American data suggests that for a city the size of Perth, economic costs of about $5 million annually could be incurred even at the acceptable standard for human consumption of 500 milligrams per litre total dissolved salts. This occurs from increased scaling and corrosion causing higher operating costs and a shorter working life for all manner of water-contacting appliances, for example, in industrial pipes and boilers, domestic water heaters, taps and valves, and the urban reticulation system. This does not include any health costs from raised concentrations of salts, or purchases of high quality bottled

◄ Pine plantations and jarrah forest flank the deeply incised Murray Valley near Dwellingup. In the distance is Nanga Bridge, below which the dam for the one dam option would be constructed. *H. Bradbury*

water by consumers. Such cost estimates are of great relevance to resource management, where water quality is affected by land use practices.

In conclusion, it should be stressed that linear programming is just one tool for planning. In terms of theoretical economics it is very sound — practical details are not so well represented. The case example is still a very open area of interest, where decisions are yet to be made. On Rational Grounds *does not make recommendations or decisions. This is not a drawback. A tool dosen't provide answers — it provides the potential for better answers.*

"Whether or not water resource development takes place, there will still be conflicts between agricultural expansion and forestry, between conservation and recreation, between mining and forestry, and between mining and conservation. It follows that any plan for resource use in the catchment needs to consider simultaneously the physical interactions between, and economic values from forestry, mining, agriculture, conservation, recreation, water yield and water quality".

Helen Bradbury

Healthy regrowth jarrah forest. ► Hardwood forestry is a valuable resource and employs the majority of the inhabitants of Dwellingup. *G. Pead*

Jarrah poles like these are used by Telecom and the State Energy Commission to support telephone and electricity cables in Western Australia. *(Photo courtesy of the CSIRO.)* ▼

THE STUDY TEAM

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P.A. Downes	: Computer programme operator
D.K. Macpherson	: Discussant
W.M. McArthur	: Landform mapping
A.M. Murray	: Clearing analysis
A.J. Peck	: Salt yield estimates
P.L. Sewell	: Temporary co-ordinator 1975-76
J.F. Thomas	: Economic studies and editor

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J.J. Havel	: Originator, conservation, runoff estimates (western region)

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On Rational Grounds was published in March 1982 by Elsevier Scientific Publishing Company, Amsterdam.