

**BAUXITE MINING  
IN THE DARLING RANGE,  
WESTERN AUSTRALIA**

A Review for the

**ENVIRONMENTAL PROTECTION AUTHORITY**

by

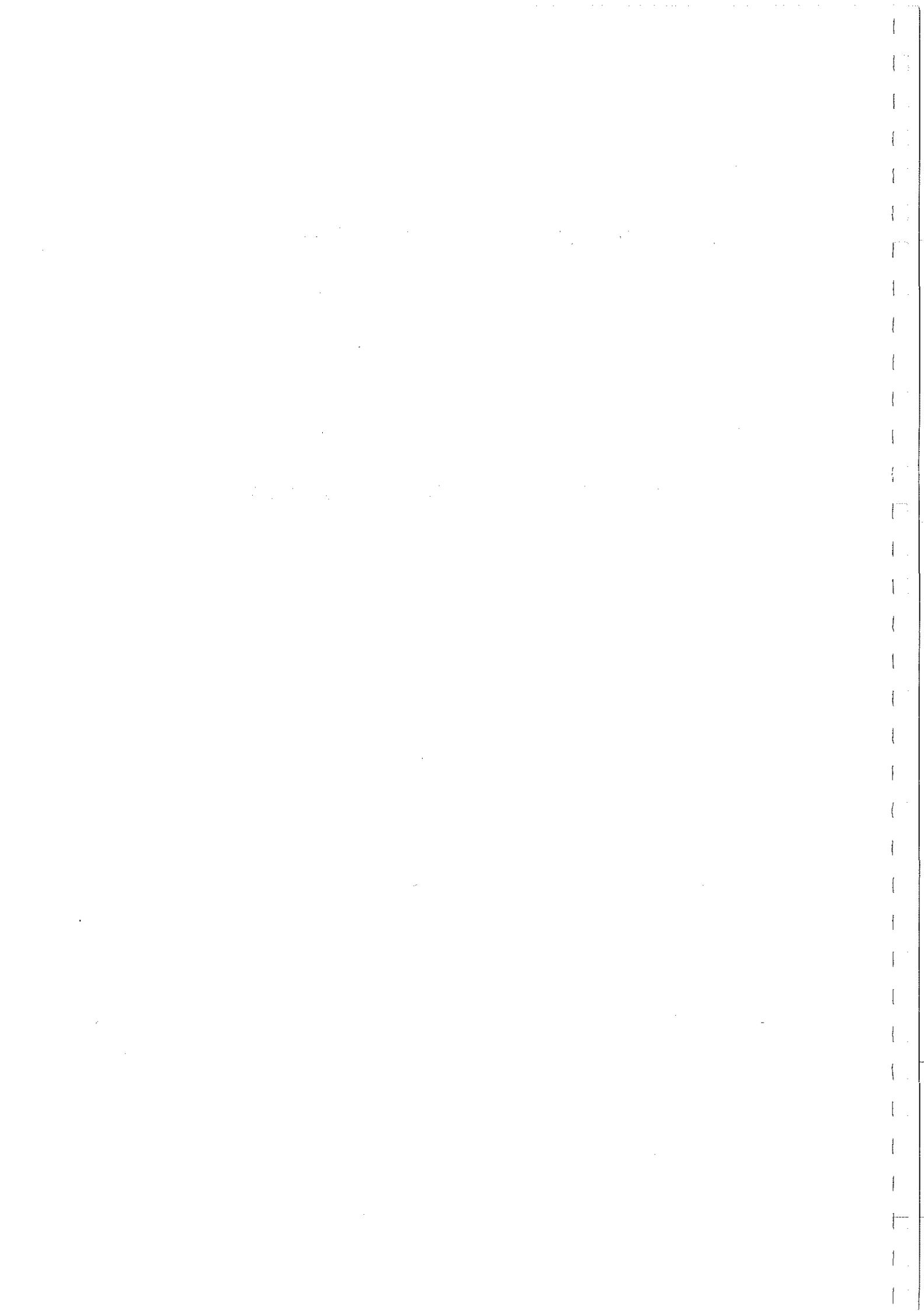
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WESTERN AUSTRALIA

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## SUMMARY OF CONCLUSIONS

The Technical Advisory Group has concluded that:

- *Bauxite mining is a legitimate and economically desirable land use in parts of the Darling Range.*
- *Bauxite mining gives rise to serious environmental problems many of which are currently unresolved.*
- *Existing State legislation is neither sufficiently clear nor adequate for the proper regulation of the bauxite mining industry.*
- *Valid alternative land use options are not adequately recognised nor protected by existing legislation.*
- *No effective system of land use planning exists for the Darling Range that will ensure the integration of bauxite mining with other land uses to the best interests of the State.*

We make the general recommendation that whilst some expansion of Alcoa's refining capacity appears justified in the economic interest of both the State and Alcoa, this should not be entertained without changes to provide better control of the industry in terms of both refining capacity, and the duration and areal extent of bauxite mining operations. The delineation of future bauxite mining areas should result from planning which recognises, secures and integrates other land use options as part of an overall strategy for the long term utilisation and environmental protection of the Darling Range.

We advise that the Wagerup Environmental Review and Management Programme be rejected. The Company should submit a revised ERMP. Provided that the guidelines given in our detailed Conclusions are followed, the State should look favourably on the Wagerup alumina refinery and bauxite mining project.

Conclusions are given in full in Chapter 12.

## CHAPTER 1.

### INTRODUCTION

Alcoa of Australia Limited proposes to establish an alumina refinery at Wagerup, Western Australia. As required by the Alumina Refinery (Wagerup) Agreement and Acts Amendments Act, 1978, the Company submitted to the Minister for Industrial Development an Environmental Review and Management Programme (ERMP) in respect of the refinery to be constructed and the mining associated with it. The Minister has referred the Wagerup Environmental Review and Management Programme (WERMP) to the Environmental Protection Authority for their advice under Section 57 (1) of the Environmental Protection Act, 1971-75. Because the issues involved in the environmental assessment are complex, and some of the most important ever to face the State of Western Australia, the Environmental Protection Authority appointed a Technical Advisory Group to review the document with special reference to the following broad issues:

- the potential increase in the salinity of stream base flow
- the impacts of mining on the ecosystem of the Northern Jarrah Forest
- the need for a determination of the long term land use objectives of the Darling Range.

Full terms of reference are given in Appendix I. It is to be noted that they exclude certain important areas of pollution control, referring mostly to the refinery site.

The Technical Advisory Group was briefed on 28 June, 1978, and this report was presented on 4 August, 1978. The members of the Technical Advisory Group are:

Dr M.J. Mulcahy	Department of Conservation and Environment (Chairman)
Mr F.E. Batini	Forests Department
Dr A.R. Glenn	School of Environmental and Life Sciences, Murdoch University
Dr D.R. Hudson	CSIRO, Division of Mineralogy
Dr D.J. Kitchener	Western Australian Museum
Mr I.C. Loh	Public Works Department
Mr J.F. Thomas	CSIRO, Division of Land Resources Management

The area considered by the Technical Advisory Group comprises part of the Alcoa and Alwest leases. It extends roughly from the northern boundary of the Helena catchment (the Perth-York Road) southward to include the Collie River catchment, and is bounded to west and east by the limits of State Forest (excluding Dryandra).

The Alwest proposal to mine bauxite at Mount Saddleback and refine alumina at Worsley are the subject of a separate ERMP, and consequently have not been specifically considered here, though many of the general considerations outlined will be relevant.

In addition to Alcoa's ERMP document, the Technical Advisory Group also had available submissions to the Environmental Protection Authority from other Government Departments and Authorities, and from the public.

The Technical Advisory Group has been greatly assisted in its work by the support of the staff of the Department of Conservation and Environment, particularly —

Mr P.J. Browne-Cooper

Mr R.M. Nunn

Mr B.M. Stewart

Mr M.J. Maher

Mrs D.M. Burnham

In addition, the valuable assistance given by briefing officers from other Departments is gratefully acknowledged, in particular:

Mr J.G. Kuehne                          Department of Industrial Development

Mr E.G. Freeman                        Crown Law Department

Mr N.C. Philip                         State Energy Commission

Mr R.A. Swan                         State Energy Commission

In reviewing the Wagerup ERMP the Technical Advisory Group required additional information on Alcoa's current operations at Jarrahdale and Pinjarra. Most of this information was made readily available by the Company at a briefing session in the Department of Conservation and Environment. Forests Department officers and Company staff conducted field trips to mine sites and rehabilitation areas at Jarrahdale, Huntly and Del Park, the proposed refinery site and mining areas at Wagerup, and other areas of the Darling Range likely to be affected by mining. The assistance of the following and their supporting staff is gratefully acknowledged:

Mr D.E. Grace                         Forests Department

Dr S.R. Shea                         Forests Department

Mr R.D. Hornbeck                     Alcoa of Australia

Mr C.J. Agnew                         Alcoa of Australia

Mr G.A.C. White                        Alcoa of Australia.

## CHAPTER 2.

### ENVIRONMENT OF THE DARLING RANGE

In the South West of Western Australia there is a combination of factors which taken together give a delicately balanced and fragile environment. The same weathering processes which produced the bauxite ores of the Darling Range have also resulted in the wide extent of extremely infertile and deeply weathered soils. Climatic conditions are characterised by hot, dry summers and cool, wet winters. The abundant winter rains carry inputs of sea salts which, particularly in the lower rainfall areas tend to accumulate in the slowly permeable clays beneath the bauxite.

The natural ecosystems are peculiarly adapted for survival in this harsh environment. Many plants are perennial, with extensive root systems in the deep, permeable, lateritic and sometimes bauxitic surface soils, enabling full utilisation of the water derived from the winter rains. Removal of the forest thus results in disturbance of the hydrologic balance; water not used by the vegetation now flows through the system, causing movement of salts into rivers and streams, and giving greater yields in surface catchments. If, in addition, the bauxitic layers are also removed, the more rapid runoff may cause problems of erosion and flood control.

The low fertility level in the soils means that the biological systems have developed and adapted in order to minimise nutrient losses and maximise efficiency in their use. Many of the processes involved, including nitrogen fixation by legumes, the role of soil fungi in facilitating uptake of nutrients by roots or protecting them from pathogens, the activities of insects and other microfauna in speeding up cycling of nutrients and thus increasing efficiency in their use, or the adaptations of the fauna in general to these conditions, are only just beginning to be understood. But it is already known that the natural systems are fragile and complex. Their functions are easily affected by loss of vigour and disease, and their operation needs to be encouraged by sound management based on scientific understanding. Further, it follows that, once destroyed, they will be impossible to replace in their original form.

The bauxitic laterites of the Darling Range tend to occupy the gentle slopes of the upland areas, where the above conditions apply *a fortiori*. The unique jarrah forest ecosystem also tends to occupy these sites, so that some conflict between its conservation and bauxite mining is inevitable. The valleys of the Range represent important and contrasting ecological conditions. These will also be affected to some extent; in particular, hydrologic changes could have a severe effect on swamps and wetlands.

Thus the natural ecosystems of the Darling Range, adapted as they are to a most unusual and harsh environment, have a scientific interest and constitute an irreplaceable genetic resource of great value, which is not calculable in purely economic terms. Due to the soil and climatic conditions the natural biological productivity of the Darling Range is bound to be low. Its management for productive purposes must recognise this, if it is to be retained in its natural state.

If society wishes to retain areas of this natural environment, careful management of the forest is needed, and other uses must be planned with due account being taken of its conservation values.

European settlement over the last 150 years, with its growing demands for production to support increasing living standards and rising levels of consumption, have had a considerable impact on the natural environment in south western Australia. The State Forest of the Darling Range appears as one of the last remaining extensive natural areas (Fig. 1).

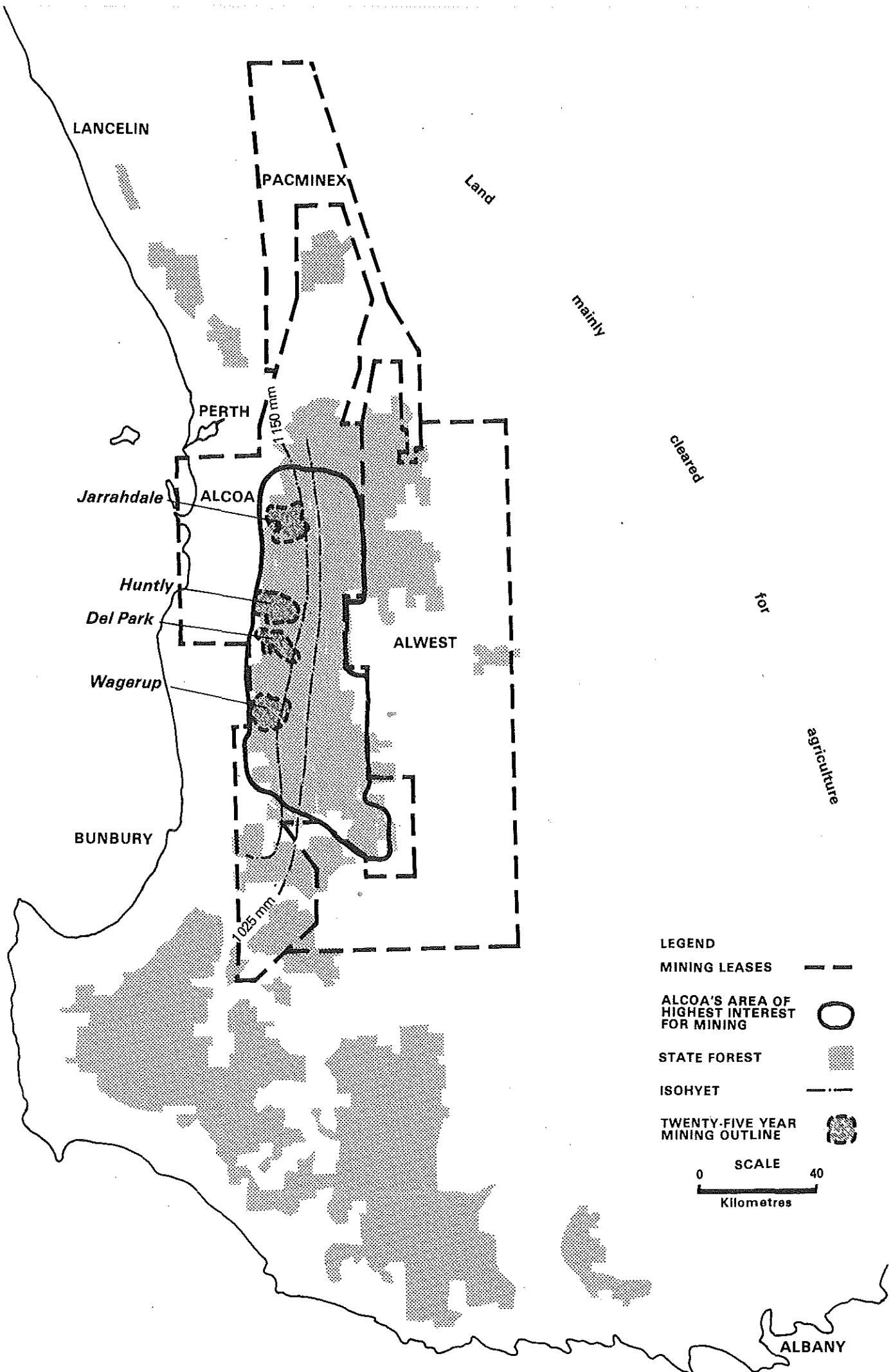


Fig. 1: State forest in south western Australia in relation to mining leases and mining plans.

Its recognised conservation value is reinforced by the need to conserve and protect water resources, and to provide for the growing demands for recreational and amenity use of the forest by the populations of the metropolitan area and other urbanised centres of the coastal plain.

The dispersed pattern of clearing required for bauxite mining constitutes a radical intrusion into the forest (Fig. 2). After rehabilitation, the Darling Range will consist of a mosaic of small areas of healthy natural forest, dieback infected forest, mine sites that have been revegetated using a variety of techniques and species, rehabilitated dieback areas, rehabilitated transport and service areas, and access roads.

The value of the forest as a continuous natural area is thus greatly diminished, and its management problems, whether for conservation, water and timber production or recreation are greatly increased. It is clear that the deployment of the mining operation should be planned to take account of the State and community's interests in terms of these competing and alternative uses of the land.

The question arises as to whether these alternative interests have been adequately presented to Alcoa, and further, if they have been taken into account in the plans and proposals of the Wagerup ERMP.

The following apply to Wagerup only:

- the Company must consult with the Conservator in the preparation of a ten year mining plan, to be updated annually and submitted to the State. Consultation does not imply the necessity for agreement
- the approval of an ERMP is required before operations can commence, and the operations must be in accordance with the ERMP and with any conditions which the State may place on its acceptance. The State may agree with the Company on modifications to the management proposals in the ERMP from time to time
- under the Act expansion beyond 2 million tonnes per year requires a further ERMP.

There is no legal impediment to expansion of refining capacity at Kwinana or Pinjarra. Site limitations at Kwinana prevent significant expansion beyond the present level of about 1.4 million tonnes. The Department of Conservation and Environment understands that a recent letter from the State has informed the Company that any significant expansion at Pinjarra beyond 2.5 million tonnes per year will be subject to approval of an ERMP. Although the Company currently feels obligated by this request we believe:

**3.2 that a legal requirement should be established for the informally proposed Pinjarra ERMP.**

Thus the means of control open to the State, other than *force majeure*, are:

- lease renewal, re-negotiation or cancellation in 2045
- the ERMP procedure, which controls refining capacity, and therefore rate of mining, but not its deployment over the land surface
- conditions of approval of ERMPs, which could possibly be used to control deployment of mining and environmental management practices
- provision for 10 year mining plans with yearly review, which could perhaps be used to achieve more detailed planning of the mining operation, in time and on the ground
- provisions for health, safety and prevention of pollution etc.

Beyond the above there is at present no legal obligation on the Company to accept any proposed modification of their mining plans to take account of the State's interest in conservation, forest and water resource management.

A further point which concerns us is that under the Wagerup Act, statements of intent or procedures for research, monitoring and management given in the ERMP may acquire legal status once approved by the State, and that they cannot be subsequently changed unless the Company voluntarily agrees to do so (*pers. comm.* Crown Law Department). This seems impracticable and unreasonable. It could be legally possible for mining to proceed for very long periods within limits set by approval of a particular ERMP, regardless of new research developments or emerging environmental concerns. In view of the uncertain legal situation we would strongly urge:

**3.3 that the State does not accept the ERMP without clarifying the legal status of the document.**

**Under no circumstances should the ERMP be accepted in toto if it has binding legal status.**

The inadequacy of the environmental safeguards in the current legislation has emphasized the need for legal expertise within the Department of Conservation and Environment. While the Department has access to Crown Law opinions, we are not convinced that such opinion is always fully aware of environmental implications or requirements. In view of this we recommend:

- 3.4 ***that the Department of Conservation and Environment employ a legal officer to advise the Department on legal aspects of environmental matters.***

We do not mean to suggest that legislation alone can provide adequate protection. It does however, set up a framework whereby management and planning strategies, designed to minimise deterioration of the environment, can be established and enforced. **The State should also give consideration to extending the powers of the Environmental Protection Authority as one mechanism of improving the current situation.**

Assurances from Crown Law of the importance of non-legal powers do not lessen these concerns. This inadequacy of the legal framework in this State contrasts markedly with the situation in many other western nations where environmental safeguards are more fully incorporated into legislation. This enables environmental factors to be evaluated along with economic, financial and technical considerations before decisions are taken. In view of this very serious concern we recommend:

- 3.5 ***that the State explore ways of regaining a greater degree of legislative control over bauxite mining as a matter of urgency.***

## **Implementation of ERMP Procedures**

In addition to the above reservations on legislative control of bauxite mining we are concerned about the methods by which the legislation came about and the methods by which the ERMP procedure has been implemented in practice.

Given that the Alcoa WERMP was already prepared we have been unable to discover the rationale for the passing of the Alumina Refinery (Wagerup) Agreement and Acts Amendment Act, 1978 before the State and public assessed the document. This haste precluded the opportunity for major amendments to earlier Acts, or for incorporation of suitable safeguards into current legislation after the review of the WERMP. One mechanism for developing adequate environmental safeguards has therefore been lost. Apart from losing an opportunity for increasing environmental protection, this action is likely to have had some adverse effect on public confidence in the Government's commitment to environmental matters.

## **ERMP Procedures**

The guidelines for the Wagerup ERMP were worked out by the Department of Conservation and Environment and Alcoa. There appears to have been little input to the guidelines by other State Government departments or the public. We would encourage a wider participation in the formulation of guidelines in future. While recognising the difficulties we feel that in some respects those for the Wagerup ERMP failed to explicitly request coverage of certain key areas. For example, we feel that there should have been a requirement for the company to discuss the effects of the Wagerup project in relation to the overall impact of bauxite mining on the Darling Range, over the full period of their mining operation.

The economic analysis of the current proposal is difficult to assess (see Chapter 4) because of the lack of a cost-benefit analysis. We believe that not only should a cost-benefit analysis have been required in the guidelines, but that it could have been performed and its results described without violating Alcoa's needs for secrecy. As it is, and as the WERMP (p. 402) admits "the cost-benefit analysis presented for this project is more accurately a financial analysis...", and it is not surprising that the reader remains unconvinced that the project represents a wise use of resources.

It is difficult to evaluate the environmental costs associated with a proposed development like the expansion of bauxite mining and alumina production, in isolation. However, we believe that such an approach is encouraged by the ERMP procedure which, constrained by legal requirements and bureaucratic rules, almost compels piece-meal assessment; this is in conflict with proposals for integrated regional planning which we advocate later under Land Use Planning (Chapter 11).

The sequence of events from the formulation of the guidelines to the approval of the ERMP appears to be unsatisfactory to both the State and the Company. We believe that a major improvement would be to separate the environmental review from the management programme; the approval by the State of a satisfactory environmental review would, we believe, facilitate the subsequent development of the management programme.

The programme would then have a basis in an agreed statement on likely environmental effects, the adequacy of our current knowledge, and an identification of areas where more information was needed. Enactment of legislation at this stage would enable the inclusion of more realistic provisions for environmental protection than at present.

We recommend:

- 3.6 ***revising the ERMP mechanism to provide for approval of an environmental review prior to developing guidelines for the management programme.***

*Adequate time must be allowed for evaluation of future ERMPs.*

### **The Wagerup ERMP**

We expected that the WERMP would give a management programme for the mining of bauxite ore and refining of alumina for the expected life of the proposed 2 million tonne Wagerup refinery. However, the mining strategy is outlined on the basis of the refinery capacity reaching 4 million tonnes and the mining plan given is for only 25 years of the possible 70 year life of the project. It is unrealistic either to expect the Company to provide mining plans beyond 30 years at this stage, or to expect the corresponding approval from the State. It is therefore not at all clear what approval of the document entails in terms of extent and length of the mining project. We believe that the project should be defined more clearly both in terms of time and area (see Conclusions, Chapter 12).

Within the Wagerup 25 year mining area, alternatives to the optimum mining plan are inadequately explored. The value of the Samson Conservation MPA is assessed in terms of the high value of the refined alumina that it might produce. It would be more appropriate to use the much lower value of the contained bauxite or the small extra costs involved in modifying the mining plan to avoid the area (Chapter 4 and Appendix V). This typifies the attitude to other land uses expressed in the WERMP, which contributes to the lack of balance and objectivity, a recurring feature of the document. It tends to gloss over problems and use inadequate data with an unjustified degree of confidence (see, for example, Chapter 9). We would have preferred a recognition of the limits of present knowledge,

## CHAPTER 4

### MINING, ECONOMICS AND ENVIRONMENTAL PLANNING

#### Social And Economic Implications Of Bauxite Mining And Alumina Refining In Western Australia

##### History

Bauxite mining and alumina refining have played an important role in the economic and industrial development of Western Australia. During the past fifteen years Alcoa has progressively developed its bauxite mining operations in the Northern Jarrah Forest and constructed alumina refineries at Kwinana and Pinjarra. In 1977 a total of 3.45 million tonnes of alumina were produced and exported, establishing Alcoa as the largest single alumina producer in the western world. This represents an estimated 52% of Australian alumina output and about 12.5% of the western world alumina production. A consequence of the development has been the provision of employment for 2,800 people, and indirect employment estimated at between 2 and 3 times this number.

Payments to State Government finances through royalties, port and water charges, payroll tax, rail freight and mining rents exceeded \$13 million in 1977. (However, one questions whether the difference between Alcoa's current royalty rate and that paid by Jamaican bauxite producers is adequately compensated by other advantages to the people of Western Australia; direct payments made by Jamaican bauxite miners are about 100 times that paid in Western Australia.) In addition the State receives a share of company corporate tax and personal income tax paid to the Federal Government.

Alumina exports during 1977 have been estimated to have a gross value in excess of \$270 million, representing 14% of Western Australia's total export earnings. As the industry is dependent on imports of both caustic soda and fuel oil the net export earnings are somewhat less than this.

Because Alcoa has not revealed the full details of its cost structure and profitability the community is forced to accept the assurances of both the Government and the Company that the benefits that accrue to Western Australia are commensurate with both the depletion of a major mineral resource, and its attendant impact on land use alternatives, and the industry's rate of consumption of a valuable non-renewable fuel resource.

##### Future Developments

Alcoa has presented a strategy for development of its bauxite lease over a period of about 70 years. This involves the construction of refineries at Kwinana, Pinjarra and Wagerup with ultimate refining capacities of 1.4, 4.0 and 4.0 million tonnes of alumina. Bauxite ore will be mined from three mining centres at Jarrahdale, Huntley-Del Park and Wagerup with operations eventually extending through about 400,000 ha of the Northern Jarrah Forest. No plans have been announced for any possible developments within the Company's lease to the north and south of the above mining areas.

Alcoa's implied mining strategy does not fully take into account constraints that may occur because of increased salinity risk in the eastern zones of the forest, jarrah forestry, water resource development, conservation, recreation or other land use alternatives. Incorporation of these alternatives into an integrated plan for utilisation of the entire jarrah forest resource might be expected to reduce the total planned refinery capacity.

Factors unrelated to the future of the jarrah forest will also influence the expansion of alumina refining in Western Australia. Whilst the State has agreed to grant bauxite mining rights to Alcoa for a period of 84 years, the Company's operations will be controlled by

such future contingencies as labour supply, profitability, market demand, fuel availability etc. *Because of the uncertain nature of these factors there can be no long term guarantee to the State of a sustained bauxite mining and alumina refining industry.* As far as we are aware a balanced view of future possibilities and alternatives for the Australian bauxite-alumina-aluminium industry and related issues of national resource allocation has not been published, but certainly is required for an assessment of the benefits of bauxite mining projects to the State.

Continued expansion of the alumina refining industry is dependent on further growth in the world market. As discussed in Appendix III, the aluminium industry appears assured of continued growth, but the rates will be below those experienced in the past and will depend on a return to more normal economic activity in developed countries, establishment of new markets in developing nations, and increased usage of aluminium in, for example, transport-related industries.

High energy demands of the industry will continue to be a problem as conventional fuels become depleted and more expensive. Higher prices for aluminium will favour recycling of scrap, and may restrict the further market penetration required to sustain high growth rates for aluminium.

Projections for aluminium demand can be shown to be unreliable (Appendix III) and even a growth rate of 4.5% must be considered optimistic. Given these observations it is suggested that:

- 4.1 *plans for the future developments of the Western Australian alumina industry should be conservative and flexible.*
- 4.2 *expansion of refining capacity by addition of the 2 million tonne Wagerup refinery is the maximum increase that can be justified at present. Future growth of the world aluminium industry will determine how long this increase will maintain Alcoa's share of the world market.*
- 4.3 *maintenance of Alcoa's share of the world market (WERMP, p. 41) should not be considered an a priori justification for increasing refining capacity.*
- 4.4 *plans for integrating Western Australia's industrial and energy development should be moderated to include the possibility that the projected 4.5% growth rate for aluminium is not maintained and that Alcoa's maximum refinery capacity might not exceed 6 million tonnes.*
- 4.5 *in planning land use for the Darling Range the inherent uncertainties of long term demand forecasts should be recognised. It would be a pity if valuable resources for timber production, water supply, recreation and conservation were lost as a result of over optimistic assumptions about the growth and long term viability of alumina refining.*

## Energy Requirements

Western Australia is fortunate in possessing nearly 60% of Australia's estimated proven recoverable natural gas reserves (Appendix IV). Gas from the relatively small Dongara field 240km north of Perth is piped to Perth for residential supply, alumina refining and other industrial use. Demand currently exceeds supply and existing contracts will be progressively terminated from 1982 until gas production ceases in 1987 (Kirkwood, 1977).

The recoverable natural gas reserves from the three Rankin Trend fields of the North West Shelf have been estimated at  $350 \times 10^9 \text{ m}^3$  (Kirkwood, 1977). The planned North West Shelf project involves the construction of two gas-producing platforms, each capable of producing 19.3 million cubic metres of gas a day from about 20 wells. Gas would be piped ashore via a 130km pipeline to a LNG processing plant at Dampier. About 28% of the gas would be made available for use in Western Australia, with some  $3.1 \times 10^9 \text{ m}^3$  per year being delivered by a proposed pipeline to Perth and the South West. The remainder of the gas would be liquified for export. Supply is guaranteed for 20-25 years.

Total natural gas reserves of Australia comprise only 1.4% of the total world reserves (Anderson and Daniels, 1977), and impending problems of local supply have been indicated for most Australian States (Appendix IV).

Australia's dependence on imported petroleum fuels is also expected to increase, in the absence of major new discoveries, from 30% at present to 70% by 1985. Esso Australia Limited has recently reported ("The West Australian", 27 July, 1978) that Australia could face an oil import bill of \$7,200 million by 1990.

Natural gas is a particularly versatile source of energy that can be substituted for petroleum in a variety of applications, including industrial and transport uses. In this context, it could assist in making up the country's increasing shortfall in petroleum; even then the total known North West Shelf resources represent less than 12 years' Australian supply, even if energy usage does not increase after 1985.

We therefore recommend:

**4.6    *That the future allocation of Australian remaining reserves of natural gas and oil be looked upon as a subject of the highest national importance.***

Bauxite mining and alumina refining dominate mineral processing fuel demand in the South West (SEC, 1978). The refineries at Kwinana and Pinjarra currently use both imported fuel oil and Dongara natural gas for energy requirements. Indeed, the guaranteed demand for gas by Alcoa was an important factor in determining the viability of the existing Dongara to Perth pipeline. A similar argument has been applied to Alcoa's role in providing an adequate base-load for the proposed Dampier to Perth natural gas pipeline, although the Company's future energy demands could equally well be met by various combinations of fuel oil, gas, coal and nuclear energy.

The State Government, through the Department of Industrial Development (DID) and State Energy Commission (SEC), have given enthusiastic support to expansion of the alumina refining industry as part of an integrated development proposal with the North West Shelf natural gas project. As discussed in Appendix IV, the degree of commitment by the State to this development could be argued as having pre-empted the WERMP.

Projections of future gas usage, made by the SEC, appear to be based on the assumption that Alcoa's alumina refining capacity in Western Australia will increase to a minimum of between 5 and 7 million tonnes per year by 1988 and ultimately will reach 9.5 million tonnes (Appendix IV), and suggest that preliminary agreements have been reached for Alcoa to purchase between half and two thirds of the proposed Dampier to Perth supply. In addition the DID have prepared statements (DID, 1978a and 1978b) which point out the many virtues of alumina refining in general and the Wagerup project in particular, but give scant treatment of possible disbenefits. This course of action invites confrontation rather than co-operation between those Government Departments committed to development and energy and those committed to conservation and environmental protection. We conclude:

**4.7    *That plans for future industrial development and energy utilisation in Western Australia should include an early assessment of environment implications.***

There is no doubt that alumina refining, even at the present level of production, provides a substantial market for North West Shelf gas, and gives the State a strong economic justification for building the Dampier to Perth pipeline. The large, and immediate gas requirements of the industry will ensure the most economic transport of gas to Perth, and will assist in minimising the transport component of gas costs for South West consumers.

This does not however, constitute justification for unrestricted growth of alumina refining. This cannot be accomplished without seriously eroding the gas supply, available for residential, commercial and non-mineral industry users in Perth and the South West (Appendix IV). We recommend that:

**4.8     *The SEC honour its undertaking to provide "top priority" treatment for residential, commercial and non-mineral processing gas users.***

Alcoa anticipates that the life of its bauxite mining and alumina refining projects in Western Australia will be in excess of 70 years (WERMP, p. 2), or until the middle of the twenty first century. No assessment has been made of the possible sources of energy for the industry if natural gas reserves are depleted before this time.

Western Australia is almost totally dependent on fossil fuels (Fig. 2, Appendix IV). Coal production from Collie is assured for 40 years or until about 2020. Present reserves of natural gas from the Rankin Trend are sufficient to guarantee production until 2005. The remaining fuel requirement is met by largely imported liquid petroleum products. If substantial discoveries of recoverable oil and gas are not made during the next 20 years, Western Australia will become dependent on imported fuels for nearly 80% of the anticipated energy demand. Prices for liquid petroleum products are expected to rise as world reserves become depleted. Our increasing dependence on overseas oil will make fuel supply potentially uncertain and will erode profitability of Western Australian industries.

Exploration activity on the North West Shelf, Exmouth Plateau and offshore Perth Basin will proceed at a high level for at least the next 6 years, and it is probable that new gas resources will be indicated during the exploration and possible that new oil fields will be found. There can be no doubt that the Government will be in a much better position to judge the magnitude of our natural gas and oil resources in 1984 than at present.

We conclude that:

**4.9     *It would be irresponsible for Government to fully commit existing natural gas and oil resources before careful evaluation has been made of the results of the current oil and gas exploration activity.***

If the current oil and gas exploration is unsuccessful the Government may find that its proposal for a nuclear electricity-generating facility will become an early necessity in order to maintain energy requirements for planned and existing Western Australian industrial development. The cost of such a venture, or the cost of imported fuel oil, will be critical in determining whether Alcoa will be able to compete successfully against countries with alumina industries based on cheaper forms of power generation.

It has been shown (Appendix IV) that alumina refining is energy intensive relative to other industries. One is forced to question:

**4.10    *Whether alumina refining is an effective use of natural gas at a time when the country's long-term energy problems remain unsolved and there is a high rate of unemployment.***

Reduced or deferred development of the North west Shelf gas resource will result in a short term loss of employment and industrial opportunities. It should be recognised, however, that this is a very real possibility in view of the depressed world economic scene, and the number of countries hoping to develop LNG projects. However the long term result for Australia of a project of reduced scale (for example, 1 platform) should not be viewed with total pessimism. It could provide the breathing space to allow a clear review of the future energy options, and may conserve a rapidly dwindling Australian resource that may assume an even greater economic significance in the future.

## **Integrated Development**

Several further integrated industrial developments dependent on natural gas, have been suggested for the South West in the next decade. New alumina refinery capacity can be designed to permit combined cycle electricity generation, which would efficiently produce substantial quantities of electric power surplus to refinery requirements. The extra power opens the possibility of aluminium smelting, the production of caustic soda (required for alumina production) from local salt supplies, and the integration of this with a

petrochemicals industry producing ethylene dichloride for export or further industrial processing such as the production of plastics.

## Planning for Development

This section has shown that the alumina industry already plays a special role in the working of the State's economy. Proposals for expansion of alumina production have considerable and far reaching implications for economic expansion, industrial development and energy resource allocation. It is tempting to assume that maximising the growth of the alumina industry is in the State's best interest. However, we suggest that while some expansion is justified, maximum expansion of the industry could be detrimental to the economic future, and that the most critical objectives of economic and energy resource development may be achieved with a more modest increase in alumina processing. In any case, it is by no means certain that the most ambitious of Alcoa's plans can be realised. In addition, we have the serious environmental impact of large scale bauxite mining.

Whilst it is easy to assert that a conservative outlook restricts development, it would seem irresponsible to fully commit existing resources — either bauxite, energy, or the natural environment — without further careful integrated planning.

## Impact of Bauxite Mining in the Darling Range

Alcoa's bauxite mining operations at Jarrahdale, Huntly and Del Park lie within the high rainfall zone to the west of the 1150 mm isohyet. This zone contains the highest concentration of bauxite ore in Alcoa's lease and has the advantage of proximity to existing and proposed alumina refinery sites. It is an area in which the risk of increased stream salinity following clearing of jarrah forest is believed to be low. Also, the zone includes the areas of greatest impact from jarrah dieback..

This area is of obvious importance for water catchment and forestry, and also has a number of features, less easy to define, that make it of unique importance as a recreational area for the people of Western Australia (see Chapter 6).

Detailed long term mining plans for Alcoa's lease have not been published. However, the WERMP indicates expected 25 year mining areas based on ultimate annual alumina refining capacities of 1.4 million tonnes at Kwinana and 4 million tonnes at both Pinjarra and Wagerup. If these capacities are realised the total area within the mining envelope by the year 2007 is estimated at about 60,000 ha or 30% of the area of the western zone. By then the area affected would be increasing at a rate of about 3,000 ha per year or 1.5% of the area of the western zone.

Areas that have been affected by all mining operations over the past fifteen years at Jarrahdale, Del Park and Huntly amount to only about 4,000 ha. Although this mining has already had a considerable impact on land use it represents only 1.5 years of mining at the planned rate for the next century.

Figure 3 schematically illustrates the extent of mining operations after 25, 50 and 70 years if the planned production rates are effected. The 50 and 70 year mining envelopes have been calculated on the basis that bauxite is less densely distributed towards the east. An arbitrary factor of twice the area per tonne of alumina produced has been used in accord with the assumption of Peck *et al* (1977).

The 25 year mining envelopes lie almost entirely within the western zone, and are based on a crudely concentric pattern of advance. Continuation of the concentric mining pattern at a rate consistent with the 9.5 million tonne combined refinery capacity would result in mining extending into salt prone areas after about 25 years. If, as part of an alternative strategy, mining were restricted to the area west of the 1150 mm isohyet there would be sufficient bauxite to support operations for about 35-40 years.

We have pointed out in the preceding section that it is by no means certain that the maximum rate of alumina production of 9.5 million tonnes per year, will ever be realised. Rather there seem to be strong reasons why plans for economic development and land utilisation in Western Australia should consider a more modest rate of expansion of the alumina in-

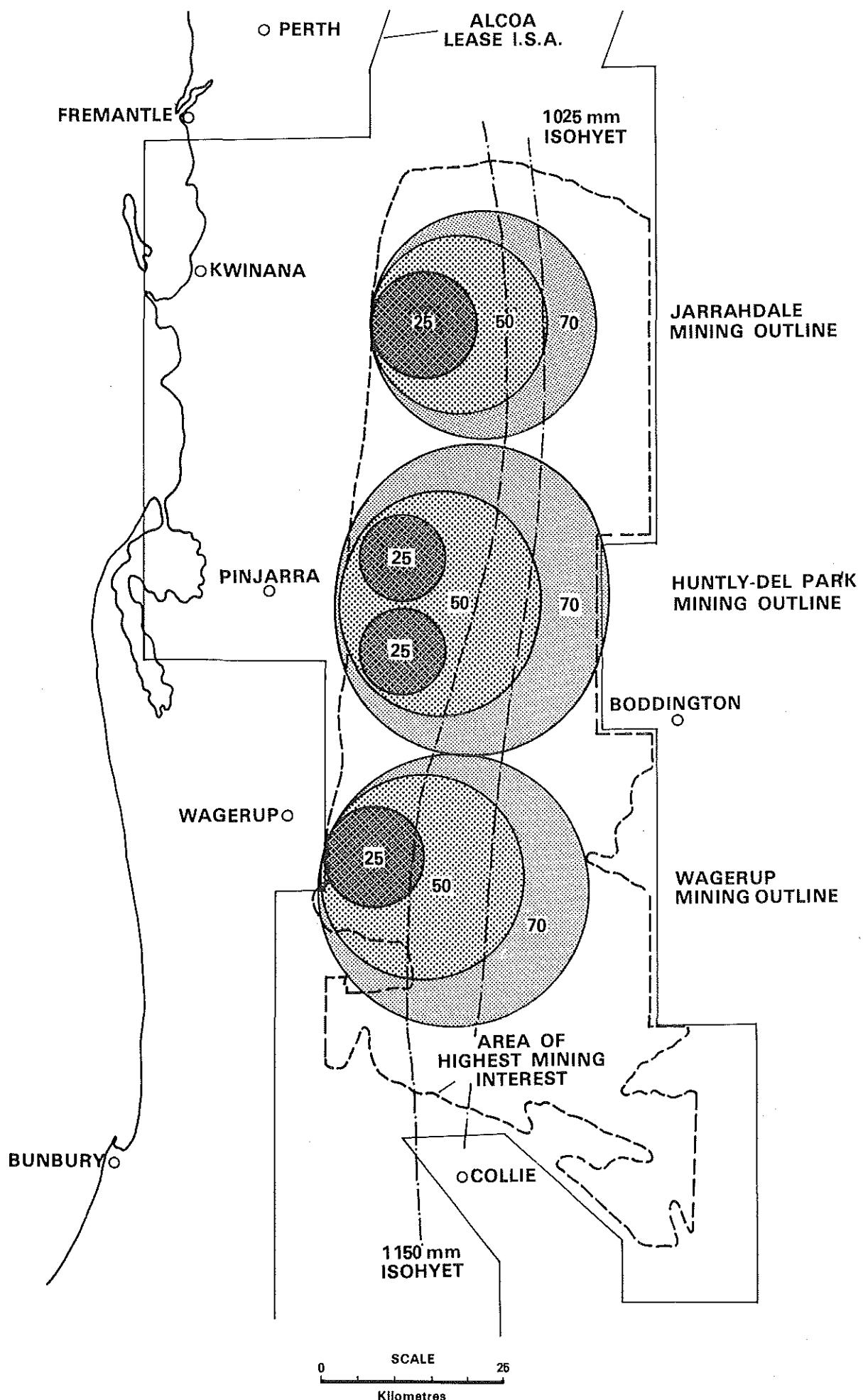


Fig. 3: Schematic diagram of areas of forest affected by bauxite mining after 25, 50 and 70 years at refinery capacities of Kwinana 1.4 million tonnes, Pinjarra 4.0 million tonnes, Wagerup 4.0 million tonnes. (Bauxite distribution in 25–50 and 50–70 year mining areas assumed to be half as dense as in 25 year mining areas).

dustry. At a refinery capacity of 6 million tonnes per year there is sufficient bauxite to the west of the 1150 mm Isohyet for 45-50 years of mining.

The total area west of the 1150 mm Isohyet that has been declared or proposed as conservation reserves can be estimated at about 13,000 ha. Scientific MPAs would cover an additional 7,000 ha and areas for timber production some 15,000 ha. A number of the conservation reserves occur along river valleys or on the dissected margin of the western zone and, as a consequence, contain large areas with little or no potential for bauxite mining. Nevertheless the total area of 35,000 ha amounts to less than 20% of the area west of the 1150 mm Isohyet. The resource contained in these areas set aside for alternate land use is about 10 years of the expected 50 years of mining activity.

This slower rate of advance of mining together with the dispersion of mining into three widely spaced centres along the length of the bauxite resource should enable a mining strategy to be developed that makes allowance for the variety of competing land uses within the western zone.

## Mining Location and Production Costs: Their Relation to Public Policy

Each of Alcoa's enterprises in Western Australia have integrated bauxite mining and alumina production in geographically concentrated complexes. This distinguishes them from other ventures such as the bauxite mining industry at Weipa in Queensland, which ships its ore to Gladstone before refining into alumina. Alcoa's ability, through its agreements with the State, to extract bauxite in close proximity to the refinery and also close to major installed regional infrastructure appears to be a most significant factor in determining the present competitive advantages of its Western Australian operations. *Indeed such is the apparent advantage gained by Alcoa from this situation, that we feel there is a considerable degree of freedom to adjust local mining strategies to environmental needs.*

The overall impression given by the WERMP is that bauxite mining is simply too profitable an activity to be hindered by the preservation of existing land uses. The WERMP (p. 52) cites factors which may cause exceptions to the general Alcoa policy "to mine all bauxite in its lease" (WERMP, p. 50). These factors relate to minimum ore body size, maximum slopes, proximity to private land or structures, situations where facilities such as roads or power lines are already located over ore bodies, and "in areas so environmentally sensitive that mining will not be conducted." (WERMP p. 52). However, there is no mention of commercial forestry, recreation, areas of scientific interest, or water resource conservation as existing land uses which perhaps should take precedence over the proposed bauxite mining activity in some parts of the Darling Range. Moreover, in its comments on the most important conservation reserve in the 25 year mining envelope proposed for Wagerup (the bullich reserve), Alcoa makes it clear that it believes bauxite mining should proceed. (WERMP, p. 355).

Thus the WERMP expresses an inflexible attitude regarding the location of mining. This perhaps stems from the legislative and legal background to the bauxite mining industry in Western Australia and we believe it is fundamentally mistaken.

For illustration, let us take an example from a metropolitan area. An industry with a high level of air pollution wishes to establish in the metropolitan area, but its preferred location would add to existing pollution to such an extent that the metropolitan planning authority proposes a second location. The site originally chosen by the industry continues in its old use, which was grazing for six ponies. Although higher costs to the industry are involved, in the form of higher transport costs to the local port, it is judged that the benefits to society in the form of reduced concentrations of air pollutants are of greater worth than the extra transport costs. In assessing the merits of the relocation, the Government sensibly ignored all costs and benefits which were constant as between the two alternative locations and only considered those which were affected by the relocation. It would have been ridiculous to suggest that a comparison of the benefits of industrial development with those of pony grazing on the site, were at all relevant to the decision about location.

Unfortunately, this is exactly the error committed in the WERMP (see the account of losses to the alumina industry of retaining the Samson Management Priority Area, p. 355). Instead of looking at the complete schedule of costs of obtaining bauxite for the refinery, and assessing the difference which alternative mining patterns would make to these costs, the WERMP simply quotes the value of alumina which could be produced with the amount of bauxite which could be obtained from the Sampson area. This is exactly analogous to the comparison of pony grazing benefits with metropolitan industrial development, and is of course irrelevant to a decision about mining location.

Accordingly, just as the Government has to weigh the costs and benefits of alternative locations for industry in the metropolitan area, it should also do this for alternative locations for bauxite mining in the Darling Range. It cannot be assumed that the least cost course of action for the industry is necessarily consistent with the interests of the community as a whole. Moderate additions to the costs of industrial production may be justified by wider criteria which take into account the costs which industry imposes on other sections of the community. Thus, we recommend:

- 4.11 **that alternative, environmentally conservative mining plans be assessed with regard to the differences they make to the costs and benefits of the alumina production project. Any net loss to the industry has to be weighed against net gains from forestry, recreational opportunity, scientific areas, supply of water or conservation of flora and fauna.**

There is of course one aspect in which the analogy between decisions about bauxite mining location and metropolitan industrial location does not hold. A mining company extracts a physical product from each location. Eventually, when the bauxite resources of the Darling Range are approaching exhaustion, it might be claimed that the costs of foregoing any remaining ore bodies become the full value of alumina production. But this is not so. The very maximum cost of foregoing some deposits in the Darling Range would be the extra cost of bringing ore to the refinery from elsewhere in Australia. From the point of view of present day decisions these extra costs lie far into the future and discounting reduces them to minor proportions.

This latter marginal measure of the cost of foregoing some bauxite deposits in the Darling Range may actually be an overestimate. The refinery plant will be fully written off within 30 years of installation. We simply cannot know what factors will influence the economics of alumina refining fifty years from now, but it seems certain that there will be major changes in world-wide demand and supply conditions. (See our comments on the world demand for aluminium and cost factors in alumina production in Appendices III and IV.). If, by the middle third of the 21st century, alumina refining in the South West had become uneconomic, no cost would be involved in "foregoing" some remaining ore bodies in the Darling Range.

Compilation of mining plans which pay regard to wider community interests as well as industrial objectives would require a considerable co-operative planning effort between the Company and State Departments. It would be irresponsible of us to recommend that such a major undertaking of analysis and planning should precede any firm commitment to a mining strategy, without being reasonably sure that this was likely to bring about a net gain to the community. It is therefore necessary to consider what magnitude of cost might be imposed on the alumina industry if it had to comply with a conservative mining plan.

**Alcoa's costs of production in Western Australia are a closely guarded secret.** But if we are to assess the trade-offs between environmental objectives and the bauxite mining industry, we must get some idea of the cost structures of mining and refining as separate operations. (See Appendix V.)

Comparison of the proposed Wagerup project, using data given in the WERMP, with alumina production in the United States and elsewhere (Commodities Research Unit, 1978) suggests that alumina refinery costs in Western Australia are roughly at par with those elsewhere, average production cost in the first 15 years being about \$120/tonne at 1977

prices; (excluding cost of bauxite and gross margin from alumina production, but including capital servicing costs of the refinery).

In contrast, the economics of bauxite mining in the Darling Range, and in particular the cost of bauxite delivered to the refinery at the foot of the Darling Scarp is unlikely to exceed \$3.00 per tonne of bauxite, or about \$10 per tonne of alumina produced. This is very much lower than the delivered cost of bauxite to an alumina refinery elsewhere in Australia in 1976 of US \$23.00 per tonne of alumina and may be compared with an average delivered cost of bauxite to alumina refineries in the USA in 1976 of US \$70 per tonne of alumina (Commodities Research Unit, 1978; this estimate includes the cost of royalties and levies, and transport to the USA).

We have thus established that the costs of bauxite mining are small relative to those of the alumina refining process. Further, from the very extensive endowment of bauxite in the Darling Range it is apparent that there are numerous combinations of ways in which a refinery with given production plans, can be supplied with bauxite throughout the period of its operations. Some patterns of mining may be more expensive than others, as a result of increased extraction, transport, or reclamation costs; but since bauxite extraction forms a minor part of the costs of alumina production we should not expect "distortions" of the mining plan to seriously affect the economic returns to the project as a whole. For example, at \$3 per tonne, bauxite delivered to the refinery represents only 8% of production costs of alumina. Hence an environmentally conservative mining alternative, which increased mining costs by 10% would add just 0.8% to production costs of alumina.

Appendix V presents a worked example of how mining costs would be affected by excluding the Samson and Mount William mine sites from the 25 year mining envelope for Wagerup, by substituting alternative mine sites at a slightly greater distance from the refinery. Exclusion of these two areas would increase discounted mining costs by only 1% over a twenty five year period. This represents about 0.1% of the total cost of producing alumina. It is easy to envisage that variations in expenditure on minesite rehabilitation could counterbalance this increase in bauxite transport costs. At little or no cost to Alcoa, bauxite mining could be directed away from areas which yield environmental benefits to the community as a whole, provided that some of the Company's valid operating requirements are recognised in devising mining strategies.

Thus we recommend that:

**4.12 the cost of modifying the bauxite mining plan in order to achieve environmental objectives, and also the cost of foregoing some of the deposits should be recognised as being fairly small.**

## **Benefits from Conservative Environmental Management**

The very fact that the costs of alternative mining plans are likely to be small in relation to alumina production costs should encourage the State to ensure that those existing land uses which serve a useful purpose, and which cannot easily be replaced by reclamation technology, are not obliterated by the mining activity. Rather we recommend that:

**4.13 mining should be directed to areas where the loss of the existing use is of least consequence for timber production, water supply, recreation, science and conservation.**

To support this opinion, we offer some general comments here about the nature of benefits to be gained from such a policy. More detailed comments about land uses affected by mining are given in subsequent sections of this report.

Our most general comment about the economic benefits of these land uses is that they should be valued in the same way as is proposed for the mining operation. That is, attention should be concentrated on the differences which alternative mining plans might make to the generation of benefits from other land uses. However, whereas the additional costs to Alcoa of adopting alternative mining plans may be small, the costs of some mining plans as they impact on the production of hardwood timber, water resources, recreational venues, and areas which are conserved in their natural condition, may be large. As an example, the cost of providing a new water storage, if an existing storage were to be damaged by the effects of bauxite mining, seems likely to be quite large, in relation to the costs of diverting mining into a direction in which the water storage was not at risk.

Not only is it possible that bauxite mining may have relatively large impacts on the cost of providing other goods and services from the natural environment; it may also affect the **total** level of benefits which it is possible for the community to experience. An example would be in hardwood timber production. Millable timber and poles are taken out of the forest immediately preceding bauxite mining. In some cases it would be economically advantageous to leave such stands to mature to provide high quality jarrah timber at a later date. In the case of jarrah, diminishing availability is confidently predicted, so premature harvesting or spread of dieback affects not only the cost of timber supply (by necessitating harvesting of hardwoods from further afield, and investment in substitutes for natural hardwoods, i.e. in softwood plantations); it also reduces the level of hardwood consumption which it is possible to achieve. A limit on consumption may be involved, and economic opportunities lost.

The recreational services of the natural environment may also be affected by mining. We recognise that in some areas recreational opportunities may be enhanced after bauxite mining has occurred, compared to the original condition of a site. In certain situations, however, the existing environment offers a unique recreational experience which it would be almost impossible or at least prohibitively costly to replace after mining has taken place. There is a good case for excluding mining from these areas.

In such cases the allocation of bauxitic land resources of the Darling Range presents a choice between a reversible and an irreversible decision. The land can serve as a source of raw material for the alumina export industry, or it can be preserved as a unique natural phenomenon for nature appreciation and related recreational and/or scientific interests. A decision to preserve the natural features is, of course, a reversible decision, as at any time it would be technically possible to permit mining to proceed. If, however, the land resources in question were allocated to bauxite mining a set of consequences would follow that would have more permanent implications. For example, mining could involve the destruction of areas of protectable jarrah forest and bullrich vegetation, which form part of the unique Northern Jarrah Forest, being the only example of this type of forest in the world today. **A decision to "restore" the area following depletion of the bauxite resource would be technically impossible to implement.** The consequences of bauxite mining, in terms of the foregone benefits from the alternative aesthetic and scientific uses, would be experienced in perpetuity.

The irreversibility of mining is nowhere more obvious than in the proposal to mine in the conservation reserves. It is still a matter of conjecture as to whether the methods of economic analysis can, or ought to be extended and developed to give society wise criteria for allocating such resources but they were notably absent from the WERMP. Certainly, in the crude terminology of economics, there are "benefits" in merely knowing that a certain species or natural habitat is extant, even if direct experience of the phenomenon is prohibited in the interest of its conservation. Society has not become used to facing questions of inter-generation conflict in resource allocation.

Environmental economists have shown how the relative value of the amenity services yielded by natural environments to increase over time, relative to the value of commodity services. They have proceeded to incorporate relevant benefit measures of these amenity

services into social welfare analyses of proposed developments which affect the natural environment (Krutilla and Fisher, 1975, Cichetti and Smith, 1976, Sinden, 1978).

There are, however, certain obstacles preventing this type of analysis in Western Australia. Data on recreation activity are not available in a form suitable to this type of analysis, and there are fairly wide margins of error on any forecast of demand for amenity services of the natural environment. No studies of the "option value" which the community places on conservation of the jarrah forest and ecotypes of the Darling Range have been undertaken. Despite manifest concern about the environment, the plain fact is that there is very little experience of applying this type of appraisal to Australian resource management, either among professional practitioners, or amongst the political and business community, or the general public.

In such circumstances, instead of trying to take formal account of irreversibility through the advancing techniques of social welfare valuation, it is at least possible and sensible to proceed with caution. That is to say, mining proposals which have little or no impact on areas of environmental quality, should be preferred to those which entail loss of environmental amenity services. Alternative means of reaching the stated objectives of bauxite mining, while reducing the loss of environmental amenity services should be identified wherever possible.

## CHAPTER 5

### EFFECTS OF BAUXITE MINING ON FOREST MANAGEMENT

Most of the area which is of prime interest to Alcoa for the mining of bauxite is vested as State Forests and managed by the Forests Department. The head of that Department is the Conservator of Forests, an independent statutory appointee. The Conservator manages State Forests according to the guidelines defined in the Forest Act and in other policy documents approved by Parliament.

During 1976 the Forests Department prepared a Forest Policy which was approved by Cabinet in May of that year. Subsequently this Policy was discussed in an issue of Forest Focus (No. 17, 1976) which was widely distributed throughout the community. In January, 1977, Parliament formally approved the Forests Department's General Working Plan No. 86 (GWP) (Forests Department, 1977a). This Working Plan assessed the management objectives, policies and strategies for the forest area in both the medium and the long term.

The Department then issued two more planning and policy documents: "A Perspective for Multiple Use Planning in the Northern Jarrah Forest" (Forests Department, 1977b) and the "Land Use Management Programme, Northern Jarrah Forest, Management Priority Areas" (Forests Department, 1978). Both these documents have attempted to translate the objectives set in the Act, the Forest Policy and the GWP into field practice, by allocating areas to specific management priorities and by preparation of prescriptions for management activities.

The presence of a large and increasing, open cast quarrying activity in the forest threatens many of the soundly based multiple use objectives of forest management. These include the production of timber and of other forest products, the protection of the existing surface catchment areas, the fostering of conservation of sample areas of the vegetation, the needs of science, of recreationists and of landscape aesthetics.

Mining has occurred in the forest for many years (Hewett, 1975a). Bauxite mining differs from others in:

- The large area cleared annually and the total area to be cleared
- the apparent unwillingness of Alcoa to deviate from its most economic mining plan
- spreading Jarrah dieback which may greatly increase the impact of mining on the forest, and
- the uncertainties which still surround key environmental aspects.

#### Production Forestry (Hardwood)

Timber is allocated to companies through either a sawmilling permit or a licence. The position in the study area was as follows (Forests Department, 1977b)

Number	— 18
Annual Permissible Intake (m <sup>3</sup> )	— 270 722
Employment — Bush and Mill	— 438

This represented about 25 per cent of the State's annual hardwood production of logwood and 20 per cent of the employment in this industry. The contribution to royalty was about 30 per cent. The requirements of Wundowie for charcoal are 136 000 tonnes of wood per annum. Although the total resource of firewood is considerable, that within economic hauling distance of the plant is limited.



Although the per capita consumption of wood in the State will probably fall, the level of demand for timber is expected to rise, mainly due to population increase. Estimates of local demand for sawn timber were 943 000 m<sup>3</sup> in 1980 and 1 222 000 m<sup>3</sup> by 2010 (Forests Department, 1977a). The current cut of hardwood sawlogs from Crown Land was 931 613 m<sup>3</sup> (Forests Department, 1977c) and it is anticipated that this could decrease to 315 000 m<sup>3</sup> by the year 2010 and to between 150 000 m<sup>3</sup> and 200 000 m<sup>3</sup> by the year 2027 (Forests Department, 1977a). The balance between demand and supply of sawlogs could be made up by an increased programme of pine planting (about 3 000 ha per annum). If this target is not met, shortages of sawlogs will occur and may necessitate considerable imports.

There are several reasons for the considerable and rapid decrease in the available hardwood sawlog resource. These include:

- an unbalanced distribution of age classes caused by a sustained period of overcutting
- effects of jarrah dieback
- loss of forest to other uses
- incorrect appraisals of volumes, growth rates, growing stock and marketability standards, and
- the unavailability of timber volumes in areas managed for other priorities or within the influence zone of other activities.

The current demand of 35 000 poles per annum is increasingly difficult to meet from the jarrah forest, particularly the larger sizes. Because of the wide ranging nature of this operation the risks of spreading dieback are greater. Pole operations are being restricted to areas designated for sawmilling, alternative species (marri, karri, pine) could be used and the establishment of plantations of pole species is envisaged. Roundwood, fencing and other small materials are currently available well in excess of demand and this is expected to continue in the future.

In the Forest Department's Land Use Management Programme (Forests Department, 1978), timber production was generally ranked lower in the management priority than other more dominant uses for the Northern Jarrah Forest. These uses include the conservation of flora and fauna, scientific, catchment protection, water production and recreation management priority areas (MPAs). However, it was envisaged that timber production could continue (with appropriate safeguards) in all areas other than the cores of the Conservation MPAs.

## **High quality forest**

Considerable differences exist in forest quality. This is exemplified by the differences between forest blocks such as Park which is severely affected by dieback and the unaffected, high quality pole stands at Holyoak. Mining should be concentrated in the severely diseased areas. The fact that some 10% of the forest is already affected by dieback and that the hardwood resource is diminishing, should not be used as arguments for promoting further mining. In fact, these same arguments can be used more effectively to promote the proper management of some high quality jarrah forest for the long term production of premier grade jarrah timber and veneers. It is widely recognised that jarrah is an excellent timber species which is likely to be in short supply in the future. Its price is likely to increase sharply.

Irrespective of the relative values of bauxite and jarrah, some good quality jarrah forests should be retained for sustained production forestry. Jarrah is better suited to the environmental conditions and in addition has other functions which may not be readily duplicated on mined-over and rehabilitated land. A number of large contiguous areas should be selected immediately and protected from the impacts of mining.

Criteria for selection could be:

- high site quality — the stands will normally be located on lateritic uplands in the 1000-1250 mm rainfall belt
- low current incidence or likelihood of dieback, and
- pole stands with many years of accumulated growth.

Fairly large (2,000 ha or more) contiguous areas of protectable forest are preferred to small, scattered areas which may degrade and be no longer viable in the longer term. Also larger areas are easier to protect and to manage. In other parts of the forest in the western zone, areas of protectable forest (200 ha or more) should also be excluded from mining, but smaller areas should be mined. Integrated planning between the Forests Department and Alcoa will be essential for the selection of these areas and the Hardwood Operations Control System (HOCS) could be the nucleus for planning at this operational level.

Alcoa has expressed some concern about the duration and viability of forestry which is restricted by the ever decreasing jarrah resource (WERMP p. 295) yet feel that mining is unlikely to have a significant impact on the local sawmilling industry (WERMP p. 409). Certainly if mining were to concentrate primarily in dieback area, and if protectable forests were to be spared, the impact on the timber industry and on the "ever decreasing" jarrah resource would be reduced.

**Because the best quality forest usually grows on high quality bauxite, this proposal would conflict strongly with Alcoa's mining strategy.** There would be a potential loss of mineable ore. However, the selection and management of these forests for timber production need not necessarily result in a loss of ore to Alcoa since the areas **could** be mined at a later date. Some changes to the sawmilling industry's optimal cutting plans (WERMP p. 348) are apparently acceptable. Similarly, medium and long term adverse impacts on timber production are also foreshadowed (WERMP p. 348). It seems reasonable that Alcoa's mining strategy should also contain the degree of flexibility expected of other land users.

### **Protection from Dieback**

If protectable areas of forest are to be excluded from mining and managed for the sustained production of jarrah timber they need to be protected from dieback. In this aspect, considerable differences of opinion exist between foresters, other scientists and Alcoa. Alcoa argues that:

- the protectable areas are probably over-estimated since early symptoms cannot be reliably interpreted on 1:40 000 black and white photos (WERMP p. 288)
- if small infections are present it is considered inevitable that the disease will spread to other areas by drainage flow and traffic (WERMP p. 288)
- protectable forest may become infected by dieback through logging and/or other agencies or activities (e.g. feral pigs) regardless of mining activities (WERMP p. 348)
- by the time the north-eastern section of the medium term mining area is cleared in preparation for mining, the uplands currently categorised as protectable, may be infected by the fungus (WERMP p. 345), and
- protectable forest once infected will die (inferred).

On the other hand, arguments by foresters and other biologists in CSIRO offer somewhat more promise. Points which should be considered include:

- spread of dieback into these protectable areas can be minimised with strict hygiene and quarantine practices
- the resistance of jarrah on these sites is reasonably high since existing site conditions do not favour fungal development and spread. Considerable differences in susceptibility between sites occur

- the resistance of these sites to dieback could be increased by various techniques (acacia understorey, fertilisation, altered burning regimes, removal of banksias from the understorey), and
- using the various options available it is likely that sustained production of jarrah timber in the long term can be achieved.

Although current research avenues look promising, there is need for further research before the adequacy of these techniques in a field situation can be proven. However, it would be improper to assume that nothing can be done about dieback and to write off these fine pole stands on the basis of today's incomplete knowledge. The dieback aspects are so significant that they are discussed more fully in Chapter 7.

Alcoa has argued that if protectable forests in the higher rainfall zones are retained, then there is pressure on them to operate in the intermediate or low rainfall areas earlier than desired (WERMP p. 356). This raises the spectre of mining in the salt prone zone before adequate knowledge is available. However, this line of argument may be readily countered by reducing the overall rate of mining to levels which are environmentally acceptable and which give the State an opportunity of salvaging protectable forest areas in the western zone and of deferring mining in the salt prone zone until adequate research data are available.

Alcoa could say that protectable forest in the western zone is already available. For example the Seldom Seen Study (Bartle, 1976), estimated that some 13% of this catchment would remain protectable after mining (WERMP p. 429). We estimate that the percentage in eastern catchments is likely to be 20 to 30%. However in the Seldom Seen Study the remaining pockets of protectable forest were small and scattered. Forestry experience suggests that these pockets are likely to degrade through exposure to changed microclimatic conditions. These pockets are also more difficult to manage and protect from dieback or fire due to their excessive perimeter. The situation is somewhat akin to the conservation MPAs which were selected by the Forests Department to be areas for conservation surrounded by jarrah forest. As such they were probably large enough to be viable units. Once the area is mined, however, these could remain as "islands" in a totally altered landscape and their survival in the long term must be open to question. The matter of conservation is more fully discussed in Chapter 9. Similarly the long term viability of small "islands" of protectable forest must be open to question. Already we have seen the invasion of some minepits with exotic weeds and the degradation of some areas which were not mined.

It is possible that some of the rehabilitated mine sites could produce a timber crop in 60 years or more. There is no certainty of this since the existing operations at Jarrahdale represent the oldest areas of rehabilitated bauxite sites in the world (Alcoa *pers. comm.*). Although tree growth to date is good it is questionable as to whether this can be sustained in the future. In forestry the 1 to 50 year drought, frost, flood, fire or pest can have disastrous effects. For example, a most promising programme of *Pinus radiata* plantations in Kenya had to be abandoned when struck by a needle-cast fungus (*Dothistroma pinl*). The aspect of rehabilitation is so important that it has been developed more fully in Chapter 10. At this stage it is sufficient to point out that there is no certainty that a timber crop can be grown on bauxite pits, also that the silviculture, fertiliser needs and burning requirements of this changed vegetative complex have only just begun to be researched.

It is recommended:

- 5.1 *that aspects of hardwood forest management be considered when planning guidelines for land use activities which may cause harm to the environment*
- 5.2 *that a number of large (>2,000 ha) contiguous areas of high quality pole and pile stands lightly affected or uninfected by dieback be selected by the Forests Department; that mining of bauxite in these areas be deferred for at least 50 years, when a better reassessment of priorities will be possible.*

- 5.3 *that in the areas of the western Darling Range where the incidence of dieback is high, mining of fairly large (200 ha) contiguous areas of protectable forests be deferred and preference be given to diseased or susceptible "non protectable" areas.*
- 5.4 *that timber utilisation in high quality protectable forests be restricted to dry weather conditions and that strict hygiene be applied.*
- 5.5 *that high quality stands should be protected from other clearing activities, such as SEC lines, roads, or other mining.*
- 5.6 *that Alcoa's offer to rehabilitate dieback affected areas within the envelope of its operations be accepted.*

## **Production Forestry (Softwood)**

About 20% of the State's pine plantations are situated within the Northern Jarrah Forest. Future plantation programmes will concentrate on the Donnybrook Sunklands, the Blackwood Valley, the Swan Coastal Plain and the sandier soils of the Collie basin. The study area's contribution to the total pine area will then decrease to about 10% of the total. Nevertheless, these plantations are still important to timber production requirements and the larger of the existing plantations will mostly be replanted to pine at the end of the first rotation.

The conflict between pine plantations and bauxite mining is not likely to be great, since the site requirements for the two activities are markedly different. Plantations are normally located on either the dissected river valleys or in broad depositional valleys. In contrast, bauxite mining is largely restricted to the lateritic uplands. However, mining will usually be located upslope of existing plantations and changes to groundwater hydrology could have harmful effects, but these are not yet quantifiable. The potential to grow pines in mined over areas is rather limited due to the rooting habits of the pines, the low fertility of the site and the management problems associated with small plots of fire sensitive species within a forest that is regularly burnt.

Other land uses, primarily recreation and development of water supply dams, are potentially in greater conflict. In the case of recreation the greatest risk is that associated with fire. Plantable land is flooded by dam construction and the remaining pockets of suitable soil are often too small to be economically viable.

It is recommended:

- 5.7 *that since areas of pine plantations have already incurred higher expenditure by the State, the compensation to be paid on areas cleared for bauxite mining should be comparatively higher*
- 5.8 *that, if mining of areas upslope from existing pine plantations disrupts the hydrology to such an extent that the growth is depressed or trees are killed, compensation be paid to overcome for the loss of accumulated growth and to pay for the cost of replanting.*

## **Scientific Areas**

In its Working Plan (Forests Department 1977a) the Forests Department set aside a number of areas in which scientific study was recognised as a management priority. These were selected because of particular features or needs. Once the purpose of each study has been satisfied, the priority use of each area can be reassessed.

Within the study area, nine scientific MPAs have been delineated and total 18,393 ha. Six of these relate to hydrological studies and include two areas where the effects of mining on water quality are being assessed. In addition to these larger areas, there are numerous experiments located within the forest. These are recorded on Research Working Plans and are normally shown on the Hardwood Operations Control System (HOCS).

There is a real need to conduct research into various aspects of forest ecology and management. Many of these experiments will be of value both to the State and to Alcoa. Security for the period of the study is essential, especially for longer term experiments, e.g. hydrological, dieback and growth studies. The degree of conflict with other land uses depends on the purpose of each study. Bauxite mining will need to be excluded from some, but not necessarily all study areas.

The main problems foreseen within the next 25 years include the northern part of the Lang MPA and the five small hydrological experiments in the vicinity of Wilson-Turner blocks. The Lang MPA has been selected so that the spread of jarrah dieback without interference from man can be studied. It is currently the only such area in this State and mining would completely destroy its purpose. Similarly, the Amphion MPA, has been selected as an area which has not been burnt for some 40 years. Again it is the only known area in State Forests where this is so, and it is of great value in providing baseline research data on biological processes in the absence of fire. Amphion has already provided useful data with respect to fauna and dieback research. Hydrological catchments are providing data on salt and water transport so that catchment management decisions can be more soundly based. Interference with these would set back this research for several years.

It is recommended:

- 5.9 *that bauxite mining be excluded from those scientific areas where mining is not an integral part of the study until the original objectives of the study have been achieved.*
- 5.10 *that the scientific MPAs proposed by the Forests Department in its general Working Plan be reviewed and that, if additional large areas are required, they be promptly selected in consultation with other research bodies.*

## Water Catchments

In Western Australia, State Forests incorporate a major part of the metropolitan, country water and irrigation catchments. Management of catchments with priority given to water production and quality is an accepted responsibility of the Forests Department.

Two authorities Public Works Department (PWD) and Metropolitan Water Board (MWB) are responsible for the construction of headworks and for distribution. Dams are of two main types, terminal storage and pipehead, and are often managed in a conjunctive system. Management practices such as sawmilling, prescribed burning, dieback control, quarantine and reforestation have been the prime responsibility of the Forests Department. Its objective is to manage State forest catchments which are needed for existing or future water supply in accordance with the requirements of Water Supply Authorities, to maintain or enhance water quantity and quality (Forests Department, 1977a).

The subject of bauxite mining on water supply catchments has been very controversial and issues of salinity, public health, turbidity and altered hydrological regimes have been raised. These issues are so important that they have been discussed at length in Chapter 8. We shall address ourselves here to some aspects of catchment management.

The Forests Department currently retains the prime catchment management responsibility "on the ground". The PWD relies on the Forests Department to supervise and control aspects such as prescribed burning, planting of trees, recreation and quarantine patrols and recreational developments. The MWB has for many years placed Rangers on their catchments. A good portion of their time is spent on maintaining and controlling pumping equipment at the headworks. They also spend time on routine patrols. In addition there is a small but increasing "Catchment Management" section. This section maintains liaison with other users, runs an experimental programme and advises on various committees. More recently its activities have included the replanting of resumed farms and orchards

with a tree crop and the rehabilitation of disturbed soil near a pipe main. Though liaison between all Departments is good, the lines of responsibility are sometimes hazy and ill defined.

Concern has been expressed that some of the engineering structures used by Alcoa such as sumps, contour bunds and spillways, could either fail in major flood events or alternatively require maintenance for a considerable period of time in the future. The responsibility for maintenance, for patrols and for repair in the event of major collapse is ill defined.

It is recommended:

- 5.11 *that Alcoa be financially liable for all patrols, maintenance and repair to engineering structures constructed by that company until the end of its operations in W.A.*
- 5.12 *that before Alcoa's operations in Western Australia cease, a substantial bond be lodged with the State Government to cover future maintenance in these aspects.*
- 5.13 *that there should be a greater input by Water Authorities on some of the engineering aspects of construction works which could affect water quality standards.*
- 5.14 *that each Department or Authority concerned with catchment management take prime responsibility within its particular area of expertise.*

## Conclusion

The previous discussion indicates that bauxite mining is of great concern to forest managers and that it impacts severely on many of the management objectives of the Forests Department. The impact of mining can be serious and many of the long term answers are not yet available. In this situation reasonable caution on the part of Government is anticipated.

An expansion in bauxite mining would cut right across one of the management strategies in the General Working Plan, namely:

"to minimise the area of forest cleared to mining operations."

Alcoa's most economic mining plan cuts across another:

"to guide bauxite mining operations into areas when the salinity problem is minimised. Seek to direct mining operations into areas when there will be least conflict with other land uses."

Both of these strategies were apparently approved by Government when they approved the General Working Plan.

With respect to timber production, the forecasts by the Forests Department for demand are the most conservative when compared to other forecasts (Forwood, Bureau of Agricultural Economics (BAE), Ferguson). If the BAE forecasts of demand (the highest of the four) are accepted, the deficit for sawlogs in 2010 AD could be as high as 663 000 m<sup>3</sup> per annum. At 1977 prices, the annual import bill for sawn timber would then be about \$33 000 000. This could exceed \$100 000 000 per annum at predicted future import costs. At this stage, economists are unsure whether this demand could in fact be met from overseas sources since regional shortfalls in timber may occur. Also, if the anticipated pine planting programme of 3000 ha per annum is not met, the deficits forecast would be even higher.

It must be recognised that compensation of \$813 per hectare is paid to the Forests Department for loss of growing stock, ongoing management costs and purchase of land for forestry activities. If this money is wisely used the Department could in fact grow more timber than could be grown on the area that was cleared. Batini, 1972 states "As the main function of the Forests Department is to provide for self-sufficiency of timber products at economically sound rates of investment, the loss of productive forest in the mined areas within the Wungong catchment could be readily overcome by investment in any of these four alter-

natives (*P. radiata* on farmland, *P. radiata* on forest land, *P. pinaster* on Swan Coastal Plain, *E. marginata* on high quality sites). Each would provide not only a better economic investment, but also higher yields of cellulose per hectare. Because of this their contribution to employment, balance of trade and possibly decentralisation would be greater than the contribution of the original forest on the Wungong catchment." It must be stressed however, that this was a financial not a full cost/benefit analysis. Factors such as possible changes in amenity, landscape, recreation or water catchment values were not assessed. If these were to be included in an analysis the land use decision could well be different.

In addition to the impacts of bauxite mining which have already been delineated, the operation places considerable strain on the planning, research and operational resources of the Forests and other Departments. The inconvenience to date has not been too great since the area cleared is still relatively small at 1,980 ha. In the next 50 years this could rise dramatically. To date we are only observing the "tip of the iceberg." Examples of the changes required will be a total re-examination of prescribed burning requirements, both for research (fire properties of introduced species, litter buildups, preparation of amended fire tables), and for management (such as planning of aerial burns). It is quite likely that the current system of aerial burning, devised after 18 years of research and testing, may need to be drastically altered. Repetition of basic research into other fields will be needed. The silvicultural needs of these stands of exotics are not known. The milling properties of the trees and their performance in use will also require investigatory work. Problems will be caused by small quantities of locally unknown species coming on to our sawlog markets. Access for vehicles in mine pits will be difficult due to the rip lines, bunds and pit walls. Fire fighting strategies will be changed and costs increased. All of these represent real costs to the State caused by bauxite mining.

It is recommended:

- 5.15 *that the Government recognise the problems arising from an expansion of bauxite mining and makes adequate provision for increases in funds and suitable staff to appropriate Government Departments.*
- 5.16 *that some of these additional funds be provided by a levy on Alcoa.*

## CHAPTER 6

### RECREATION, AESTHETICS AND OTHER LAND USES

#### Recreation

Most studies of the Darling Range have recognised that because of its location and natural features it is an area of importance for recreational activities. Visitor surveys in this region have been conducted by the Forests Department, Alcoa, the National Parks Board and the Universities. Estimates of use (Hewett 1975) indicate that the number of forest visits per year approach 250,000 within 60 km of Perth. An increase in demand of between 7 to 10 times the present level within the next 25 years is predicted. The forest is used for a wide range of recreational pursuits. The demands of each and the conflict between alternative uses and between these uses and the environment varies, depending on the type and level of the activity being pursued.

Probably the more valuable parts in the landscape from a recreational and aesthetic point of view are:

- the deeply incised river valleys which are not yet dammed
- isolated hills or monadnocks
- the scarp face, much of which is already in private ownership, some of which is vested as National Parks or State Forest
- wandoo and powderbark wandoo breakaways typical of the drier, eastern portion of State Forest
- developed reservoirs

Various submissions concerning recreation in the Darling Range have been received by the System 6 Study. These incorporate comments by Companies, Government, Clubs and individuals. In its planning documents (Forests Department 1977a, 1977b and 1978) the Forests Department recognises the importance of recreation as a legitimate component of multiple use. Some areas of State Forest, primarily those on catchments which are not currently used, were designated as Recreation Management Priority Areas (MPAs). Within other parts of the forest recreation was still considered a legitimate "tertiary" use. This would mean that activities would need to comply with the guidelines and zonings set by the Water Purity Committee in its submission to System 6, or to other constraints associated with forest management. In addition, the Tourism and Recreation Committee has prepared a report (1978) to the System 6 Study. A number of recommendations were made dealing with recreation policy, planning, research and management.

We recognise that recreation is an important, growing and legitimate land use within the State Forests of the Darling Range. We are concerned that the needs of recreationists are often ignored or not fully recognised and that land use policies may have severe and detrimental impacts on recreational activities. The area available for recreation appears to be shrinking at a time when the demand is continuing to increase.

Alcoa recognises that recreational use of the Darling Range is a prominent land use activity (WERMP p. 236) which is largely concentrated around Waroona and Logue's Brook dams (WERMP p. 238), and that it is an activity which is expected to grow (WERMP p. 298). The Jarrah forest is deemed as potentially attractive (WERMP p. 269) and preference centres around "peace and quiet", "natural surroundings" and "scenery" (WERMP p. 239).

We note that the majority of recreation sites and facilities which exist in the Darling Range are located in the western high rainfall zone. This present distribution of facilities reflects

both the attractiveness and accessibility of the Darling Scarp and the undammed river valleys as well as the existing restrictions governing recreational activity in domestic water supply catchments and dieback quarantine areas.

This western zone will be subjected to increasing environmental degradation as the result of:

- growth in bauxite mining activity and its associated developments
- construction of SEC transmission lines from Muja to Perth
- the presence of pipehead dams and water supply pipelines in the Helena, Serpentine, North and South Dandalup valleys and the proposed construction of future dams on streams such as the Murray, Little Dandalup, Gooralong, Brunswick and lower Collie.

These activities will further restrict public access and bring into question the capacity of this western forest zone to provide for the leisure needs of increasing numbers of people.

Yet, at the same time, considerable degradation of existing popular sites, e.g. the Murray valley, is already occurring. Recreationists are being caught in a "pincer movement" with quarantine and water supply restrictions limiting recreational opportunities in the eastern zone, while logging, SEC lines, bauxite mining and future pipehead dams severely reduce the existing opportunities in the western zone. Because it is not easy for recreationists to speak with a single voice it is quite possible that they could readily be swamped by policies in which they, as individuals, have little or no say.

Alcoa argues that the proposed mining is not expected to be in the vicinity of facilities near the existing reservoirs (WERMP p. 14) though it is recognized that some visual intrusion will occur (WERMP p. 237) and that the preferences expressed above for "peace and quiet" and "natural surroundings" may be disadvantaged by blasting noise and forest clearing (WERMP p. 354).

We believe bauxite mining will result in a reduction in the area physically available for recreation; it will cause considerable changes in the landscape and aesthetic values of the forests and will also produce a rough, unpleasant terrain for walking, as the result of deep ripping procedures.

The effects are likely to vary considerably depending on the nature of the recreation being undertaken. At one end of the scale, the popularity of an artificial picnic area, such as Langford Park, is already high with some groups of visitors. Alternatively, a bushwalker seeking a semi-wilderness experience would be disadvantaged by the rough terrain and "plantation effect" of a rehabilitated mine pit.

Probable benefits of mining include improved vehicular access, special recreation developments as part of the rehabilitation programme (such as picnic sites, trail bike circuits, golf courses) and the opening up of new landscape vistas. In this respect it is of interest to note that 40% of recreation groups contacted in surveys carried out by the Forests Department were located in sites which had no developed facilities (Schmidt *pers. comm.*). This is supported by results of questionnaires which indicate that a substantial number of forest visitors prefer minimal development.

The key recreational landscapes in conflict with bauxite mining are assessed to be as follows:

#### Incised Valleys and Dam Sites

Though mining will be visible from the walls of a number of existing reservoirs, it is unlikely that Alcoa will mine and blast close to the retaining structure itself. Also, bauxite deposits do not occur within the steeply incised river valleys themselves but are usually confined to lateritic surfaces upslope of these. Some visual intrusion will occur.

### **Isolated Hills or Monadnocks**

Many of the isolated hills are composed primarily of granites and dolerites (Mounts Cooke, Randall and Eagle Hill). Mount William and Mount Saddleback are two notable exceptions which could be extensively mined. The visual impact of this should be considerable and will be seen from afar.

### **The Darling Scarp**

This is largely a visual not a physical resource since much of the attractive scarp areas are held in private ownership. Bauxite deposits are not usual in these more dissected surfaces and mining is usually confined to the laterites upslope. However parts of the scarp, particularly closer to Perth, are being utilised as quarries for blue metal.

### **The Wandoo and Powderbark Wandoo Breakaways**

These are located in the eastern areas of forest which are unlikely to be mined by Alcoa in the near future. The bauxite deposits in these areas are generally smaller, more scattered, and at greater distances from the refineries. These areas will however be considered for mining in 30 or more years time.

### **The Stable Lateritic Surfaces**

These are the areas most suitable for bauxite mining and where the greatest direct conflict will occur. Though often disregarded, these uplands are an important recreation resource. While lacking some of the scenic beauty of the valleys and scarp, they are physically suited to many activities and act as an important link for users travelling from one attraction to another. If large areas of this type are closed to the public whilst mining is in progress (as around Jarrahdale) this will place added pressure on already overcrowded valleys and reservoir sites, as well as physically and visually disrupting the lines of recreational travel. In addition to the impact of the mine site itself, ancillary facilities, especially roads and conveyor belts will also have an impact both visually and physically on the recreational environment.

We recognise that bauxite mining is only one of a number of activities which may cause a detrimental impact on the recreational resource. Damming of streams for water supply, release of areas for agriculture or urban use, logging of forest and prescribed burning are some other examples. Similarly, the policies of Government Departments on aspects such as quarantine, use of roads, camping, or recreation on catchments also place considerable restrictions on recreational pursuits.

It must also be recognised that the towns of Jarrahdale and Dwellingup have had a long and interesting historical association with the timber industry. This is acknowledged by books such as "The Mills of Jarrahdale" and the "Sea and Forest", in the current popularity of the Pinjarra Steam Society's nostalgic excursions to Dwellingup, and in the strong recreational demands in and around both of these town sites. In overseas countries which cater to such trends, this has injected considerable tourist and recreational money into the local communities. We should ensure that some of the forests which provide for this historical link are retained around both of these towns.

We recommend:

- 6.1   *that any land use studies recognise the significance of recreation as a legitimate land use in State Forests.***
- 6.2   *that management authorities with responsibility in this area, primarily the Forests Department, the Water Authorities and the Community Recreation Council, be given sufficient financial support to adequately cater for the incurred responsibilities of research, planning, education and supervision of recreation.***
- 6.3   *the importance of yet undammed streams and rivers be recognised by Water Authorities and that trade offs in terms of divertible supplies will be necessary.***
- 6.4   *that research into the public health risks of recreational activities on catchments be encouraged.***

- 6.5 *that Forests Department, in co-operation with the Metropolitan Water Board and Public Works Department, provide for the development of additional recreational areas where use is seen to be in demand and where such development will not endanger water values.*
- 6.6 *that if sufficient areas to adequately cover the needs of conservation are set aside (primarily Conservation MPAs) the needs of nature study, bushwalkers and those seeking a wilderness experience will have been met.*
- 6.7 *that no mining be carried out close to water supply reservoir structures and existing recreational facilities in forest areas.*
- 6.8 *that in determining the rehabilitation objectives after mining, the appropriate Authorities recognise the significance of recreation and where appropriate carry out the reforestation with this objective in view.*
- 6.9 *that bauxite mining be planned in such a way that the area unavailable for recreation be kept to a minimum, even if this means departure from Alcoa's most economic mining plan.*
- 6.10 *that some breakaway areas with recreational potential be selected in the eastern forest and that bauxite mining be prohibited in them.*
- 6.11 *that bauxite mining be prohibited from the slopes of the major isolated hills with recreational potential (Mount William for example).*

## Aesthetics

The contribution made by Mr. W. Schmidt (landscape architect) to this section is gratefully acknowledged.

Reactions to landscape and aesthetic values are, to a large extent, a personal assessment of factors such as unity, harmony and contrast, and also of a personal interpretation of what might be "natural". Certainly, whilst many man made features may be extremely ugly and distasteful, others may be exceedingly beautiful.

There is little question that bauxite mining on the scale now being proposed will substantially alter the appearance of extensive areas of the Northern Jarrah Forest. There is, however, some uncertainty as to the type, degree and duration of the visual change which is likely to result. This is largely a function of the following three groups of factors:

- the visual character of the landscape itself as defined by the geologic, topographic, climatic, edaphic, vegetative and land use patterns which characterise a particular region or locality
- the requirements or characteristics of the particular land use to be applied to the landscape
- the long term land use objectives for an area and the techniques used to achieve those objectives

Many of Alcoa's comments relate to the landscaping of the refining and disposal pond areas (WERMP p. 33, p. 386-390). They conclude that the ponds will be generally obscured from the South West Highway (WERMP p. 270), though they will remain as mesas in the generally flat landscape (WERMP p. 303). Retention of existing trees, addition of new ones and the landscape itself should satisfactorily screen the refinery site from the highway (WERMP p. 387). The larger sized elements of the refinery will make an interesting and dramatic impact, through not necessarily detrimental (WERMP, p. 287).

We consider that, because of the scale of the mining operation, its potential for harmful impact is far greater than that of the refinery and mud disposal areas. It is accepted that the problems of the latter are more easily modifiable by judicious siting of the refinery and mud lakes and by appropriate plantings. The possible impacts of the mining operation itself are however dealt with less fully in the Wagerup ERMP.

Although the forest to be mined is acknowledged as being potentially attractive (WERMP p. 269) considerable changes to the natural order such as dieback, cutting and fire have occurred (WERMP p. 13), so much so that some areas have lost their appeal (WERMP p. 269). The latter statement has not been documented or supported and data from Forests Department surveys would suggest that it may be quite incorrect. The mining operation is acknowledged by Alcoa as having significant visual impact in the short term (WERMP p. 390) but that in dieback areas rehabilitation will result in aesthetic improvement (WERMP p. 390). In the long term, the mining areas could be expected to return to "natural" appearance. Operations are expected to be mostly isolated from humans (WERMP p. 384) both by their location and by denial of public access for safety reasons (WERMP p. 463).

We consider that the following visual impacts have or are likely to occur as the result of bauxite mining in the Darling Range.

#### Potential Negative Visual Impacts

- There is a distinct possibility that mining could destroy much of the natural diversity and variety of the existing forest landscape and will eventually lead to the creation of repetitive, artificial patterns; that is, a pattern in which the lateritic ridges are cleared and mined while the lower slopes and valleys remain uncleared.
- Because bauxite tends to be located in the higher portions of the landscape, the areas to be mined are often the most prominent and, consequently, more sensitive to visual disturbance.
- Where mining has been confined to small, isolated pits as around Langford Park, the landscape may begin to take on a "moth eaten" appearance. This problem has resulted, in part, from the earlier practice of leaving the pit walls unbattered. Consistent with storm water drainage requirements, there is a need to ensure that post-mining landforms complement and merge with adjoining areas of unmined forest. This is currently being attempted.
- Mining can substantially alter the texture and appearance of the ground surface. The harsh laterites, in contrast to the deeper, more fertile valley soils, take longer to visually regenerate once disturbed. Apart from destroying all vegetation on a given area, mining also removes large organic matter or fallen trees and limbs. Immediately following rehabilitation, the surface of the mined area consists of bare soil displaying prominent parallel rip lines. Even with highly successful planting and seeding programmes, it will be some time before the rehabilitated pit floor begins to take on a more natural appearance.
- The use of exotic species presents problems in terms of integrating vegetated mined areas with adjoining forest.
- The possible introduction of exotic weed species that could compete with and even replace many native shrubs and ground covers. The visual impact of such a foreign plant invasion could be both major and irreversible. This is already occurring on a small scale in some pits.

#### Potential Positive Visual Impacts

- Mining in areas of severe dieback infection provides the means for revegetating areas which are now largely downgraded.
- The clearing of large areas provides an opportunity to retain selected vistas or views. One of the reasons why many people apparently find the eastern forest areas so attractive is probably due to the more open character of the forest as well as the contrast between farmland and forest. Apart from the added diversity provided by these openings, the retention of selected gaps may facilitate future land use objectives.

If there is one single major criticism concerning the approach used in rehabilitating bauxite mined areas over the past 15 years, it is the apparent lack of forward, co-ordinated land use planning. Because of the experimental nature of the rehabilitation programme itself,

there has been an understandable tendency to treat individual mine pits in isolation. Consequently, efforts at landscape planning have been largely piecemeal. The deficiencies of such an approach are already very obvious and unless radical changes occur will become more so, particularly as the rate of mining escalates.

If adverse visual impacts to the Darling Range landscape are to be minimised, then it is imperative that land use plans and associated rehabilitation programmes are finalised prior to the commencement of mining, or as quickly as possible for the existing operations at Jarrahdale and Pinjarra. It is at this initial stage that design and planning decisions concerning the future function and form of rehabilitated areas must be made, if we are to recreate landscapes that are aesthetically pleasing as well as ecologically stable. Such forward planning will require the involvement of many disciplines, including landscape architecture.

We recognise that the operation is very wide ranging and that the area affected is much greater than the area physically mined. It must therefore be accepted that, through dieback and mining, the landscape of a very considerable part of the jarrah forest of the Darling Range will be changed, in some cases quite drastically. A considerable amount of money will however, be available for its rehabilitation.

It is essential, therefore, that this rehabilitation be done with care and with sensitivity. The full-time services of at least one landscape planner will be required. It is essential that this person be involved in planning mining and rehabilitation operations **right from the very start**, well before the first tree is cleared and the first road built. The project will not necessarily cost more — it could even cost less if well planned. To use a landscaper to patch up once mining is completed is both a waste of time and of money (Sylvia Crowe *pers. comm.*).

We also recognise that, although the public is generally excluded from mining areas, the proposed operations will encircle the townships of Jarrahdale and Dwellingup (in the medium term) and that the Mount William tower will overview a large part of the proposed Wagerup mining area. It is understood that mining is carried out to within 500 m of private property and that it may proceed to within the same distance of the two townsites mentioned.

We recommend:

- 6.12 *that co-ordinated decisions on land use objectives and on the rehabilitation of mined areas are essential prerequisites to sound landscape management.*
- 6.13 *since a very considerable part of the Darling Range will be affected by mining and other activities, the landscape and aesthetic aspects of all operations require careful control. Greater use of landscape planners is required.*
- 6.14 *that for mining alone, the full-time services of at least one landscape planner are required; that this person be involved in planning the mining and rehabilitation phases right from the start of the project.*
- 6.15 *that mining of dolerite, granite or any other rock or mineral on the other isolated hills (Mounts Cooke, Randall, Eagle Hill) should be restricted.*
- 6.16 *that research be conducted on public attitudes and preferences in the matters of landscape and aesthetics.*
- 6.17 *that research be carried out to assess whether self regeneration will occur on rehabilitated mine areas and as to whether species are likely to become exotic weeds in our environment.*

## Other Land Uses

A number of land uses and land use activities other than mining of bauxite have potential to impact on the environment and the forests of the Darling Range. These include activities by Government Authorities, by Local Authorities, by private companies, by private individuals and farmers.

A lot of people use the forest and a number of Acts relate to activities within it. Some activities require and permit the clearing of forest land, for example about 2,400 ha, including parts of two Conservation MPAs will be flooded when the South Canning reservoir is constructed. A dam on the Murray would flood considerably more land. An SEC line requires the clearing of some 6 ha per kilometre of line through the forest. Bauxite mining is not the only mining activity in State Forest (Hewett 1975a).

Other uses, unless strictly controlled, have potential to spread dieback, for example off-road vehicular and trail bike access, road grading and graveling by Local Authorities, firebreak construction by farmers. Others have potential to reduce the aesthetic appeal of the landscape (clearing by farmers, improperly managed recreation areas, poorly located roads and SEC lines, prescribed burning, and rubbish dumps). Others may cause pollution (such as possible salt, fertiliser or bacterial pollution from agricultural pursuits on water catchments).

A considerable number of land use activities may be detrimental to the environment and forests of the Darling Range. It would be improper to place strict planning controls on some land users and limited, or no controls, on others. Land use planning within the Darling Range must therefore address itself to all potentially harmful uses and activities. This will be difficult because the responsibility for planning is currently compartmentalised over a broad range of Departments and Authorities. However, co-ordinated land use planning is essential since the land use objectives set by the various Authorities and individuals are often in direct, severe, and apparently irreconcilable conflict with each other.

It is recommended:

- 6.18 *that integrated land use planning must consider all uses and activities within the State Forests of the Darling Range.*
- 6.19 *that research techniques be developed to assist in the determination of complex land use decisions.*
- 6.20 *that some method be found to ensure that the true costs of clearing the forest are taken into account by decision makers in both the private and public sectors.*

## CHAPTER 7

### JARRAH DIEBACK

Land and resource use in the Northern Jarrah Forest is complicated by the presence of jarrah dieback. This root-rot disease, caused by a soil fungus *Phytophthora cinnamomi* (Podger, 1972) takes the form of gradual thinning of foliage, chlorosis of newly formed leaves, and a loss of photosynthetic area — this effect becomes more severe until the plant dies. The physiological basis for death is still not clear.

The fungus has a wide host range and affects many of the forest understorey species, e.g. *Banksia*, *Macrozamia* and *Xanthorrhoea* in addition to jarrah (Titze and Palzer, 1969). The pathogen can, therefore, cause major changes in the floristic composition of an infected region (Batini, 1973), e.g. from a jarrah forest with *Banksia* and *Macrozamia* understorey to an open marri woodland with a sedge dominated understorey.

*P. cinnamomi* has a world wide distribution and is an important pathogen of many horticultural crops. In particular the avocado groves of California have been affected by *Phytophthora* root-rot for many years. This prompted the establishment of the major centre for the study of the pathogen in the University of California, Riverside. Although *Phytophthora* root-rot is widespread, jarrah dieback in Western Australia represents the most severe and complex outbreak of the disease in the world.

#### Monitoring

The Forests Department have estimated that around 183,000 ha of forest have been affected by the disease. Monitoring programmes employing a number of techniques, e.g. black and white aerial photography, colour photography, infra red photography, 70 mm colour photography, LANDSAT imagery and ground surveys, have been underway for the past twenty years and to date 70 mm colour photography appears to be the most reliable method. Nevertheless, the vast area and mosaic distribution of the disease pose considerable difficulties in accurate monitoring, e.g. in comparing remote sensing data with observations on the ground. Even when "ground truth" observations are carried out, tree or plant deaths from other causes, e.g. drought, can complicate and confuse the pattern. In very few cases is the pathogen isolated from a presumptively infected plant. Indeed detection of the fungus in Western Australian soils appears to be a major problem.

The true extent of the disease and its overall rate of spread is, therefore, difficult to quantify with great accuracy. In view of these monitoring problems we recommend:

#### 7.1 *the development of new and the improvement of existing disease monitoring techniques.*

Dieback is more prevalent in the valley floors and disturbed sites of the wetter, western section of the Darling Range than the more saline eastern area (see Fig. 4). This is partly because most road-making, timber getting and bauxite mining activities have been in the western section and thus caused the spread of dieback to be more rapid in that region.

#### Spread of the Disease

There is unequivocal evidence that most dieback outbreaks arise from some human activity. Animal vectors are believed to play a minor role, if any, in the spread of the disease. Extensive soil and gravel movements associated with roadworks, logging and bauxite mining contribute to the spread of the disease. It should be noted that bauxite mining is only one of the several land uses that causes spread of jarrah dieback.

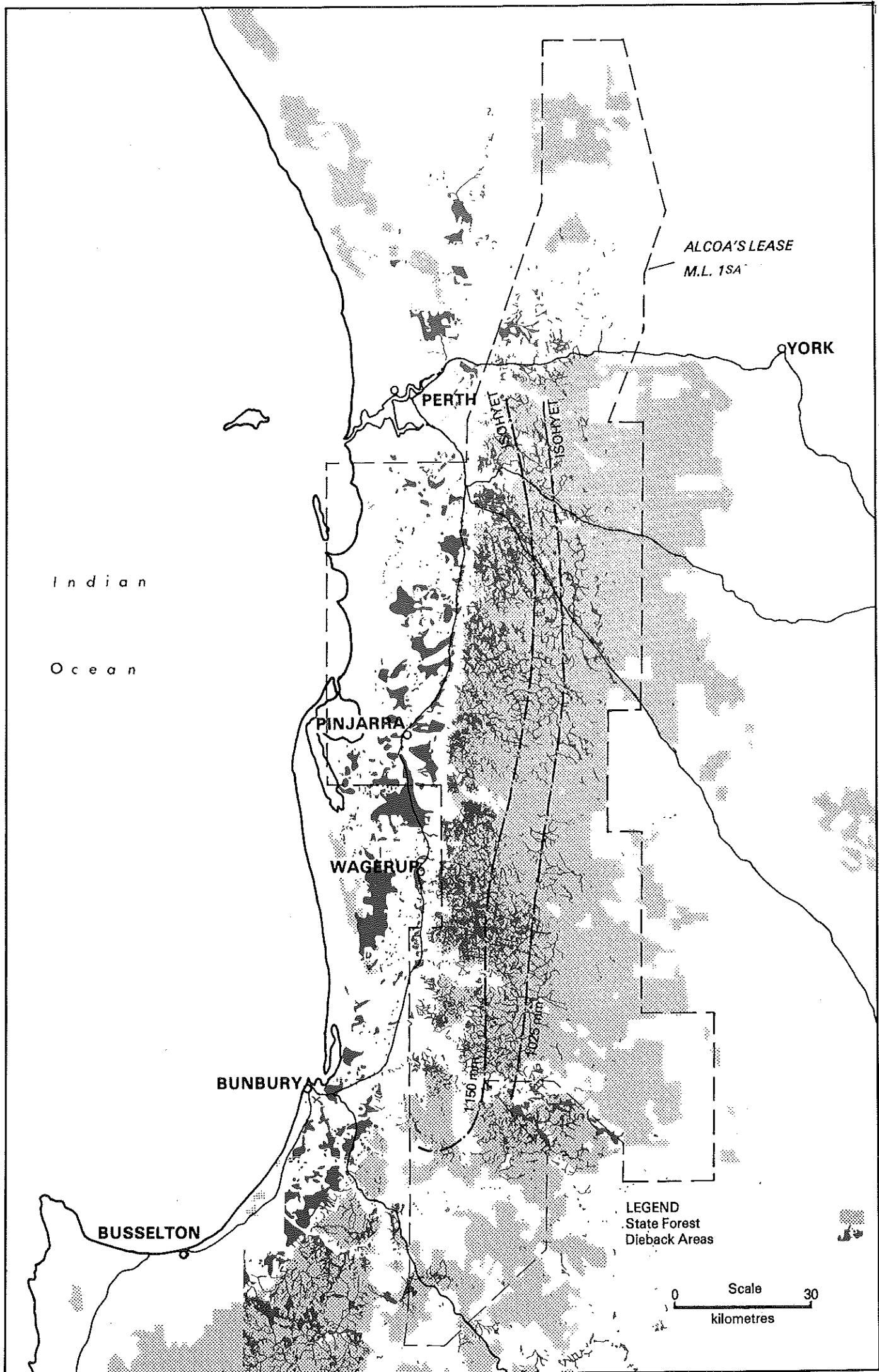


Fig. 4: The distribution of jarrah dieback disease in the Northern Jarrah Forest.

Spread of the disease from a focus of infection may be relatively rapid downhill, though this varies markedly from site to site, and slow on level surfaces and uphill. The WERMP (p. 287) gives the incorrect impression that the disease always moves rapidly downhill, though the possibility of slow degradation is suggested in a later section (p. 422). The extent and the rate of disease spread under natural conditions, is markedly influenced by soil temperature, moisture, nutrient status, floristic composition and micro-flora. The most favourable conditions for natural spread of the infection occur in spring and autumn. Conditions most favourable for maximum soil movement are in the wet months when soil will cling to equipment and vehicles. In view of this risk we recommend:

- 7.2 *that soil moving operations cease when soil moisture conditions are likely to result in spread of soil. Criteria for this need to be defined.*

## Dieback Risk Classification

To assist its own management planning the Forests Department identified a number of dieback risk categories. They are as follows:

- Dieback and suspected dieback regions. These are known or believed to contain plants infected with *P. cinnamomi*.
- Non-Protectable. This includes healthy areas of forest downslope from existing infections which it is believed will become naturally infected at some time in the future. In some areas infection and spread downslope may take a considerable time and there may be variation in the intensity of expression of the disease symptoms.
- Protectable. Areas uphill from known dieback sites, or an area with no mapped infections. With correct management these areas may be protected. Such areas may still be subject to a slow uphill spread.
- Resistant. Some plants are more tolerant or even resistant to the disease; soil factors may confer resistance on otherwise susceptible species.

This classification is somewhat arbitrary and represents a set of working guidelines. Recent discussions with Forests Department personnel indicate that there are reservations about the indiscriminate use of this classification and that such categories require clarification. Indeed the Department is currently re-examining its own use of these categories. Thus, they should not be directly used as inputs to planning a mining strategy.

In the total 25 year mining envelope some 45% of the area is dieback infected (J. Williamson, *pers. comm.*), another 30% is classified as non-protectable. These two categories are grouped together in the WERMP (p. 22) so that they occupy 75% of the 25 year mining plan. The view is then expressed (WERMP, p. 332), that much of the total area to be mined is already severely affected by dieback. Mining and subsequent rehabilitation of these degraded areas is regarded by the Company, therefore, as a positive benefit to the State and provides environmental as well as economic justification for the proposed mining programme (WERMP p. 333). It is acknowledged that mining of the protectable forest would accelerate loss of a natural vegetation system (WERMP p. 332).

Forests Department officials indicated to us that the use of the dieback risk categories in certain parts of the WERMP is not in complete accord with current thinking. It was pointed out that non-protectable forest is currently healthy and not degraded.

We accept the argument that bauxite mining is a legitimate land use and we recommend:

- 7.3 *that Alcoa devise a mining strategy such that areas within their 25 year mining area currently infected with jarrah dieback are mined in preference to those which are uninfected. The classification of dieback infected forest to be determined by, and acceptable, to the Forests Department.*

We have reservations about the grouping of non-protectable forest with infected forest into one category (WERMP p. 22). We have calculated that 60% of the forest in the bauxite regions i.e. the areas to be mined, of the 25 year mining area is currently healthy. There are large variations in the rate at which dieback spreads into different "non-protectable" regions. Some of these regions, therefore, will survive for only a short time, whereas others are likely to survive for a long time. Because of this variation the "non-protectable" category is seen as unsatisfactory for widespread use. Therefore, we recommend:

**7.4   *that the use of the term "non-protectable" be discontinued and alternative risk categories be introduced. The establishment of sound predictive criteria for such categories should be regarded as a priority.***

If a satisfactory control measure for dieback is found then substantial areas of forest currently labelled "non-protectable" might be saved. This might help to minimise the impact of the disease in the forest. Because controls may be developed in the future we suggest that attempts be made to identify "non-protectable" areas likely to survive in the long term. We recommend:

**7.5   *that those areas which would be regarded as likely to survive in the long term should be mined after those which are likely to have only short term survival.***

The view has been expressed that all protectable areas of jarrah forest should be saved from mining irrespective of their size. However we believe that the size of protectable areas may well be a crucial factor in their survival. Therefore, we recommend:

**7.6   *that Alcoa be allowed to mine protectable areas of forest when such areas are of a size which renders them non-viable as biological or forest management units.***

## **The Potential Impact of Jarrah Dieback and Bauxite Mining**

It is currently estimated (S. Shea, N. Malajczuk, *pers. comm.*) that on average bauxite mining spreads dieback disease to three or four hectares for every hectare cleared for mining. This multiplier effect markedly increases the impact of mining on the landscape, e.g. in the current year about 240 ha will be cleared for mining and a further 720-960 ha infected with dieback, i.e. the impact area is 960-1200 ha. This accelerated rate of spread of dieback arises because of:

- the drilling operations in ore surveying
- movement of infected soil on company vehicles and machinery
- changing the moisture relationships of particular areas, e.g adding water onto haulage roads to reduce dust

It is Alcoa's stated aim to mine all suitable grade bauxite within lease ISA (WERMP, p. 50) and it is suggested that some 30,000 ha will be cleared over the next 50 years to provide ore for Kwinana, Pinjarra and the proposed Wagerup refinery (WERMP, p. 43). However, if no satisfactory control measure for jarrah dieback is developed within that time then the multiplier effect of dieback could result in a substantial area of devasted jarrah forest.

Looking more closely at the potential effect of mining for the Wagerup refinery we estimate, from Alcoa's figures, that an area of approximately 5,000 ha could be mined after 30 years if the optimum mining plan goes ahead. The company claim that ancillary dieback will affect only 0.27 ha for every hectare mined (WERMP, p. 24). We believe this is an underestimate because of:

- the distribution of bauxite and current jarrah dieback
- the widespread surveying activity in healthy and currently healthy forest at risk from the disease.
- the mining and road making operations
- changes in soil moisture conditions associated with mining

We would regard a figure of 1:1 as a more accurate conservative estimate based on current experience. The ancillary dieback during this period could, therefore, be an additional 5,000 ha. If, at the end of 30 years mining moves to the east, where dieback is much less prevalent, the multiplier effect could be far greater because of the conducive soil and proteaceous understorey. An area of 4 ha could be affected for each hectare mined. This rate of spread over the subsequent 30 years would result in a cumulative area of approximately 50,000 ha being affected over the 60 year period.

If this pattern were repeated for Pinjarra and Kwinana the area affected over this time period could be nearer 100,000 ha. The impact could be far greater if the dieback multiplier effect is larger than the conservative values used in this report.

We suggest that a mining strategy should be developed by the Company, in conjunction with the State, which attempts to minimise these environmental impacts. We recommend:

- 7.7 *that bauxite mining, apart from the possibility of limited trial mining, be restricted, for the present, to the west of the 1150 mm isohyet, this restriction to be subject to review from time to time*
- 7.8 *that areas designated as reserves, or conservation areas, should only accommodate activities consistent with their conservation purpose. This would exclude all bauxite mining activities.*

In the development of a mining strategy which will minimise the environmental impact we recommend the adoption of the following guidelines:

- 7.9 *that in the western high rainfall region, areas should be mined in the following order of preference:*
  - *dieback infected forest*
  - *high risk healthy forest*
  - *non-viable protectable forest*
  - *low risk healthy forest.*

However, we realise that the economic realities of the venture need to be taken into account in the development of a mining strategy. There is need for ongoing negotiations between the Company and the State. We recognise and recommend:

- 7.10 *that some measure of flexibility is essential in the development of economic mining plans which attempt to follow these guidelines.*

Obviously if jarrah dieback can be controlled the combined impact of mining and dieback could be minimised.

## Dieback and Land Use

Land use in the Darling Range will be covered in greater depth elsewhere in the report (Chapter 11). Nevertheless, we feel that it is appropriate to tabulate the likely effects of jarrah dieback on various land uses in this region (Table 1).

Dieback has effects on many land uses and it is clear that in the long term, in the absence of any suitable control measures, the continued major spread of the disease will have profound effects on land use in the Darling Range. All land users have a responsibility to minimise the environmental impact of their activities, including the spread of dieback, to reduce the effect on other land users. Clearly in the situation where there are multiple users of an area, for varying purposes, conflicts arise. We suggest that bauxite mining be integrated with other land uses and not considered as a special category around which all other activities must be organised.

**TABLE 1**

LAND USE	COMMENT ON LIKELY EFFECT OF JARRAH DIEBACK
1. Conservation areas	Impoverishment of native populations.
2. Honey production	May be affected, though karri, wandoo and marri are preferred species and are tolerant.
3. Mining	Activity probably unaffected by dieback, problem of ancillary spread to healthy forest.
4. Recreation	May, or may not be affected by dieback, some aesthetic values may be affected.
5. Scientific Research and Monitoring	May be severely affected by changes in biological environment.
6. Timber	Only one crop of jarrah can be taken — loss of potential crops in future, loss from premature harvesting.
7. Water Supply	Increased run-off; erosion may increase; salinity may, or may not increase depending on the area.

## Potential for Control of Dieback

The total ecological, land use and economic impact of bauxite mining in the long term is clearly contingent upon two factors, viz. the discovery of satisfactory disease control measures, and the success of the rehabilitation programmes.

### Hygiene Measures

Different activities are likely to have different risks of spreading the disease. Clearly those activities which involve large movements of soil are more likely to spread the disease. The use of strict hygiene measures by well-informed, trained and motivated personnel can undoubtedly assist in reducing spread of *P. cinnamomi*. While close consultation between the Forests Department and Alcoa is to be encouraged it should be recognised that hygiene measures are currently imperfect. Further, as the WERMP (p. 441) concedes, effective hygiene is not feasible in mining operations.

The WERMP (p. 438) says that "effective hygiene measures are necessary to prevent the spread of jarrah dieback" but recognises elsewhere in the document (WERMP, p. 30) that "fully effective hygiene measures have not been developed". Hygiene measures are always subject to human error. In view of the importance of this measure in reducing disease spread we recommend:

- 7.11 that there should be an ongoing education programme to raise awareness of the importance and techniques of hygiene for all land resource users.**

### Control Measures

There are currently no control measures for jarrah dieback. In the avocado groves in Queensland, Pegg (1977) has achieved some control of the pathogen by the use of organic soil amendments. While this approach provides some measure of encouragement for the future, we feel that it is important to strongly emphasise that the management of a forest disease on a huge scale is a much more complex problem. It is worth pointing out that the world's leading *Phytophthora* research group have still not established control of the disease in the California avocado groves.

In addition there are some apparently unique features about the disease in the jarrah forest which make it difficult, and perhaps misleading, to translate the results of studies elsewhere directly to the local situation. In view of this we recommend:

**7.12 that, wherever possible, research into the dieback disease be conducted within Western Australia.**

There are currently a number of lines of enquiry which singly, or in concert, may yield techniques for control or partial containment of the disease. These may be briefly summarised as follows:

- The use of fire to encourage a legume understorey, which appears to produce a soil environment suppressive to the pathogen; fire manipulation also reduces the *Banksia* understorey.
- Encouragement of build-up of soil organic matter.
- Localised use of liming and soil fertilisers.
- Localised use of new systemic fungicides, e.g. Ridimil and Aliette.

We believe that reliable control measures operable on a large scale are likely to be achieved only by land management techniques based on effective research and development programmes. We are greatly concerned at the lack of information in many areas of dieback research. The Company has clearly stated its intention to provide substantial funds for research. (WERMP pp. 396, 442) The provision of more funds for dieback research is essential. The Government has already given an important lead in this direction in the provision of funds for a mycologist to work on detection of the fungus. We recommend:

**7.13 that some mechanism for the collection and allocation of research funds be established as a condition of the Wagerup proposal proceeding.**

In addition there are specific areas of dieback research that we believe are worth promoting. We recommend:

**7.14 that research funds are made available to support the following areas of dieback research:**

- (a) *development of understanding of the epidemiology of the disease*
- (b) *support for the evaluation of promising potential control methods, e.g. legume understorey, organic matter, fertiliser, liming, fungicides*
- (c) *research aimed at increasing our understanding of the biology of the pathogen*
- (d) *analysis of soil, floral physical and biological factors which affect the survival and rate of spread of the pathogen*
- (e) *investigation of host response to the pathogen and the physiological basis of plant death*
- (f) *ecological effects of jarrah dieback, e.g. on the flora, fauna, hydrology and recreation*
- (g) *role of mycorrhizae in plant protection against the disease.*

A more complete coverage of dieback research is given in Appendix VI.

## **Conclusion**

It is clear that the combination of bauxite mining and ancillary dieback could have profound effects on the landscape of the Darling Range. The impact on water quality in the eastern areas (covered in detail in Chapter 8) could be serious. In addition other land users will suffer as a result of the activities of Alcoa. A control measure for the disease would lessen the impact. At present no such control measure exists, for even promising leads may not be satisfactory as long term field measures. In view of this uncertainty and the potentially large impact, the State must retain strict control over options for expansion of bauxite mining.

## CHAPTER 8

# WATER RESOURCES AND HYDROLOGY

### Introduction

The surface and ground waters of the Darling Range and coastal plain provide potable, industrial and irrigation water supplies to over 85% of the State's population. Their protection and wise management are fundamental to the future development of the State.

However, we have not managed our water resources wisely in the past. Serious deterioration of the quality of the surface water resource has occurred through agricultural development on the catchments of the Avon, Murray, Collie, Blackwood and Frankland River systems. The basic relationship between agricultural development and increases in stream salinity has been known since the turn of the century (Wood, 1924), but little or no action has been taken to protect the resource until recently. Presumably this has been a consequence of the desire to develop the State through the agricultural sector, the substantial time which usually occurs between clearing and salinity increase, and the relatively small utilisation of the available water resource in the past.

Some 28% of the total divertible surface water resource between Jurien Bay in the north and Manjimup in the south are now regarded as brackish or saline (PWD, 1977). That is, they have salinities over 1,000 mg/l Total Dissolved Solids (TDS). Only about 50% are regarded as fresh (salinities below 500 mg/l TDS). The bulk of the freshwater resources emanate from the State Forest areas where a permanent deep rooted forest vegetation has been maintained.

However, additional pressures on the remaining State Forests have developed rapidly in recent years. These pressures include bauxite mining, forest disease, utility developments such as roads and power lines and woodchipping. As argued by Sadler (1975)...“Regarded separately some of these operations are not of great significance, but collectively they leave very little of the forest land free from new pressures”.

The pressures on the water resources of the study area (as defined in Chapter 1) are particularly severe since:

- 51% of the current potable divertible water resources of the study area are currently developed (rather than 22% for the South West as a whole)
- the expected demand by the year 2010 will exceed the supply from the region (PWD, 1977) (although additional groundwaters to the north and surface waters to the south of the study region will be available)
- pressures for increased services, environmental and recreation demands will increase as population grows and the resource becomes more fully committed. This will effectively exclude from development some of the available divertible resources.

The predicted demand for water from the study region is dominated by the Perth Metropolitan Area's requirements. Means of obtaining increased metropolitan demand have been discussed by the Metropolitan Water Board in the submission on System 6 (MWB 1977). Likely broad options in the long term include:

- increased development of the artesian and shallow unconfined groundwaters of the coastal plain near Perth together with further regulation of the existing hills catchments and manipulation of catchment yields from high rainfall areas

- large scale transference of fresh waters from southern portions of the study area (Harvey and Collie Rivers) and even further south (Donnelly River) (Sadler and Field, 1973)
- blending saline surface waters with existing supplies together with large scale reforestation of saline affected catchments (e.g. the Murray and Brockman Rivers)
- special methods of developing the Murray River to selectively harness the fresh tributaries

The most likely development may well involve a combination of the above options. Undoubtedly, however, maintenance of good quality water in terms not only of salinity but of low turbidity and high bacteriological quality from the Northern Jarrah Forest will become increasingly important as other poorer quality sources are developed. Any deterioration in the quality of water from the Northern Jarrah Forest must, therefore, be considered with serious concern.

The relationship between planning, water quality criteria and bauxite mining is further explored in Appendix VIII.

Existing forest operations are considered to be largely compatible with the provision of water of high bacteriological quality, low turbidity and low salinity. However, unrestricted mining for bauxite throughout Alcoa's complete lease area may not. The following sections discuss the likely effects of bauxite mining on the local hydrology and water resources of the study region.

## Hydrological Effects of Bauxite Mining

The hydrologic effects of bauxite mining must be viewed in the context of the sharp gradient of interrelated factors which occur across the study area. From west to east these include:

- decreasing rainfall
- increasing evapotranspiration potential
- decreasing land form relief
- decreasing streamflow yield
- increasing streamflow variability
- increasing groundwater salinities and associated increasing storage of salts in the soil profile.

Of particular importance is the gradient of increasing groundwater salinities and soil salt storages. Extensive drilling programmes to determine the quantities of stored salts and groundwater salinities have been carried out over the last 5 years throughout the Darling Range. These data form one index of the potential threat to the surface water resource if the vegetation is disturbed. Despite great variability a general trend of increasing salt storage and groundwater salinity with decreasing rainfall has been identified.

The Forest Department (Forest Department, 1977b) have identified two broad zones of low and high salinity risk, separated by a zone of uncertainty. The low risk zone consisted of areas with base flow salinities below 250 mg/l TDS, the eastern boundary of which approximated the 1150 mm isohyet. The high saline risk zone included streams with base flow salinities in excess of 500 mg/l TDS, the western boundary of which was approximated by the 1025 mm isohyet.

For the purposes of discussing Alcoa's long term mining strategies in terms of salinity risk, these zones will be accepted (see Fig. 3). It is realised, however, that additional drilling and further compilation of available drilling data is required before more precise boundaries can be drawn.

## **Effects on the Flooding Characteristics**

Bauxite mining removes the top 3 or 4 metres of the very porous bauxite material from between 6 and 29% of the entire landscape. However, only limited discussion of the hydrologic effect of this major change is included in the WERMP (page 311).

Within the pit all the components of the water balance are dramatically altered during the mining and initial rehabilitation phase. Both interception of rainfall and evapotranspiration are virtually zero, and increases in deep groundwater recharge beneath and downslope of the pit occur (Hunt Steering Committee, in press). Surface runoff occurs causing major ponding of water in the lower sections of the pit. Increases in the recharge to the deep groundwaters are expected immediately following mining and initial establishment of the vegetation and will persist to varying degrees depending on the rehabilitation techniques adopted.

However, much less soil water storage is available above the clay material following mining, and continued collection of surface or shallow sub-surface waters must be expected in the bottom of pits in wet years even after many years of rehabilitation. This is confirmed in the WERMP (page 311) where infiltration capacities of 15 to 20 mm/day have been measured on newly rehabilitated pits. Rainfall in excess of this capacity will occur frequently in wet years.

The additional water shed from the pit generally will infiltrate into the downslope gravels and will cause significantly increased moist conditions in the adjacent forest. Recent observations at Jarrahdale (July, 1978) following heavy rainfall indicated substantial flows seeping from the gravel soils some 20 to 40 metres downslope of a pond at the base of a pit which was currently being mined.

It is considered that a major effect of mining will be to increase the magnitude, frequency and duration of such seepages. As seepages play a major part in streamflow response to rainfall (Dunne and Black, 1970) it is expected that the frequency of small to moderate floods will be increased and that the volume of streamflow from specific rainfall events will be increased.

The effect of mining on major floods is more difficult to predict. It has been argued that land use changes such as clearing cause significant changes to the magnitude of frequent floods but only small differences in extreme flood events (Boughton, 1970). Catchments are usually saturated from previous rainfall prior to extreme flood events and therefore flood response is normally governed by the extreme rainfall rather than the catchment land use characteristics. However the catchments of the study region are particularly porous and produce very small flood volumes and peak flow rates relative to other hydrologic regions throughout the world (Loh, 1974; Weeks, 1976). Peak flood magnitudes in Victoria are 5 times larger and maximum recorded peaks in the world are greater than 30 times larger than recorded in the study region. During the 1964 floods in the region more than 60% of the flood-producing rainfall was lost as infiltration, interception or evaporation. It is clear then that bauxite mining could significantly increase the flood volume of major events through reducing the soil moisture storage capacity of the landscape. Quantitative estimation of the effect is beyond current knowledge. However, in the natural state the upland laterites rarely, if ever produce surface runoff. The mining operation can concentrate water shed from a pit in localised areas downslope which can then produce significant surface runoff (see above). With some 24% of the Mt. William area to be cleared and about 18% actually mined (WERMP p. 49) the effect is likely to be substantial, but will be spread over a number of catchments.

The WERMP argues (page 312) that dieback may well have a larger effect on flood response than bauxite mining. While this may be true for minor, frequent flood events, it is not necessarily the case in more major events. Moreover bauxite mining has an additive effect to dieback in terms of increasing flood response.

Because of the effect of bauxite mining on flood response modification to existing spillways may be necessary (WERMP p. 312). As the magnitude of the effects are not predictable at this time, the design of improvement to existing spillways will need to be approached conservatively for safety reasons.

We recommend:

- 8.1 ***that the Company be advised that certain dam spillways in this region are expected to require improvements and an appropriate contribution will be required towards the costs of investigation, design and construction whenever provision is considered necessary due to the effects of mining.***

## Effects on Water Yield

It has been claimed (WERMP p. 30) that bauxite mining followed by planting a low density forest has a potential benefit in increasing water yield. As areas downslope are likely to be affected by dieback and may be rehabilitated by Alcoa the discussion below encompasses the effects of management of vegetation on the whole landscape. Many forest hydrologic studies have consistently shown that significant increases in water yields can result from reduction in stand densities (Anderson, et. al, 1976). Increases up to 50% have been recorded in areas of naturally low streamflow. **However, the yield increment decreases if regrowth occurs and can, in fact, reduce yields to below existing levels (Langford, 1976).**

Studies of the effects of various land use changes on water yield in Western Australia only commenced during the 1970s and no detailed studies have been completed to date. Initial evidence from dieback studies (Clifford and Black, 1977) and agricultural clearing in high rainfall areas (Stokes, 1978) shows that significant increases in annual flow volumes are likely. However, there is considerable doubt about how that increased yield will be distributed throughout the year. Results from agricultural clearing (Wights catchment near Collie) indicate that almost all the increased yield occurred at high flows during the winter months (Stokes, 1978) and support the previous discussion of increased flood response following bauxite mining.

These findings are contrary to the comments in the WERMP where major increases in the base flows were predicted (WERMP p. 310). The justification for an increased base flow component stems from studies of the effects of dieback on streamflow yield. Results of a recent study by Herbert (pers. comm.) indicate a strong relationship between substantial base flows during summer and dieback disease as measured by catchment crown canopy cover.

However the hydrologic effect of removing forest cover in the valley bottoms as a result of dieback disease may be significantly different from removal of vegetation upslope. Vegetation downslope of mined pits (if not infected with dieback) may well fully utilise the additional groundwater and thereby limit changes in the summer base flow response.

If, on the other hand, the increased soil moisture downslope of mining accelerates the downslope spread of dieback (as seems likely) the combined effect of mining and dieback on water yield may be greater than the sum of the two separate effects and significant increases in summer base flow could occur.

A long term detailed study of stream/flow sequences is required before these conflicting effects on water yield can be adequately assessed. Within our limited knowledge, however, the figure of an extra 100 mm per year as increased yield estimated in the WERMP (page 310) is considered possible in the western high rainfall zone if rehabilitation strategies which aim at enhancing water yield are encouraged. With 20% of the area mined the order of increase in possible yield could be around 8-10% of current yields from catchments in the Wagerup area. Combining the effect of dieback and active silvicultural techniques to enhance water yield (Shea and Herbert, 1977) increases of 15% to 20% are

conceivable. While this represents a significant potential increase in the surface water resource the magnitude of the increase in the divertible water resource will be smaller. Factors which will influence the effective increase in the divertible water resource include:

- the proportion of the increased yield which occurs at high flows (discussed above).
- the available storage at the dam site and its integration with the total demand and storage system.
- the techniques of pit rehabilitation and silviculture practiced in the adjacent forest, which enhance water yield, and the success in maintaining these practices in the long term.

At this stage the proportion of the additional yield which could be harnessed in the long term is difficult to assess without detailed investigations of current and future engineering diversion schemes and more details on the hydrologic changes that bauxite mining and other silvicultural practices may have. There is undoubtedly some scope for increasing the divertable water resources of the western region.

*However, in a regional water resource demand context it is difficult to see that the increase in divertable water resource which might result from mining in the western Darling Range, will have a significant impact on delaying the need to develop major additional sources.*

Some increase in the divertable resource may offset the temporary salinity increases due to mining in the more saline susceptible areas to the east. But other trade-offs, however, may involve increased flood response and risk of erosion and turbidity.

It may be concluded that increasing water yields in the western Darling Range should not be regarded as a benefit to justify bauxite mining on water supply catchments. Other problems of increased probabilities of bacteriological and viral infection, of increased turbidity and sedimentation problems and flooding frequencies are major costs to the water authorities.

## **Biological Contamination and Turbidity**

The Metropolitan Water Board (MWB 1977) have clearly indicated the role of water storage in reducing the risk of biological contamination and the need to maintain low turbidity waters to ensure that chlorination alone is sufficient disinfection to maintain a low risk of water born disease.

The maintenance of strict controls are therefore considered necessary on catchments where nominal detention times are short (less than 40 days). While large storages reduce the risk of serious biological pollution, nominal detention times may not be a satisfactory measure of the safety factor (Loh, 1977). The detention time of a particular component of water within the water body is particularly dependent on the very complex dynamic water mixing processes within the body. Until we can ensure that water withdrawn has had adequate detention time, relatively conservative policies and stringent control measures should be maintained. From current modelling studies, some scope for assessing the seasonal risk based on general seasonal reservoir mixing processes has been developed (Patterson, 1977). However, these may not have direct relevance to bauxite mining since it is unlikely that the operation could be entirely restricted by season. Some scope for mining restriction to certain seasons may be possible in specific areas.

Consequently the presence of large work forces on water supply catchments (190 and 240 people currently at the mine sites of Jarrahdale and Del Park) is regarded with serious concern. Current water authority policy is to exclude all recreation from these catchments (Water Purity Committee, 1977). To allow bauxite mining but not recreation would appear inconsistent. It should be noted, however, that it is possible to exercise more control over

Alcoa's work force than the general public. In this context ensuring that Alcoa adequately plan and maintain their garbage and human wastes programme (WERMP p. 432) is most important.

We recommended:

- 8.2 *The appropriate water authority (PWD or MWB depending on the catchment) take responsibility for ensuring that Alcoa carry out an adequate programme of garbage and human waste disposal.*
- 8.3 *Wherever possible long term service facilities associated with mine sites should be constructed off any utilised catchment.*

### Effects on Stream Salinity

The potential for bauxite mining to increase the salinity of streams in the Northern Jarrah Forest has been widely discussed in recent years (Peck *et al*, 1977; Shea and Herbert, 1977; Hunt Steering Committee, in press) and is discussed in six different sections of the WERMP. The following paragraphs summarise the background to the problem.

Small concentrations of a range of common soluble salts, roughly in the same proportion as found in the ocean, are continuously transported inland from the Indian Ocean and fall onto the landscape in rainfall and as "dry fallout". Most of the rainfall is transferred back to the atmosphere through evaporation and by the vegetation through evapotranspiration. This process leaves behind the salts in the soil and on vegetation surfaces. The remaining water which enters the stream and river systems by surface runoff or groundwater seepage collects and concentrates some of these salts, discharging them back to the Indian Ocean.

For an undisturbed catchment there is an approximate balance between incoming and outgoing salts (saltfall and saltflow) (Peck and Hurle, 1973). It is probable that this balanced condition was originally reached over a period of thousands of years during which time saltfall exceeded saltflow and a gradual accumulation of salts occurred throughout the deep soil profile of the Darling Range.

The natural balance is maintained by the natural deep rooted forest vegetation which transpires large quantities of moisture throughout the year. Any activity which reduces this moisture usage can cause greater quantities of water to infiltrate the soil mantle, raise the groundwater table and thereby initiate a gradual release of the accumulated salts within the landscape to the surface stream system.

As discussed above major increases in stream salinities have occurred following agricultural development. Clearing for agriculture represents a permanent removal of the existing deep rooted vegetation. In comparison, bauxite mining with a successful rehabilitation program will only cause a temporary increase in the additional moisture recharging the groundwater system. Consequently the disruption that bauxite mining might cause to the previous salt balance is more complex and depends on such factors as the area mined, the groundwater and soil salinities, the annual rainfall, the local soil hydraulic properties, the associated spread of dieback, the area of healthy forest downslope, and particularly the speed and efficiency of the water use of the revegetation following the rehabilitation treatment.

Appendix VII discusses the limitations of the available techniques for predicting the effects of bauxite mining on stream salinity and appraises the predictions made in the WERMP.

The predicted effects of clearing in the first 30-35 years at Wagerup are considered to be of the correct order given our current limited understanding of the hydrologic effects of bauxite mining (Table 42 — WERMP p. 314). The small predicted increases are a consequence of the low groundwater salinities encountered in the region and are typical of areas in the western high rainfall region as previously discussed (Forests Department 1977b, Forests Department 1978). However, groundwater salinities are highly variable (WERMP p. 293)

and anomalously high or low groundwater salinities can occur within general rainfall zones. Moreover the change between relatively fresh and extremely saline levels can be particularly dramatic over short distances (Herbert et al, 1978).

In this regard Alcoa should continue an active groundwater salinity investigation commitment sufficient to assess the impact of their 3 and 10 year mining strategies on stream salinity. The details of drilling requirements clearly depend on the results obtained in any one area and cannot be set down here. However the onus of proof should be on Alcoa to convince the State that their operations will not adversely affect water salinity. This is different from statement 6 on page 434 of the WERMP which gives the benefit of doubt to mining in a situation of uncertainty.

We recommend:

- 8.4 ***that Alcoa should continue an active groundwater salinity investigation commitment sufficient to assess the impact of their 3 and 10 year mining plans on stream salinity. Predictions of their likely effect and strategies to minimise the predicted increases should be developed in conjunction with the State using the best available techniques at the time and these should be described in their three yearly reviews.***

Although Alcoa plans to mine to the west of the 1150 mm isohyet for at least the first 25 years their intention is eventually to mine the bulk of the bauxite in their total lease area. To assess the long term impact of bauxite mining in the low rainfall area the WERMP discussed a simulation study of the effect on the South Dandalup River if all the ore in its catchment were mined in an approximate 30 year sequence (Peck et al, 1977).

A review of the study and the limitations of the simulation model used is discussed in greater detail in Appendix VII. However, important points to note are that the model used is a highly artificial representation of the deep groundwater systems' response to various inputs of additional recharge, the mathematical conditions for which are not fulfilled in practice. The model assumes that only one groundwater system is present and that the role of perched water tables and changes in the surface runoff can be neglected. These limitations are primarily a reflection of our restricted quantitative understanding of the complex groundwater and hydrological processes involved. However, the model provides a technique, albeit very crude, for assessing the spatial, temporal and transient nature of the mining and rehabilitation operation. In this context the model is considered to be a useful tool for the prediction of broad scale hydrologic effects of mining in the eastern zone. However, the predicted changes in salinity should not be considered as absolute figures, but only be taken as a general indication of the magnitude of likely change. Alteration of various assumptions in the model could either increase or decrease the predictions significantly (WERMP Table 51, p. 399 and Appendix VII). It is considered however, that the original conclusions in the paper still stand, namely that:

- bauxite mining alone without dieback will have a negligible effect on South Dandalup salinities
- that in conjunction with dieback significant increases in salinities are likely
- but that substantial control should be achieved by a prompt and successful programme of reforestation of mined and diseased areas

Given that changes in the various assumptions could either increase or decrease the predicted salinities it is considered that much more detailed research and application of this research on a planning and management scale is required before more precise predictions of salinity increases can be made. It is considered, however, that the current estimates are of the correct order.

We recommend:

- 8.5 **that a major ongoing research commitment is necessary to improve current predictions of the effects of bauxite mining on stream water quality, since current methods of prediction are based on very simplistic concepts of the groundwater system and little is known about the mechanisms of water movement in the natural environment.**

The success of the rehabilitation is fundamental. If deep rooted tree species which transpire moisture throughout the summer months cannot be successfully established following mining in the eastern saline susceptible zone, the effect of mining on stream salinity will approach that of agricultural clearing. Major permanent increases in streamflow salinities must be expected particularly if vegetation downslope is severely affected by dieback and cannot transpire the additional moisture available from the upslope mining.

Unrestricted mining in the next 70 years could encompass between 50 and 70 percent of the Canning and Serpentine catchments and virtually all of the South Dandalup catchment (see Fig. 3). These catchments currently supply over 60% of the current metropolitan demand. Permanent Increases of at least 100 mg/l have been predicted by Peck *et al*, (1977) for South Dandalup River if rehabilitation is not successful and increases of the same order could be expected on the other major catchments. Higher increases in salinity (400 mg/l TDS plus) would occur on small water resources such as the Yarragil catchment which are entirely within the eastern saline susceptible zone.

Such increases represent a major deterioration in our current limited fresh water resource. Because of the time scale for mining and the slow response of groundwater systems, the increased salinities would not develop until after the turn of the century when virtually all of the fresh water resources of the study region would be developed. Major costs to the State may be incurred if more expensive fresh resources to the south have to be developed because the hills catchments could no longer dilute cheaper resources of marginal quality closer to Perth. The World Health Organisation, when discussing their International Standards for Drinking Water (WHO, 1971) state "...Nothing in these standards should be regarded as implying approval of the degradation in any respect of an existing water source of a quality superior to that recommended. Existing and potential sources of water should as far as possible, be protected against pollution, even though there may be no immediate intention of developing them..."

We therefore recommend:

- 8.6 **that no mining should be tolerated on existing or potential water supply catchments if there is a risk that measurable permanent increases in stream salinities could occur.**

Aspects of acceptable water quality criteria are discussed further in Appendix VIII.

There is no certainty about the success of possible rehabilitation strategies for the eastern low rainfall zone. Difficult problems to be overcome include:

- reproducing the unusually high transpirative characteristics of jarrah (Doley, 1967; Kimber, 1974; Shea and Herbert, 1977)
- achieving a satisfactory root system for the revegetation to survive drought conditions and draw water from the deep pallid zone clays
- the establishment, survival and natural regeneration problems in harsh soil conditions of low pH and high salinity, and
- the removal of the bauxite layer causing a reduced soil moisture availability on the pit floor

This is not to say that rehabilitation (in terms of salinity control) will be unsuccessful but rather that very little is known about solving these problems at this stage.

The impact of mining in the eastern zone is also strongly dependent on the effect of dieback on downslope vegetation. There are known examples of salinity problems developing on dieback affected sites (Mt. Cooke, Helena Catchment) but its effect combined with bauxite mining is likely to be much greater than these isolated occurrences (see Chapter 7). The magnitude of the combined effect is however, subject to debate but the entire area downslope from a pit could readily become affected.

Currently, major uncertainty exists about both the likely success of possible rehabilitation and the magnitude of the increased spread of dieback following mining in the eastern zone. Until these issues are resolved we believe that unrestricted mining throughout the lease area places our limited fresh water resources at risk. It follows from recommendation 8.6 that no commitment should be given to mine in the eastern saline susceptible zone at this stage.

We therefore recommend:

- 8.7 ***that no approval or commitment be given to mine east of the 1150 mm annual isohyet until the long term success of rehabilitation proposals can be assured and that no permanent increase in stream salinities will occur.***

There is no need to give the company a commitment to mine the eastern zone at this stage as there is sufficient ore within the western zone to support mining for at least 40 years (Chapter 4).

As greater knowledge and data on aspects of the salinity problem develop, variations in the current mining strategy will be necessary to account for salinity and other hydrological factors.

Therefore we recommend:

- 8.7 ***that the State obtains the legal means of dictating the location of all bauxite mining activity to protect the water resource.***

Although we have recommended no mining in the eastern areas at this stage we consider it necessary to actively research problems associated with mining and rehabilitation in this zone now, in order to:

- enable sufficient time for assessment of the long term survival (and natural regeneration potential) of the rehabilitation in the low rainfall areas.
- ensure that if rehabilitation is successful (with respect to salinity) then mining strategies could be altered and thereby preserve a larger proportion of the western areas

We recommend:

- 8.8 ***that detailed long term hydrologic and biological studies of trial mining and rehabilitation in the eastern saline susceptible zone be commenced.***

Selection of sites and formulation of the monitoring strategy of these studies should be carefully carried out as their results could be crucial to the future of the environment and to the future of the bauxite mining industry in Western Australia.

To date little or no quantitative studies have been carried out on components of the hydrologic cycle specifically related to bauxite mined pits other than studies of the changes occurring in the deep clay aquifer systems (Hunt Steering Committee, *in press*). While these are of fundamental importance they do not provide adequate quantitative data on:

- surface or shallow sub-surface discharge from bauxite pits, both quantity and quality
- measurements of water movement in the lateritic gravels downslope of pits
- Interception and transpiration of vegetation in the pits relative to the natural forest

Such data are necessary for the assessment of the various rehabilitation strategies and prediction of their possible long-term performance.

A recent study of water movement in the gravel system has commenced (Hurle, pers. comm.) and the Project 5 working group of the Hunt Steering Committee plans to commence a project involving transpiration studies of both the natural forest and trees in a rehabilitated pit.

We recommend:

8.9 *the EPA actively supports further studies of the components of the hydrologic cycle relevant to the problem of rehabilitation of bauxite pits in terms of both staff and funds. Specific topics for investigation include:*

- (a) *discharge of surface and sub-surface waters from mined pits;*
- (b) *measurement of water movement in gravels downslope of pits;*
- (c) *interception and transpiration of vegetation in the pits relative to the natural forest.*

## Conclusions

Bauxite mining represents a major permanent change to the natural vegetation and landscape of the Darling Range. Removal of deep rooted native forest vegetation during the mining process will cause a reduction in the evapotranspiration and an increase in the recharge to the deep groundwater system. As long as the groundwater salinities are low and only slightly higher than the associated average surface water salinities (say groundwater salinities less than 250 mg/l TDS) no major increase in salinities of the surface waters are likely to result. Bauxite mining is considered a legitimate activity in these areas and may provide some, though small increase in streamflow yield.

If, however, groundwater salinities are high relative to the surface water salinities prior to disturbance (groundwater salinities as high as 10,000 mg/l TDS can occur in the eastern saline susceptible area) major increases in the surface water salinity are likely to occur. Whether these changes are temporary or permanent depends on the strategy of rehabilitation and its success in the long term.

Mining also involves the permanent removal of the top shallow layer (3 or more metres) of bauxite rich laterite from between 6% and 29% of the Darling Range landscape. As this layer is particularly porous, a significant reduction in the landscape's ability to store water will result. Consequently increases can be expected in the flood response of streams which have substantial areas of their catchments mined.

Permanent changes in the local topography will change the distribution of water held in the soil profile, particularly between areas upslope and downslope from the lower pit face. The removal of the bauxite layer and the compaction of the pit floor will induce increased lateral flow (either surface or shallow subsurface flow) and produce a concentration of moisture at the bottom and the downslope of the pit particularly during the mining phase.

The consequent increased moisture in the downslope forest will be much more conducive to the spread and activity of *Phytopthora cinnamomi*.

Bauxite mining exposes significant areas of bare soils during the mining phase and for some considerable time after rehabilitation. Without adequate rehabilitation serious problems of local erosion and turbidity can occur.

Bauxite mining on water supply catchments may increase the potential for biological contamination of the supply because of the relatively large and concentrated workforce involved. Without adequate safeguards serious problems could result.

**It is clear that bauxite mining has the potential to seriously affect the limited high quality water resource of the study region and involves a major additional management responsibility for the Forests Department and the water authorities.** With careful co-operative planning, management and research between the State and the Company many of the risks to water supply can be minimised. However, at this stage numerous problems are poorly understood and solutions unavailable. In this situation of uncertainty we believe that the State should maintain very strict controls over the Company's mining operations. **Current legal controls are not considered adequate to control the location of mining within the lease or adequate to force the Company to change its management strategy in the light of new information (Chapter 3).** Our concern is best exemplified by the possible mining in the eastern saline susceptible areas. Serious deterioration of our limited remaining fresh water resources could occur if rehabilitation proves to be unsuccessful in the long term.

The WERMP states (p. 301) "...limited experience in the low rainfall zones and existing state of scientific knowledge...preclude detailed assessment of impact..."

***The Company clearly accepts that very little is known about rehabilitation in the eastern zone and have not put forward an appropriate management programme. Yet acceptance of the WERMP without modification seems to imply approval to mine ore for the Wagerup refinery in the eastern zone.***

Until both improved methods of predicting the effect of bauxite mining on stream salinity and successful management programmes for rehabilitation in the eastern zone can be proved, the State should restrict mining to the western zone (Recommendation 8.7). We believe the State must have the power to control the location of mining with Alcoa's lease area if adequate protection is to be given to the water resources of the study area (Recommendation 8.8).

## CHAPTER 9

# CONSERVATION, FAUNA & FLORA

### Conservation

The need to conserve representative species and assemblages of animals and plants is almost universally supported by civilized communities. Most of the reasons for conservation areas have been stated by Costin and Frith (1971).

They include:

- maintenance of reservoirs of genetic diversity so that animals and plants which potentially may have value in commerce, medicine and food, are not lost
- scientific standard or reference points against which to monitor extent of a given change in an altered environment
- aesthetic pleasure of being able to enjoy wildlife in its natural setting
- philosophical considerations related to the belief that all life is not at the disposal of man

A combination of bauxite mining and dieback could result in 87% of the western zone requiring rehabilitation (Bartle, 1976). In the eastern zone we estimate the figure to be between 30-50%. With the possibility of such a dramatic impact on the jarrah associated ecosystems within this region, it is of the utmost importance that examples of these ecosystems are set aside in a representative and integrated reserve system. Further, it is necessary that we are able to predict changes likely to occur in the fauna and flora throughout the region in order to manage them in a changed environment. The ability of native animal and plant species to survive in the long term will be enhanced if rehabilitation of damaged areas provides as broad a spectrum of their habitat requirements as possible.

### Existing conservation areas within the study area

The areas which have conservation of flora and fauna as a vesting purpose are Nature Reserves, National Parks and Selected Conservation Management Priority Areas (MPAs). The size frequency distributions of these groups of reserves is shown in Fig. 5 (see also Appendix IX). Clearly, National Parks and Nature Reserves occupy a very small area (3,445 ha) of the jarrah forest in the study area, as defined in the Introduction, compared to the area covered by the MPAs (150,051 ha). Further, from Fig. 6, which shows the distribution of nature conservation areas in the study area, it is clear that National Parks and Nature Reserves are mainly confined to the north west corner of the study area. Other nature reserves must be regarded as supplementary to the Conservation MPAs which form the major conservation reserve system in the region. The importance of Conservation MPAs is further emphasised by the observation that National Parks have a multi-purpose vesting and they are all downgraded through too-frequent burning and other activities.

#### Forests Department Conservation Management Priority Areas:

- (a) **Do the MPAs represent all major ecotypes?**

Selection of MPAs was based primarily on vegetation because this offers the best basis for classification, both as an integrator and indicator of environmental factors, and as a factor in land use in its own right. This is particularly so because the vegetation is relatively undisturbed and the relationship between soils and vegetation has been demonstrated in a small proportion of the Northern Jarrah Forest. The floristic composition of understorey appears to be the best basis of classification (Havel 1975a, p. 30). On this reasoning, Havel developed a system to enable

recognition of site-vegetation types, based on 55 indicator species related to each other by means of a multi-dimensional framework based on principal component analysis. Havel (1975b) found that the study area is a strongly integrated continuum with a high degree of predictability, so that both ordination of the vegetation and geomorphological classification of the landscape can be used for land use planning on an ecological basis. Using these techniques the Forests Department selected areas which best represented the determined vegetation sites.

It has been argued that a more traditional vegetation classification based on clearly defined associations arranged into a hierarchical classification would be more appropriate to selection of ecotypes; the structural component of vegetation being considered equally as important to fauna as the floristics. Another concern expressed was that the Forests Department had not considered all land uses in selection of the particular ecotypes to be reserved in MPAs and that those chosen were not necessarily the most representative available — and therefore the location of MPAs was negotiable. It could also be stated that the selection techniques for MPAs may have overlooked unique or rare and endangered plant and animal species.

We consider that the system of MPAs established by the Forests Department represents one of the more imaginative design concepts for nature reserves implemented anywhere in the world.

We agree with Havel (1975a and b) that his prime use of vegetation to determine important ecotypes is soundly based; that in a vegetation continuum such as occurs in the jarrah forest (see also Diels, 1906, and Speck, 1958) his site-vegetation approach has advantages over more traditional vegetation classifications. While we agree that vegetation structure is often vitally important to fauna, we recognise that most vegetation physiognomic assemblages would appear to be present in Havel's vegetation types.

Further, examination of Forests Department reasons for selection of the vegetation types to be reserved in MPAs convinces us that they have been selected with care and that the system of MPAs presented in their working plan (Forests Department Working Plan No. 86 (1) — 1977) contains good representation of **the most representative ecotypes** in the region, with possibly two exceptions: Collie Basin vegetation and Wandoo Woodland Vegetation. The Collie Basin, because of its extensive surface sands, has an assemblage of shrub species found only further to the south west and south east. An example is the number of *Stylidium* species in the basin (N. Marchant pers. comm.). Wandoo woodlands are also inadequately represented; these woodlands have a shrub assemblage which, although less diverse than that in the jarrah forest on the intact plateau surfaces, contains a number of species of shrubs that vary considerably from the same elements in the jarrah forest. **The exact nature of this variation is not well documented and the basis for it is even less well understood (W. Loneragan pers. comm.).**

We are not particularly concerned that some rare or endangered plant or animal species may have been missed by the MPAs. The prime thrust of nature conservation policy must be aimed at establishing reserves for representative communities. A supplementary reserve system may be required for endangered species.

Selection of areas to conserve a non-replaceable resource such as a natural ecosystem, should not be constrained by the economic value of other resources in the area for which there are substitutes or which are replaceable. It would appear on the basis of the large proportion of the Northern Jarrah Forest set aside for conservation of MPAs (*circa* 21%) and the proportion of the timber resource foregone by forestry in these MPAs (15%), that selection by the Forests Department of the most representative ecotypes was made principally on nature conservation requirements. We recognise that some of the MPAs occupy areas containing other resources required by man. For example, an estimated 10% of the bauxite reserve is located on Conservation MPAs; others are on areas which may require to be

flooded for water supplies. We would hope wherever Conservation MPAs (and other nature reserves) provide a conflict between nature conservation and other resources, that great consideration be given to the fact that fauna and vegetation communities are usually not replaceable in their natural state once substantially damaged.

We recommend:

- 9.1 *that the system of Conservation MPAs in the study area should be accepted as best representing the major ecotypes present.*
- 9.2 *that consideration should be given to enlarging several MPAs to include more of the Collie Basin and more Wandoo woodland.*
- 9.3 *that the location of MPAs be considered non-negotiable because this would almost certainly result in the acceptance of a substandard nature conservation reserve system in the region.*
- 9.4 *that a survey be conducted of the fauna and flora of the area to evaluate the need for secondary reserves to be established to protect unique communities or rare species not present on the MPAs, National Parks, or Nature Conservation Reserves.*

(b) **Are MPAs large enough?**

There are several components to the question of the spatial adequacy of MPAs. First, are they large enough to allow the fauna and flora within their boundaries to persist in perpetuity, with or without contiguous forest outside their boundaries, and secondly are they large enough to be buffered from disturbances outside their boundaries? The Forests Department Working Plan considers the Conservation MPAs are larger than is required for fauna and flora and that really only the core areas are required as sanctuaries. Further they consider that the buffer zone within each MPA should be adequate to protect the core zone.

The question of what size reserves should be to maintain representative and viable communities of animals and plants is contentious. In general the philosophy of biggest is best prevails (Diamond, 1976; Terborgh, 1976; Whitcomb et. al, 1976). However, in areas of intense land use conflicts the maximum size obtainable for reserves is severely limited. In such situations it has been argued (Simberloff and Abele, 1976) that smaller areas, judiciously located, may form a most satisfactory system, particularly if corridors can be formed between such reserves to allow for gene flow between populations (Diamond, 1975).

It is often conceded that primary reserves should be of sufficient size to support a stable population of large mammals (Sullivan and Schaffer, 1975). The Australian experience suggests that this requires areas of between 6,000 ha (Tyndale-Biscoe and Calaby, 1975) and 20,000 ha (Main and Yadav, 1971). It could be argued, however, that none of the mammal species in the jarrah forest is dependent on it for their persistence (Tyndale-Biscoe and Calaby, 1975) and that because of this fact, nature reserves in this area need not be of a size sufficient to maintain populations of mammals.

We consider that mammal species in the forest are an integral component of the biotic community and therefore their conservation within the area to be necessary. On this premise many of the Conservation MPAs (buffer area plus core area) are considered too small, even after combining the area of MPAs which are contiguous (see Fig. 5). Only seven groups of MPAs are larger than 6,000 ha (the smaller of the above estimates for reserve size). Of further concern is the realisation that the buffer zone of MPAs can be managed in ways that may be inimical to a nature reserve. For example the Working Plan states... "any future logging (in the buffer) will be selective, and carried out under detailed prescription specifying the intensity of cut and the timing and mode of logging so that operation is hygienic and does not lead to the introduction of diseases". Although

the Conservation MPAs, as proposed in the 1978 Forests Department Working Plan (Forests Department, 1978), have been accepted by Government, at this stage these areas are only afforded the protection of a C class reserve. This is of great concern to use because confidential documents indicate that the MPA buffer zones are not being regarded as part of the conservation area, but merely as a negotiable area around the core.

If we regard only the core area of the Conservation MPA as the true nature reserve then we are left with no Conservation MPAs which may be considered large enough as conservation reserves (see Fig. 5). Further we consider that the MPAs may well be far too small should they become isolated by large scale physiognomic and floristic changes to the forest outside their boundaries attendant upon bauxite mining and jarrah dieback infection.

In the light of the above statements we feel that it would be desirable that most of the smaller Conservation MPAs should be expanded slightly to connect with adjacent ones, and that in other cases corridors of natural vegetation could be envisaged to physically connect Conservation MPAs. We are concerned also that disturbances to drainage patterns outside reserves may lead to the infection by jarrah dieback of MPAs and other nature reserves. This may require the expansion of Conservation MPA boundaries to ridge lines, or to the restriction of bauxite mining from upslope of conservation reserves. Further, Forests Department burning practices may be inimical to fauna and flora in MPAs (see Springett, 1976) and consideration should be given to amending burning practices in Conservation MPAs and their immediate vicinity. We are also concerned at the absence of formal management plans or guidelines for fauna and flora in National Parks or Nature Reserves in the area. There has not yet been time to develop these in Conservation MPAs although we understand that detailed mapping of vegetation has commenced in several of them.

We recommend:

- 9.5 ***that the outer perimeter of Conservation MPAs should not be contracted but that consideration be given to selected MPAs for their enlargement so as to provide a more integrated reserve system both between Conservation MPAs and with National Parks and Nature Reserves.***
- 9.6 ***that the concept of a buffer zone should apply outside the current boundaries of MPAs, but that within their boundaries there should be a single vesting purpose, i.e. conservation of fauna and flora.***
- 9.7 ***that management plans be prepared by the vesting authorities for the fauna and flora in Conservation MPAs, National Parks and Nature Reserves in the area as a matter of urgency.***

With particular reference to the Samson MPA, we feel that the WERMP clearly expresses a lack of an understanding of the principles and philosophy of conservation areas and in particular the Forests Department's MPAs (WERMP p. 357). The Samson MPA was established not only to preserve Bullich (*Eucalyptus megacarpa*) but also the entire biological community.

- 9.8 ***We recommend that the Samson MPA be not mined for bauxite but that consideration be given to the enlargement of its existing boundaries to the ridge lines. This enlargement would make it a more viable biological entity once it is partially isolated by change to the surrounding forest and provide it more protection from jarrah dieback.***

## Fauna and Flora

Little detailed information is available on the species of animals and plants in the Northern Jarrah Forest. While species inventories are probably complete for vertebrates, this is far from the

case with invertebrates. The level of knowledge concerning invertebrates in the jarrah forest is reflected in the Australian Entomological Society submission to the Woodchip enquiry. (See "Woodchips and the Environment", report from the Senate Standing Committee on Science and the Environment, 1977 Aust. Govt., Canberra) which states that about 40% of insect species in Australia (estimated at about 108,000 species) still have not received scientific attention, even to the most elementary level of being included in collections that are studied by entomological taxonomists. There is no inventory of plants in the Northern Jarrah Forest, and of those present, about 2-3% remain to be described (N. Marchant, *pers. comm.*). Further, there is a general lack of detailed knowledge concerning the distribution and environmental requirements of animals and plants from the region.

In view of the existing level of knowledge concerning animals and plants in the Northern Jarrah Forest, Alcoa was specifically requested to examine the vegetation and fauna of their proposed mining area, with particular reference to rare species, and discuss the effects of mining on the native fauna of the area.

We consider that the WERMP has made a superficial and completely inadequate attempt at documenting the fauna and flora within the Wagerup impact area. It almost completely ignores invertebrate fauna, both terrestrial and aquatic, and the work presented in the report is extremely careless.

For example, the WERMP states (p.179) that mammal trapping, which was carried out for only one month, resulted in the capture of 22 individuals in the vicinity of the initial mining area. Table D2 lists only 17 individuals captured. On the same page, in discussing *Antechinus flavipes* (8 specimens collected) it is stated that this species was much more prevalent in dense vegetation types C and Q but Table D2 records it only from vegetation types, C, D, P and S. Further, such a statement on prevalence based on eight specimens is extremely dubious and more so when only two specimens of *A. flavipes* were captured in dense vegetation type C, compared to four specimens on P and S (laterite). The extrapolation from such a poorly documented short term project to general statements such as "The main habitat for small mammals is provided by the stream and swamp areas and their fringing vegetation" (WERMP p.179) is unacceptable. Schmidt and Mason's (1973) preliminary trapping data from nearby Dwellingup, while suggesting that two species of native mammals (*Setonix brachyurus* and *Isoodon obesulus*) prefer swampy country, indicates that *A. flavipes* was, in proportion to trapping effort, as frequently captured in upland jarrah as it was in swamps. Further, we consider that the statement that "In general, more species of fauna and higher population densities are present in the moist valley vegetation types" (WERMP p.335) cannot be substantiated with existing knowledge. There are numerous other inaccuracies in the WERMP. For example, *Cercartetus concinnus* does not confine itself mainly to *Banksia* spp. (WERMP p.180); there is no evidence available or cited to suggest that *Dasyurus geoffroii* and *Phascogale tapoatafa* are most likely to be found in thickly vegetated moist valley types (WERMP p.180); *Phascogale topoatafa* is not known to occur in Nature Reserves and the Red-eared Firetail Finch, *Emblema oculata*, is rare and likely to become extinct and is listed under Section 14(2) of the Fisheries and Wildlife Conservation Act (WERMP) p. 120. Further, we know of no evidence to suggest that the Dunnart (presumably *Sminthopsis murina*) relies on vegetation that is susceptible to *P. cinnamomi* (WERMP p. 181) or to support the statement that "species diversity of mammals in the western part of the jarrah forest including the mined area is low compared to areas of uncleared forest further east and also compared to uncleared areas of the Darling Scarp, Ridge Hill Shelf and Coastal Plain (WERMP p.179).

With the birds, it is not clear whether an actual survey was conducted of much of the mining area. No details of bird distributions related to site—vegetation types are presented. Statements made in this part of the report are very vague and could be culled from literature. Again the bird section emphasises the importance of riparian vegetation with a statement that many other birds will (note that the report does not say that they have been found there) utilise such vegetation (WERMP p.185).

The survey of reptiles is completely inadequate with only four of the possible 50 species collected. The conclusion that reptiles generally prefer areas of relatively thick undergrowth and that larger reptiles congregate around streams and swamps (WERMP p.187) is inconsistent with Dr G.M. Storr's understanding of the distribution of lizards in the area. Dr Storr (*pers. comm.*)

considers that lizards occupy specific habitat types throughout the jarrah forest and that riparian or densely vegetated sites are not favoured with increased reptile diversity — rather lizards prefer more open forest areas.

We are also concerned with statements that perennial streams contain a low diversity of flora and fauna (WERMP p.12), and that the aquatic ecosystems are unlikely to be affected significantly by mining operations (WERMP p.23). The survey of aquatic fauna is considered totally inadequate in its scope; no survey appears to have been done of the aquatic flora. Because we predict changes in flooding intensities and possibly increases in turbidity in streams, it is important that a thorough survey be conducted of aquatic biota in streams within the mining sphere.

The vegetation survey is very broad scale, using the site vegetation approach of Havel (1975a) which utilises only 55 plant species. While we consider that this approach is eminently suitable for the purpose for which it was designed, it is no substitute for a floral survey. The WERMP makes little attempt to describe the floristic components that characterise the Wagerup area. For example, Table G1 lists 40 'Native' shrub species that "will make up the bulk of routine supplies in the future". It is significant that of these, seven are not native to the jarrah forest. Further the WERMP makes no attempt to review the vegetation of the Wagerup area with respect to the remainder of the Northern Jarrah Forest.

We consider that the inadequacy of the floral and faunal survey renders meaningless the statement "that no rare or endangered species are known to be present in the project area" (WERMP p.12). We believe that an inventory of the flora and fauna of the Wagerup area has yet to be done.

Faunal and floral comments that pertain to rehabilitation are placed in that section of this report (Chapter 10).

We recommend:

- 9.9 ***that a much more extensive and comprehensive survey of the flora and fauna of the Wagerup area be carried out to allow for a reasonable consideration of the impact of mining on the biota of the area***
- 9.10 ***that in the event of such a survey discovering important or significant biological species or communities, secondary reserves be created and excised from the mining lease to protect them.***
- 9.11 ***that indicator species be selected and monitored within the mining sphere; this should proceed under the direction of the State***

We are drawn inevitably to the conclusion that the faunal data has been forced so as to present an argument that most groups of animals prefer, or are confined to, riparian vegetation.

Presumably the objective behind this is to show that most animals are in areas that have little bauxite and will not be mined. This would of course support the statement that "the protection of stream vegetation will ensure the protection of viable populations of much native fauna" (WERMP p.334). We dispute this assertion on the grounds that there is no evidence from their study to (a) support the belief that a higher diversity of fauna exists in moist valley vegetation (with the exception of frogs) and (b) that even if all species were found in riparian vegetation that such habitat alone would enable persistence of viable populations of "much native fauna". Many faunal species may occur in riparian vegetation but require other surrounding habitats for food or shelter or space, either continuously or occasionally. For these reasons we also disagree with the generalisation of p.23 of the WERMP that "the fauna populations (inhabiting valley floor vegetation) should remain at close to existing levels". We do, however, acknowledge that riparian vegetation is an important habitat, along with many others.

## CHAPTER 10

### REHABILITATION

Under the Kwinana and Pinjarra Agreements rehabilitation of mined land is carried out either by the State or the Company to the satisfaction of the Conservator of Forests. The Conservator is advised on this matter by an inter-departmental committee of State Government officers who make recommendations after consultation with Alcoa. The requirements of the Wagerup Agreement are somewhat more detailed and continue until the work is fulfilled to the satisfaction of the Minister for Industrial Development. The Company is required to implement the WERMP and to carry out continuous monitoring to determine the effectiveness of the rehabilitation measures. Progress must be reported regularly to the State.

Rehabilitation commenced at Jarrahdale during 1965, and a number of plant species and techniques such as fertilisation, ripping and contouring, have been tried in the following 13 years. The programme has concentrated largely on planting tree species, although recent attempts have been made to encourage a more diverse understorey by returning fresh topsoil to the pit floors and by direct seeding. Other techniques such as straw mulch, graded banks, clover soil and jute waterways have also been investigated. The main aim of all these is to reduce erosion from pit floors and thus to control turbidity. The wider aim of seriously attempting to recreate at least some of the characteristics of the jarrah forest ecosystem in the mined areas has not been investigated to date.

#### Revegetation

Examination of rehabilitated areas and discussions on site with personnel concerned indicate to us that many mined pods are subject to different rehabilitation procedures, but that objectives are not always clear. There seem to be many trials but few designed experiments. In particular little consideration has been given to native fauna or flora.

We disagree with Alcoa (WERMP, p. 474) that the impact on native species is reversible. The removal of the dominant plant species, and permanent changes to leaf-litter characteristics, soil texture, drainage, nutrient levels, and micro-environment may preclude re-establishment of much of the natural ground vegetation and hence of the native fauna. We consider, however, that one desirable objective is to maximise the natural plant diversity.

To date the performance of selected trees and shrubs appears in general to have been good. However, a reasonable time period to assess the long term success of revegetation would be 15 to 20 years. It should be borne in mind that the current revegetation is relatively young and that the oldest stands occupy limited areas. Despite this the use of some species of tree has already been discontinued. The future structural stability of the trees is of particular concern. Root excavation studies indicate a tendency for root development to occur in the plane of ripping, which could lead to instability. We are not convinced that vegetation in rehabilitated areas will be self-perpetuating and are greatly concerned that such areas will require continued and extensive silvicultural treatment.

We are concerned as to the changes revegetation may have on the fire ecology of the region. We predict that greater foliage densities and larger crowns of introduced tree species compared to jarrah and marri may result in a large accumulation of leaf-litter. This build-up may well be contributed to by the absence of many leaf-litter microfauna resulting in slowed decomposition of leaf-litter. Changes in intensity of fires can be expected in the region. The impact of wild fires and controlled burning procedures on the vegetation in rehabilitated areas is also cause for concern, because little is known regarding the ability of some of these introduced species to cope with fire. A direct seeding experiment

established in 1975 emphasizes the early stages of the rehabilitation research programme. The experimental area of dense wattles and mixed young eucalypts is likely to be a major future fire hazard and management problem.

Another concern is that some of the tree species used in rehabilitation will flourish and become weeds competing with native species. There are some old stands of introduced trees in the jarrah forest, and there is evidence to suggest that *Eucalyptus saligna* is invading natural vegetation adjacent to an arboretum (WERMP p. 201). Further, several acacias are currently spreading through parts of the forest, for example, *Acacia pycnantha* at Mundaring. The planting of introduced species on the scale envisaged for rehabilitation of bauxite mined areas and some associated dieback infected areas, will provide more opportunity for this to occur. There is some concern that straw mulching has introduced exotic grasses in some rehabilitated areas and the use of clover to consolidate surfaces of mined sites appears to be inhibiting the subsequent germination of native seeds.

Jarrah dieback greatly restricts the species of plants used in revegetation. However, it may be that mined sites are no longer favourable to the fungus and that the emphasis being placed on leguminosae and tolerant species is unwarranted. If the disease is not present or inactive on the mined sites consideration should be given to the re-introduction of jarrah.

We note that there is no certainty that a timber crop can be grown on bauxite pits and that the silvicultural, fertiliser, and burning requirements of this changed vegetative complex have only just begun to be researched. Because most of the original nutrient cycling system has been greatly altered, further study of the changed nutritional system is required.

We recommend:

**10.1 that revegetation programmes be periodically reviewed in the light of long term rehabilitation objectives as they are determined.**

## Fauna

The statement that rehabilitation can re-establish the "full range of fauna" (WERMP p. 23) is naive. Despite our lack of knowledge of species in the area, perhaps one of the few positive statements that can be made regarding the fauna on mined-over areas, is that the full range of species will not re-establish in such a dramatically altered environment. Further, the assumption on the same page that rehabilitation areas will provide better habitat for fauna than extreme dieback areas will depend on the group of fauna under consideration, and will depend on what is meant by 'extreme dieback.' While it may be true for some arboreal species, as a generalisation the statement is without foundation.

We consider it of importance for rehabilitation to provide favourable habitat for the widest range of fauna. First, to assist in stabilising the artificial ecosystem; second to reduce the impact of isolation on fauna occupying patches of natural vegetation resulting from the mosaic of cleared and mined areas; and third for aesthetic and cultural considerations.

The impact of bauxite mining on the fauna and the subsequent recolonisation of the mined areas has received almost no consideration to date. The one exception is the work of Dr. J. Majer who has documented recolonisation of a number of mined sites by ants and by some of the surface arthropods. This work, however, has proceeded entirely at his own initiative with little external support.

In this general vacuum of knowledge and concern we can only turn to literature for indication of the ability of animals to recolonise similarly devastated areas. The effect of clear-felling in forests is perhaps the nearest analogy although that practice does not alter the environment nearly as dramatically as bauxite mining. The impact of clear felling on fauna in Australian forests is extensively covered in the 1977 "Woodchips and the Environment"

Report from the Senate Standing Committee on Science and the Environment. The impact on the fauna cited in that report is equivocal, and ranges from predictions of dramatic loss and extinction of many mammal species, to short-term disturbances with re-establishment of all species in cut-over areas. Investigations on the impact on vertebrates of severe bushfires at Nadgee in NSW showed that populations of some small mammals were declimated; ability to re-establish in the burnt area varied between species (Newsome *et al*, 1975).

We recommend:

- 10.2 ***that an immediate assessment be made of the fauna at present established in or utilising rehabilitated areas of various age and treatment***
- 10.3 ***that selected groups and species be monitored both in the rehabilitated and adjacent, less disturbed areas.***

## Hydrology

Selection of a hydrological rehabilitation strategy involves the balancing of many mutually exclusive, or directly opposing objectives. For example, rehabilitation which aims at increasing water yield may also increase stream flood responses. Different approaches to rehabilitation will be required in different areas. Protection of the available water resource may require different rehabilitation strategies between the western and eastern zones, and between developed and undeveloped catchments.

Objectives for rehabilitation with respect to water resource conservation in the eastern areas are relatively clear. The primary aim must be to minimise the disturbance to the saline groundwater system. This means ensuring that the post-mining water use by the landscape is as similar as possible to the pre-mining condition. While this primarily means establishing relatively quick growing, deep rooted tree species it is fundamental that these species survive in the long term and be self regenerating. Some difficulties foreseen in achieving this are discussed in Chapter 8. Because the consequences of failure are so great, full scale investigation and research should precede any movement into the eastern and intermediate zones as stated in recommendation 8.9.

Suggestions have been made that surface waters from pits in the eastern catchments could be discharged into streams directly, increasing their yield. This would reduce recharge to the deep groundwater system and minimise salinity problems. Such an approach would require substantial engineered channel systems to ensure that the additional water did in fact reach the streamline. Department of Agriculture experience indicates that significant operational and maintenance problems can develop in the long term with artificial waterways.

Therefore, we recommend:

- 10.4 ***that rehabilitation strategies necessitating permanent engineering works be actively discouraged because of their long term operational and management problems.***

Where salinity is not a problem attempts can be made to increase water yield. The potential for increasing water yield from mined areas is considered small but manipulation of the forest densities downslope has greater potential. However, this manipulation would necessitate major thinning and continued control of understorey coppice and advance regrowth by either fire management or herbicide application. Both control methods may have adverse environmental effects. More research is required to adequately assess both the hydrologic effects and economic benefits of such thinning practices.

In addition to possible management and maintenance problems, techniques for enhancing water yield can affect the recreational potential and aesthetic appeal of the rehabilitated areas. In view of the above discussion and since these practices are unlikely to have a significant affect on the development of the region's water resources (Chapter 8) we recommend:

**10.5 that rehabilitation strategies which favour water yield should not be encouraged to the detriment of other land uses.**

Rehabilitation in the western zone may need to be different for the following three types of catchments:

- non-utilised catchments
- catchments with major storages
- catchments with pipehead structures

As discussed in Chapter 8 major effort at controlling turbidity in the short term on non-utilised catchments and catchments with major storage is unwarranted if stable ground-covers can be developed within two to three years. In many situations, therefore, the construction of major banks to control turbidity is considered unnecessary and also inappropriate since they require regular maintenance (Recommendation 10.4) and may, in fact, make turbidity problems worse if they fail.

Other factors such as the effects of severe turbidity on aquatic fauna may justify special approaches to control in specific situations.

On catchments with pipehead structures, however, turbidity and erosion is of major concern. Current approaches to control turbidity have centred on contour deep ripping and construction of containment banks. Problems occurred in 1974 where banks were found to be in danger of over-topping and have since been built in a more conservative way. Bank performance has generally been satisfactory, probably because the structures are relatively porous while including a clay component which is generally non-dispersive. A reasonably satisfactory compromise between percolation and containment without serious risk of piping failures seems to have been achieved.

Some greater control, however, is desirable over the Company's design and construction of these containment structures if they are to be a permanent feature of rehabilitation on catchments with pipehead structures.

Alternatives to the construction of such banks should be actively studied since they may well fail in a major flood event and exacerbate flood magnitude. An alternative on pipehead catchments may well be to accept the possibility of some turbidity problems and provide filtration as well as chlorination as treatment. Additional costs of treatment should be borne by the Company.

In view of the above we recommend:

**10.6 that Alcoa's design criteria and construction procedures for water containment structures be reviewed and approved by the State and that performance of the structures be regularly reviewed in Alcoa's yearly reports.**

## **Objectives of Rehabilitation**

The previous sections indicate a range of objectives available for the rehabilitation of mined sites. Others are indicated in Chapters 5, 6, 8 and 9.

The Report by the Steering Committee on research into the effects of bauxite mining on water resources in the Darling range (Hunt Steering Committee, *In press*) summarises rehabilitation progress to date and identifies some future objectives for rehabilitation. We would emphasize Alcoa's statement (WERMP, p. 35) that "in the high rainfall zone, there is a wide range of options for future land management. The choice of rehabilitation method depends on the future use of mined areas." Considerable scope appears to exist to fulfil such objectives because Alcoa have indicated (WERMP, p. 419) that \$10,000/ha is available for rehabilitation. Some possible rehabilitation options are listed in the steering Committee Report and in the Forests Department's 1978 document.

Alcoa have expressed a willingness to rehabilitate according to the objectives of the State (WERMP, pp. 28 and 418). While we sympathise with the Company that rehabilitation objectives have not been clearly defined to them, the WERMP (p. 423) does tend to convey the impression that if the State could only define its objectives then the appropriate rehabilitation measure could be designed. This is an over-simplification. For example, current lack of understanding of the hydrological changes on mined sites makes it difficult to define the dominant objectives related to water, or to balance the effect of one treatment against another.

While we recognise that selection of the most appropriate rehabilitation techniques for a particular mine site may be attendant on the future accumulation of extensive base-line data, we recommend:

- 10.7 *the establishment of a group to identify all rehabilitation objectives, and evaluate long term purpose of each mined area in accordance with pre-determined objectives in a land use planning framework. In view of the need to balance land use objectives on rehabilitated sites the group should be broadly based and include —*

*Engineers*

*Hydrologists*

*Foresters*

*Biologists*

*Landscape architects*

*Recreationalists  
and possibly others.*

The foregoing discussion of site considerations and rehabilitation techniques provide a range of options from which choices have to be made. They should depend on the final objective of rehabilitation, defined by some planning procedure, and should ideally be determined prior to mining.

## CHAPTER 11

# LAND USE PLANNING

### General

R.G. Downes (1976) in a Symposium on the South West of Western Australia offered the following concept, which might be taken to refer to land use planning:

"...really a matter of fitting man into his environment in a way that caters for the community needs without destroying the capability of the environment to continue to provide them. In practical terms it is a matter of achieving the proper use and management of the resources available to the community so as to satisfy both the present and long term needs."

He was not, however, defining land use planning, but in fact was referring to conservation. Clearly there is a close relationship between the two; Downes' concept recognises conservation as a main objective of planning and land resource management, and sees it as an absolute necessity for the continued well being of society.

In earlier sections we have outlined the effects of bauxite mining operations on other uses of the Darling Range; on conservation of the natural environment, of water resources, and of the forest for both productive, recreation and amenity use. While the Company does, at it is obliged to, discuss its detailed mining plans with the Forests and other State Departments, subsequent modifications of these plans seem to have been slight, and based on the premise that all ore of economic grade would eventually be mined. The WERMP strongly suggests that mining even in conservation MPAs may be acceptable.

However, we have demonstrated (Chapter 4 and Appendix V) that the economics of the mining operation should permit some flexibility, admittedly with the danger but not the inevitability, of some loss of profitability. If this argument is accepted, then it follows that there is scope for real joint planning between State and Company, in order to optimise benefits to all parties concerned.

### Land Use Planning in the Darling Range

Most discussions of planning suggest that it may take place at different levels. Higher levels, often referred to as framework plans, strategic plans or regional plans, provide guidelines for more detailed appraisal and operational type plans at lower levels of implementation. An important purpose of planning at each level is to give indications of future developments which are permissible or likely, and therefore at least some element of certainty, not only for planners and managers, public and private, but also for individuals.

So far as we are aware there is no formal framework plan for the Darling Range with, of course, the important exception of those parts of it that fall within the Metropolitan Region Scheme. We do not mean, however, that there is no land use planning. It has been suggested (by one of the SRI consultants) that the whole complex of relevant statutes, cabinet decisions, regulations and by-laws, supplemented by more detailed planning by a large number of authorities do, in fact, constitute the plan for the Darling Range. Hohnen (1976) lists the departments, authorities and some relevant acts concerned with land use planning in south western Australia, amounting to a total of 12 departments, 20 authorities and 95 statutes. While some co-ordinating role is filled by such bodies as the MRPA, the Town Planning Board, the Environmental Protection Authority, the Planning and Co-ordinating Authority and the Department of Industrial Development, the situation is obviously an extremely complex one. It is difficult for most people to comprehend, it contains inconsistencies and so can hardly be said to provide a satisfactory framework within which further planning by Government, company and individual can proceed with any degree of certainty and understanding.

## **Forests Department Planning**

Most current and proposed mining for bauxite is within State Forest. Thus the Forests Department's important initiatives in land use planning are timely and relevant. Its Working Plan 86 of 1977 (Forests Department 1977a) provides the policy statements and framework within which land use plans for the Northern Jarrah Forest are now being developed. The form they are likely to take is outlined in two important documents. "A Perspective for Multiple Use Planning in the Northern Jarrah Forest" (Forests Department 1977b) outlines the policy of multiple-use management which the Department has adopted, allocates areas to a number of management categories and proposes management strategies for each. The "Land Use Management Programme, Northern Jarrah Forest, Management Priority Areas" (Forests Department 1978) is a confidential draft, which allocates management priorities to defined forest areas, and illustrates the proposed further development of planning to the detailed implementation level, through what is called the "Hardwood Operational Control System".

The Programme, based on a multiple use concept, in effect applies a zonation to the Northern Jarrah Forest and on that basis identifies the primary or highest priority use for each zone, whether it is timber production, catchment management, conservation of flora and fauna, recreation, or scientific research and experiment. It also lists secondary, tertiary and incompatible uses for each area. Two related questions immediately arise.

Although the plan in its various stages of development has been referred for comment to other State Government departments does it, in fact, take sufficient account of uses other than timber production, and would bodies other than the Forests Department agree with the set of priorities proposed?

The second question refers to bauxite mining specifically. Does the plan offer a framework within which the bauxite mining operation might be planned, integrated with the State's planning for the conservation and use of the other resources of the area?

A satisfactory answer to both questions cannot be taken for granted, although the Forest Department believes that it has put forward a workable plan which certainly was developed in consultation with other interests. It is currently being distributed for discussion to over 30 Government bodies, before being made public (Appendix X). However, because departmental planning objectives may not always be clear, will at times be in conflict, and because there is no formal mechanism, there are difficulties in resolving the conflicts and in developing guidelines for departmental officers attempting to negotiate them. Consequently, it cannot be taken that the Forests Department's plan will be entirely acceptable to other Government agencies. Nevertheless, it could provide a starting point or framework within which the bauxite mining operations might be integrated to take account of the State's interest in the conservation and use of the other natural resources of the Darling Range. Thus, while it may be said that the Forests Department's land use planning activities are a most important starting point, they do not resolve all the problems nor provide mechanisms for their solution.

## **Land Use Planning Mechanisms**

It is clear that the Company's mining plans, exemplified by those given in the WERMP, have paid scant regard to interaction with other land uses. The document makes it clear that its proposals, in the long and short term, are those which it would pursue to maximise economic gains to the Company in the absence of other constraints. This may be understandable in the absence of clear land use policies. While, as we have suggested, there may be a *de facto* framework plan to be derived from a study of the numerous statutes relating to land use, it would be difficult to use these for planning at the operational level, which would integrate the objectives and activities of the Company with those of other users, both public and private.

In these circumstances the approach taken by the Company virtually amounts to an invitation to remedy this undesirable situation, by forcing the State to identify those constraints which need to be imposed on the mining operations to safeguard the State's interest.

We have indicated some of these interests in earlier chapters. There are the environmental risks of widespread deterioration of the forest due to spread of disease and of adverse effects on water quality, the need to make adequate provision for conservation reserves, the necessity to integrate the management of the forest areas to provide an optimum combination of mining, timber production, water catchment management, aesthetics and recreation, and in consequence, the need to plan rehabilitation after mining with long term objectives in view. Our economic analyses (Chapter 4, Appendix V) show that the acceptance of such constraints on mining would not necessarily involve unacceptable losses of profitability.

But it would be irresponsible to propose constraints on mining plans without pointing out the need for the necessary complementary planning by the State. During briefing sessions with officers of the Crown Law Department, the Department of Industrial Development, and the State Energy Commission, we were impressed with the degree of integration of plans for alumina refining, planning for the provision of energy requirements in the South West, and for other consequent industrial developments. A similar integration and co-ordination of planning is needed for land use in the Darling Range. It should take place both at the regional planning level to provide the guidelines and appraisals, and also at the operational level.

Sadler (1976), discussing public participation in the planning process, points out its effectiveness and value at the framework, or policy determining levels. Here public input can help to determine objectives while options are still open, and may thereby avoid some of the dissent, criticism and confrontations which nowadays commonly arise as operational plans are produced. These views are extremely relevant to the present public debates about bauxite mining.

Planning in the sense in which the term is used here is not simply a matter of committee work or negotiation to resolve competing interests. The assembly and analysis of the relevant information demands full time staff work to develop policy options and predict the outcome of decisions which may be taken. It is perhaps not our place to propose an organisation for these purposes, and in any case, we cannot give it the consideration it deserves in the time available to us. However, we are aware of the SRI consultants' draft report, which is concerned with the same problem. In considering the solutions which may be offered there we suggest that Government also takes into account our discussion of legal and other controls on mining, and our critique of the ERMP procedure (Chapter 3). These indicate that:

- the legislation effectively applies some controls on mining, but only in so far as it relates to the Wagerup refinery
- the ERMP procedure, if strictly adhered to, tends to promote consideration of proposals in isolation
- the ERMP procedure tends to confuse the review of environmental factors with the management proposals which should be developed subsequently
- the ERMP procedure may not adequately provide for the revision of management proposals after initial acceptance by Government.

We therefore recommend:

- 11.1 *that, for the Darling Range, Government establishes a means for developing land use policies and options, and for co-ordinating land use planning at the regional, appraisal and operational level. These should include adequate provision for public participation at all stages.*
- 11.2 *that Government reviews the legislative controls on bauxite mining with a view to ensuring that the necessary control is placed on the Company in respect to environmental and other matters.*

- 11.3 *that the ERMP procedure be critically examined, and modified if necessary, to ensure:*
- (a) *that proposals are considered in an integrated and long term planning framework*
  - (b) *that the environmental review and subsequent management proposals are clearly separated*
  - (c) *that provision is made for revision of environmental management proposals with experience and with increases in knowledge and understanding.*

## CHAPTER 12

### CONCLUSIONS

We recognise that bauxite mining is a legitimate and economically desirable land use in the Darling Range. However, mining gives rise to environmental problems which are currently unresolved and are cause for concern. Existing legislation is neither clear, nor adequate for the proper regulation of bauxite mining and protection of the environment. The uncertain legal status of the Wagerup ERMP is a particular cause of concern.

The Wagerup ERMP presents Alcoa's most economic mining plan in a manner lacking in balance or objectivity, and fails to properly appraise mining options (see Chapter 3). In this sense it is incomplete. Further, since it is our understanding that the whole of the WERMP has some legal status, binding upon the State, the implications of which are not at all clear, we suggest that there is no alternative but to reject it.

We recommend:

- 12.1 *that the Wagerup ERMP should not be accepted in its present form because of its failure to present an accurate, balanced appraisal of the mining options, and because of the uncertainty of the legal obligations, binding on the State, which would be entailed by its acceptance.*

Nevertheless, we recognise that the Wagerup proposal has economic benefits to the State. In addition to mining, the construction of a gas-pipeline from the North West Shelf and the co-generation of electricity would provide a valuable stimulus to the economy. With adequate constraints and integrated land management, we believe that mining could proceed with an acceptable minimum of environmental damage.

We recommend:

- 12.2 *that, in principle, a proposal for the construction of a refinery at Wagerup be accepted, subject to the following conditions:*
- (a) *that the refining capacity of the Wagerup refinery should not exceed 2 million tonnes per year.*
  - (b) *that the State has no commitment to allow bauxite mining for the Wagerup refinery in areas other than those approved as part of an ERMP.*
  - (c) *that the Company, as part of an ERMP, be required to produce a map of an area containing sufficient bauxite to maintain the refinery for 30 years. The map should clearly show all areas to be mined as well as those for conservation, timber production, water catchment, recreation and other land uses.*
  - (d) *that the State requires the Company to submit a further ERMP for any extension of mining beyond the approved 30 year mining area.*
  - (e) *that, as mining proceeds, the detailed mining strategy be worked out with, and acceptable to the State; it should take account of environmental impacts and of other land uses; it should be kept under review, and from time to time the State should have the option of imposing such further conditions as are reasonable in the interest of the community.*

Our concerns about the environmental impact of bauxite mining clearly extend beyond the area of the current Wagerup proposal. They apply equally to the operations at Kwinana and Pinjarra. We are strongly opposed to mining proceeding in the present uncontrolled man-

ner until 2045. Even at a limited refining capacity the total impact on the environment and other land uses could be severe. (See Chapter 4, Fig. 3).

It is inconsistent to constrain activities at Wagerup if those at the northern refineries proceed unchecked.

We recommend:

**12.3 that, as a condition of acceptance of the Wagerup refining project, the following limitations should be placed on the operations at Kwinana and Pinjarra:**

- (a) **that there should be no further expansion of the Kwinana and Pinjarra refineries beyond 1.5 and 2.5 million tonnes per year respectively.**
- (b) **that the State, in respect of the Jarrahdale and Dwellingup mining areas, should require the Company to produce an ERMP, and should allow bauxite mining to proceed only in those areas that have been approved as part of an ERMP.**
- (c) **that the company, as part of an ERMP be required to produce a map of areas containing sufficient bauxite to maintain the refineries for 30 years. The maps should clearly show all areas to be mined as well as those for conservation, timber production, water catchment, recreation and other land uses.**
- (d) **that the state requires the Company to submit further ERMPs for any extension of mining beyond the approved 30 year mining areas.**
- (e) **that, as mining proceeds, the detailed mining strategies be worked out with, and acceptable to the State; they should take account of environmental impacts and of other land uses; they should be kept under review, and from time to time the State should have the option of imposing such further conditions as are reasonable in the interest of the community.**

If mining activities are to be worked out by Alcoa in collaboration with the State there has to be some mechanism whereby this can be achieved. To date there appears to have been lack of integrated land use planning and we believe that the State has been somewhat remiss in this area. We have argued for the establishment of a mechanism for integrated planning and have recommended (see Chapter 11):

**11.1 that Government establish a means for developing land use policies and options in the Darling Range and for co-ordinating and appraising land use planning at the regional and operational level. These should include adequate provision for public participation at all stages.**

We believe that a strong case has been made for both the environmental desirability (see Chapters 5 to 9) and economic practicality (see Chapter 4) of a flexible mining strategy. This flexibility allows the Company and State to develop an environmentally sensitive mining strategy which maximises benefit to all land users and hence to the State.

The same chapters of our report contain recommendations which could serve as guidelines in the development of mining in the future.

Planning is required not only for determining the location of mining, but also the subsequent rehabilitation of mined areas. There appears to have been insufficient attention given to the establishment of rehabilitation objectives (see Chapter 10).

A land use planning body would determine objectives, ensure their implementation and allocate responsibilities for rehabilitation. We have not been convinced that current rehabilitation techniques are sufficiently proven for the final outcome to be predicted with confidence.

We recommend:

- 12.4 *the assessment of current rehabilitation methods and their appropriateness to particular land use objectives.*

This integrated approach to land use is totally at variance with the philosophy expounded in the Wagerup ERMP. Since the latter document is radically different from what we suggest is desirable we recommend:

- 12.5 *that Alcoa produce, in collaboration with State planners, a revised ERMP based on a 2 million tonne capacity refinery, and a 30 year mining strategy which takes account of the recommendations in this report.*

The completion of this joint planning venture should be a condition of acceptance of a Wagerup refining project. We do not see that this exercise should be time consuming or costly for the Company though it requires planning activity on the part of the State.

We are not aware of any existing mechanism for implementing these conditions. However, we have recommended (Chapter 3):

- 3.5 *that the State explore ways of regaining a greater degree of legislative control over bauxite mining as a matter of urgency.*

The overall strategy we are proposing limits both refining capacity and the guaranteed lifetime of bauxite mining in the Darling Range, for the present. This is necessary if the State is to avoid a commitment at present which would permit mining in the future to proceed east of the 1150 mm isohyet, where the risks of serious damage to the water resources and the forest are greater. In addition, the strategy insists that mining is integrated with other land uses. At the same time it would allow associated industrial development to proceed, giving Alcoa a guarantee of another 30 years operation. This would enable them to sign and satisfy 30 year contracts, and to amortise their capital investments.

There is no doubt that in many areas the present technical basis is insufficient to adequately cope with some of the complex environmental problems. Only time, and further work will tell if satisfactory methods for overcoming these problems can be developed. The containment policy we have advocated is a method of ensuring time for research to try to provide solutions to the problems. There is a need for a substantial increase in the level of research funding in order that this work may proceed. We have recommended (Chapter 7):

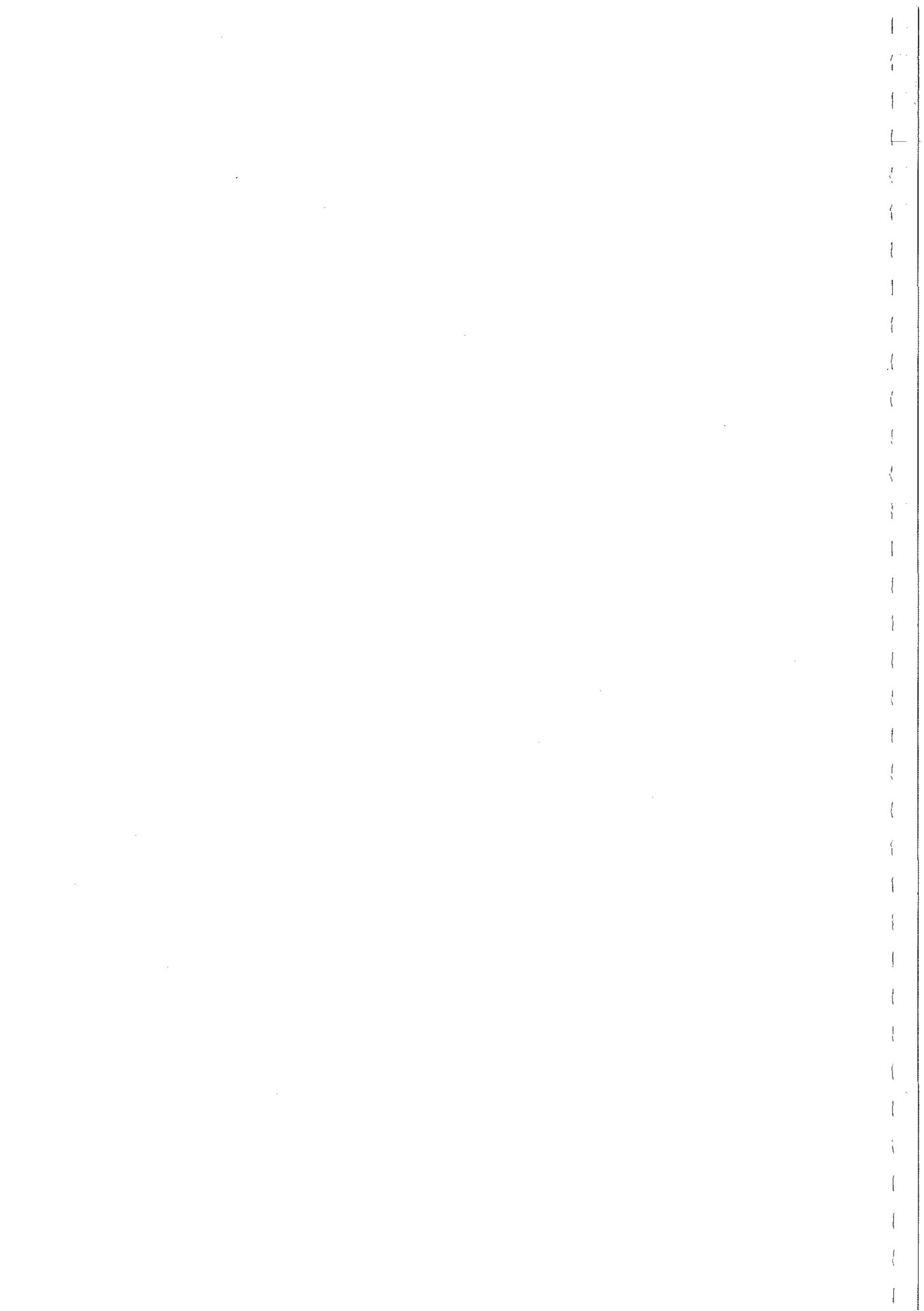
- 7.12 *that some mechanism be established for the collection and allocation of research funds as a condition of approval of the Wagerup refinery.*

If Alcoa wishes to preserve any possibility of extension of mining into the eastern zone at some time in the future we recommend:

- 12.6 *that the land use planning body for the Darling Range (which we have recommended above) consider trial mining and rehabilitation research in the eastern zone.*

If research provides solutions to these problems then Alcoa would have a degree of confidence in producing a convincing case for extension of their activities in the future. Because of this possibility there should be sufficient flexibility in long term planning arrangements to enable the Company to submit new proposals. It is suggested that this is done only when the planning authority agrees that the environmental problems have been overcome. These further proposals would obviously have to conform with the environmental practices current at the time. On the other hand, if the problems are still not solved at the end of 30 years the State should have a mechanism for closing down the industry.

Adoption of a strategy for controlling bauxite mining such as that outlined in this report is responsible and in the best interests of Western Australia. In the interests of this, and future generations, we ask the Environmental Protection Authority to give due consideration to recommending its adoption.



## APPENDIX I

### TERMS OF REFERENCE FOR THE TECHNICAL ADVISORY GROUP FOR THE ENVIRONMENTAL ASSESSMENT OF ALCOA'S ERMP/EIS ON THE WAGERUP PROPOSAL.

#### Introduction

The environmental issues involved in this assessment are complex, and some of the most important ever to face the State of Western Australia. They concern a mining activity in the hinterland of Perth, the capital and major population centre. The project involves a very large capital expenditure and probably extends over several decades. It is essential that the Technical Advisory Group appreciates the scope and context within which the EPA requires them to review and assess Alcoa's ERMP, and the whole question of bauxite mining in the Darling Range, as well as the general principles of the environmental assessment process.

#### Scope and Content of the Assessment

The Wagerup ERMP presents the company's most economic mining strategy in the Mt. William sector of the Darling Range for the first 25 years of the project. As such, it is part of the Company's planning for mining in that part of the Darling Range covered by Mineral Lease 1SA, a programme which could last 70 years or more. The Wagerup proposal therefore cannot be considered in isolation.

It is the State's concern that adverse environmental effects are minimised and that the costs of the project, in terms of adverse effects on other land uses such as forestry, water supply and recreation, are accounted for as well as the benefits. It is possible that the optimum plan, from the State's point of view, could differ significantly from that of the Company in the rate of development of refining capacity and its ultimate level, the consequent deployment of the mining operation, and the programming of these aspects in time.

The first twenty-five years of mining in the Mt. William area only accounts for one-third of the bauxite reserves there, and would only be in the western and higher rainfall section of the Darling Range. What happens to the whole of the forest is critical to the company, the State and the Darling Range.

The EPA requires the Technical Advisory Group to review the Wagerup document in this context, and in this regard, if more information is required than is available in the ERMP, it should advise the Department, which will make the necessary approaches to Alcoa.

#### The Aim of an ERMP

- (i) to describe in detail the existing environment likely to be affected by the proposed development.
- (ii) to describe the details of the proposed development — and any feasible alternatives to the proposed actions which make up the whole proposal.
- (iii) to describe in detail the environmental changes which would be incurred if the proposal is implemented.
- (iv) to determine which changes enhance the environment, and which are detrimental to the environmental 'status quo'; and of the latter which can be ameliorated by the adoption of certain management and rehabilitation procedures.

To this point, the document should provide an adequate basis for Government, as advised by its overall responsible environmental body (the EPA), to make a decision as to whether the proposal is environmentally acceptable (as well as economically, socially, etc.) and therefore whether or not it should go ahead.

An ERMP should also go one step further.

- (v) It should proclaim the detailed procedures which the proponent will implement in order to ameliorate any adverse environmental effects. In short, it should describe in detail the proposed Environmental Management Programme.

In all cases this programme should:

- (i) be based on the latest scientific results and technology; and
- (ii) be able to be changed, updated and improved on the basis of new results and improved techniques.

Consequently there should be an ongoing monitoring programme, the results of which are regularly assessed in order to modify and improve procedures.

## Normal Assessment Procedure

In the case of most proposals which come before the EPA (including Wagerup) many of the potentially adverse environmental effects are both predictable and technically possible to control and/or ameliorate. Most of these effects are covered by specific legislation which is the direct responsibility of specialist government bodies or departments. For example, air emissions are covered by the Clean Air Act and are consequently the specific responsibility of the Air Pollution Control Council.

The EPA has already directed copies of the Alcoa ERMP to such specialist departments with a request for their advice and comments. Upon receiving this information, the Department of Conservation and Environment will then collate and co-ordinate the information and pass it to the Authority who will take it into consideration in their overall environmental assessment.

**Note —** These comments will also be made available to the Technical Advisory Group.

## Concept of a Technical Advisory Group

On the other hand there are several complex environmental issues associated with the mining of bauxite in the Darling Range which are neither the responsibility of a single government body under any specific statute, nor are they technically simple to resolve at this point in time. Broadly these issues are:

- (i) the potential increase in the salinity of stream-base flow;
- (ii) the impacts of mining on the ecosystem of the Northern Jarrah Forest.
- (iii) the need for a determination of the long term land-use objectives of the Darling Range.

These potential environmental problems of the Wagerup proposal cannot at the moment be accurately quantified. At best their long term environmental impacts can only be predicted on the basis of current and, in many cases, inconclusive research.

The EPA has the responsibility of advising Government on the overall environmental assessment of these matters. In order to meet this obligation in respect of these issues, the Authority has requested, and had approved at the political level, the assistance of an Independent Technical Advisory Group which represents a high level of the scientific expertise necessary to review and assess the above complex environmental issues associated with the Wagerup proposal.

It is emphasised that the members have been chosen by the EPA on their personal and relevant expertise and that their advice to the Authority should reflect this expertise and not any official policy of the organisation with which they may be affiliated.

## **Issues to be Addressed by the Advisory Group**

The three broad issues the Advisory Group is required to address are:

- (I) the hydrological effects of bauxite mining, particularly the increase in the salinity of stream base-flow.
- (II) the impacts of mining on the ecosystem of the Northern Jarrah Forest; and
- (III) the consequences of the foregoing effects in determining mining strategies, seen in relation to other land uses, particularly water supply, recreation, conservation and timber production.

Within these three broad categories some of the specific aspects to be reviewed are:

- (I) the potential increase in the salinity of ground water and stream base-flow; and the effects on the jarrah forest, adjacent agriculture and the water resources of the Darling Range.
- (II) the need to conserve Jarrah as:
  - (a) a species,
  - (b) commercial timber.
- (III) what will be the effects of mining into the forest quarantine areas and what will its relationship be with respect to the spread of dieback.
- (IV) what is the current state of knowledge on dieback (*Phytophthora cinnamomi*) and its control; and are present mining and forestry practices adequate to contain dieback and protect areas of the forest.
- (V) in view of the current state of knowledge on dieback, and its present and forecasted rate of spread; what will its long term hydrological and environmental effects be.
- (VI) should dieback infected and "non-protectable" areas be mined immediately in order to rehabilitate as soon as possible.
- (VII) should "protectable areas" of the forest be mined.
- (VIII) is the present knowledge of rehabilitation adequate to ensure that rehabilitation will be successful in.
  - (a) all areas of the forest likely to be mined, and
  - (b) the long term.
- (IX) having assessed the effects of the proposal on the environment and on other land-uses, the group should determine whether the overall trade-offs associated with the proposal are acceptable. This should include a review of the short term economic gains against the longer term effects on the natural environment, the human and social environment, etc. Questions which need to be answered are:
  - (a) what does the State and its people get out of the proposal, and
  - (b) how do these gains stand up against the environmental costs which will be incurred (e.g. cost of rehabilitation, additional research on *Phytophthora*, resource depletion, etc.)?

## **Specific Questions to be Asked of the ERMP**

In addressing all of the environmental issues and assessing the Wagerup proposal, the Technical Advisory Group should ask the following questions:

- (I) Does the ERMP accurately describe all the required aspects of the existing environment?
- (II) Does the ERMP accurately forecast the potential environmental effects which will result if the proposal is implemented as described?

- (iii) Within the framework of the long term land-use objectives defined by the Advisory Group, are these environmental impacts acceptable?
- (iv) If the environmental effects are acceptable, are the rehabilitation, environmental management and ongoing monitoring procedures adequate, and if not what recommendations should the EPA make to Government?

OR
- (v) If the ERMP does not answer the above questions on the issues defined, what recommendations should the EPA make to Government?

## **Administrative Arrangements**

The Environmental Protection Authority sought and obtained approval for individual members of the Technical Advisory Group to be permanently detached from their employment for a period of approximately five weeks. During this time the Advisory Group will act as full-time consultants to the EPA although it is anticipated that members will be able to maintain reasonable contact with their own offices and organisations.

The role of the Department of Conservation and Environment is to assist the Technical Advisory Group in all ways necessary for the completion of their report to the EPA. This will include staff support as well as funding, purchase of any materials required, provision of office space and transport, and secretarial and typing facilities. Dr. Mulcahy will provide the communication link with the EPA.

## **Presentation of Technical Advisory Group's Recommendations on the Wagerup ERMP to the EPA.**

The Technical Advisory Group's assessment of the wagerup ERMP will be presented to the EPA as a comprehensive report consisting of the group's cogent arguments, conclusions and recommendations on the long term environmental implications of the Wagerup proposal viewed as part of the whole question of bauxite mining in the Darling Range.

It is envisaged that individual members of the group may be responsible for writing sections of the report while the Department of Conservation and Environment will collate, edit, prepare and print the final report.

## **Timetable for Assessment**

A provisional timetable and flow chart is appended. This will be discussed in detail at the group's first meeting at which the Chairman of the Environmental Protection Authority will brief the group on the task before them.

Provision has been made in the timetable for the Advisory Group to meet with the EPA for the presentation of their final report (if desired) and, after a period of deliberation by the EPA, to discuss and elaborate on their report if necessary.

The advisory group's report will need to be completed by 4 August, 1978.

22 June, 1978.

## **APPENDIX III**

### **FUTURE SUPPLY AND DEMAND FOR ALUMINIUM**

#### **Introduction**

The development of Australian bauxite mining and alumina refining has been important in satisfying the growth in the world demand for aluminium. Between 1962 and 1977 Australia produced over half of the increase in world production of alumina. Alcoa's Western Australian alumina production in 1977, of 3.45 million tonnes, is estimated to be more than half of total Australian output, and accounts for approximately 12.5% of the western world refining capacity of 28 million tonnes per year (WERMP, 1978).

Expansion of refining capacity has been planned in anticipation of an increased world demand for aluminium.

Proposals are as follows:

- Kwinana to expand from 1.25 to 1.5 million tonnes of alumina per year.
- Pinjarra to expand from 2.2 to 4.0 million tonnes of alumina per year.
- Wagerup to commence in 1981 and expand to 2 million tonnes by 1994 and to 4 million tonnes by 2002.

The increase in alumina production from 3.45 million tonnes in 1977 to 9.5 million tonnes in 2002 requires a demand growth rate of about 4.5% per year, assuming Alcoa maintains its share of the world market (Fig. 1).

#### **Prediction of Aluminium Demand**

Demand for aluminium has grown faster than for any other metal in recent years. Since the first shipment from Alcoa's Kwinana refinery in 1964, western world aluminium production has increased from 5 million tonnes to greater than 11 million tonnes.

Various projections of likely future growth rates have been made using time series of past production, and anticipated demands based on a variety of economic indicators. It has been observed, for example, that over the period 1945-77 growth averaged about 8 % per year cumulative (DID, 1978a). However, even the most optimistic forecasters concede that this rate of growth is unlikely to continue. In a study for the United States National Commission on materials policy Malenbaum (1973) estimated that western world demand for aluminium would increase at a rate of some 6% per year to about 36.8 million tonnes by the year 2000.

However, in response to increased energy costs, inflation and faltering western world economies, the aluminium industry experienced a sharp downturn in late 1974 and 1975. Aluminium producers cut operating rates and 1975 output levels declined 11% to about 2 million tonnes below the projected demand. Since then production has increased sufficiently to be slightly ahead of the 1974 level (Fig. 1).

The slower growth rate was reflected in a revised projection of future demands by Malenbaum (1977). His recent calculations indicate a growth rate of about 4.5%, with a demand of 29.4 million tonnes by the year 2000, a reduction of 7.4 million tonnes from his 1973 estimate (Fig. 1).

Alcoa's proposed increases in refinery capacity are compatible with Malenbaum's latest projections. They are also within the range of the 4-5% growth rate suggested by the DID (1978a).

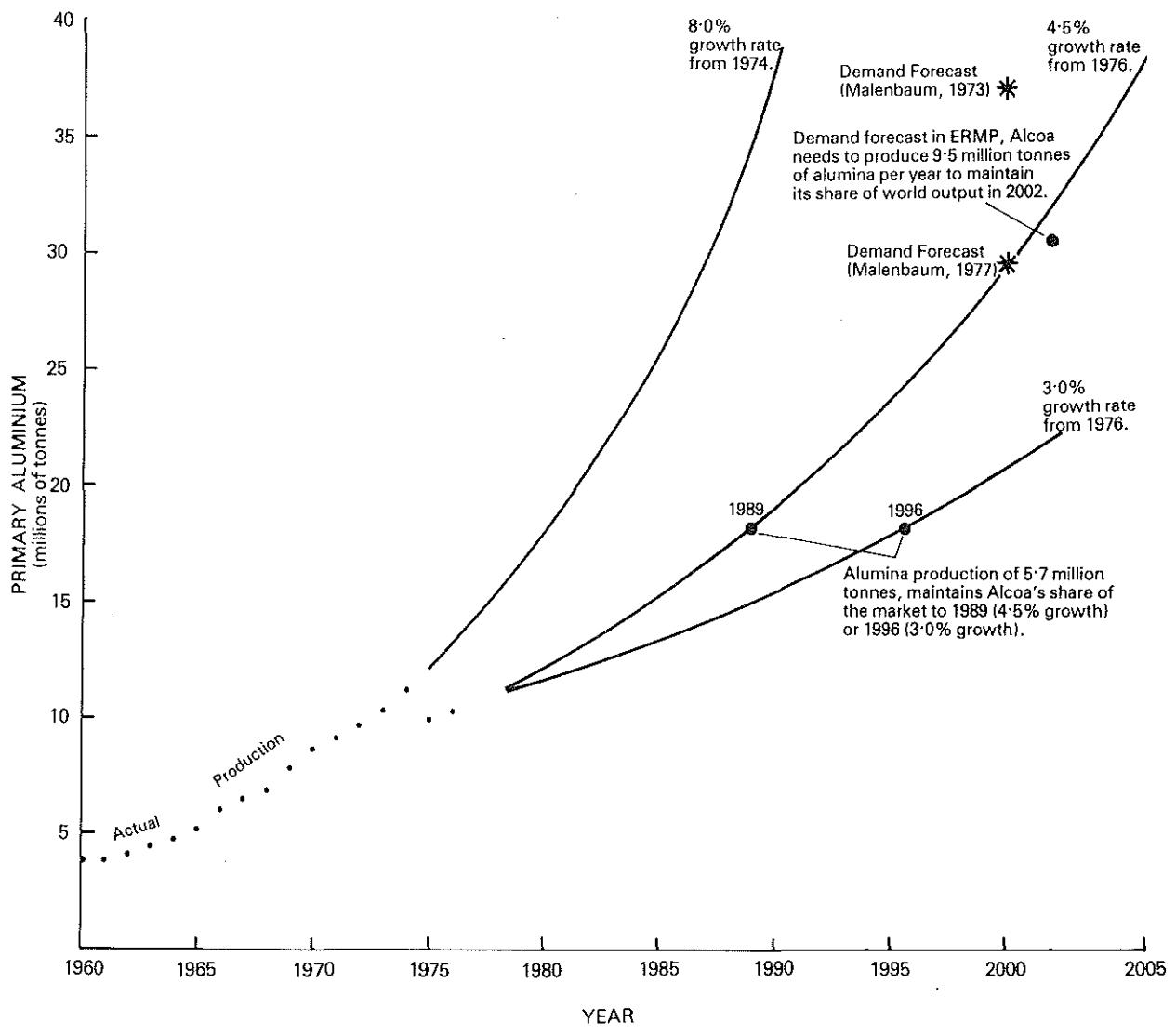


Fig. 1: Western world production of primary aluminium 1960-1976 and projected growth of aluminium demand to the year 2005.

The inherent uncertainty of long term predictive models is well demonstrated by Malenbaum's reassessment. It would be imprudent for the EPA to suggest yet another possible trend in the face of continued sluggishness in the world economies, particularly those of the USA, Japan and Europe. Nevertheless, the overall growth scenario has been used to determine proposed rates of expansion of the local alumina industry, and thus it has an important impact on the environment, plans for future industrial development and on energy resource allocation in Western Australia. *Whilst it is easy to assert that a conservative outlook restricts development, the current problems experienced by the vehicle industry, nickel mining and mineral sand mining point to the unpredictable nature of demand and the grave dangers of an overly optimistic outlook.* Some factors that will influence future aluminium supply and demand are discussed below.

## Energy

Aluminium requires large amounts of energy for its production. Alcoa's alumina refinery consumes about  $11.5 \times 10^9$  joules per tonne of alumina produced, equivalent to 0.3 tonnes of fuel oil or 300 m<sup>3</sup> of natural gas on an energy basis (WERMP, 1978), and smelting of alumina to aluminium requires of the order of  $50-80 \times 10^9$  joules per tonne of metal. Total energy involved in converting *in situ* ore to aluminium metal has been estimated to be in excess of  $250 \times 10^9$  joules per tonne (Kellogg, 1978).

On a weight basis aluminium production is about twice as energy intensive as copper and about seven times as intensive as steel. Fortunately, the low density of aluminium makes it less energy intensive on a unit volume basis. Also, its low weight may produce energy savings when it is used in the transport industry, and the metal has wide usage in building insulation and solar water heaters.

Despite the possible energy savings attained by using aluminium, the high energy input during refining and the shortage (and eventual depletion) of traditional forms of energy remain major problems for the industry. Energy conservation programmes within the industry have had some effect, but cheap power remains more than ever the key to a viable aluminium smelter. Alcoa's Pt. Comfort (Texas) smelter is powered by natural gas, and typifies the problem of refineries powered by non-renewable energy sources. It has been forced to operate well below capacity and its operating costs exceed market prices of aluminium (Mining Annual Review, 1977). The future of aluminium smelting may well be in the untapped hydro-electric power of large rivers in South America, Africa and Asia.

## Price of Aluminium

Aluminium prices remained relatively constant within the range US 23-29c. per pound between 1955 and 1973. Since then average annual US prices have escalated rapidly as shown below:

TABLE 1 — AVERAGE PRICES OF ALUMINIUM 1973-1977

(US cents/pound)

1973	1974	1975	1976	1977
25c	33c	40c	45c	52c

At present, the price of aluminium is almost at par with copper, whereas it used to be half as much. In the short to medium term aluminium's ability to eat into the copper market, and also the steel and plastics market, has been significantly eroded. Most commentators however, think that the long term aluminium market is assured.

## Increased Markets

It has been argued (Malenbaum, 1977) that the rate of growth of use of a metal as related to gross domestic product first increases in a given economy, then levels off and then declines as GDP continues to grow. The rate of growth of world aluminium demand which

was rapid in the early 1960s, has gradually declined. During that earlier period, aluminium was substituted on a large scale for other materials in a variety of uses, particularly in building and construction, transport equipment, food and beverage packaging, and domestic equipment. Having achieved penetration in the markets for these products, it might be expected that the rate of growth of aluminium consumption would thereafter decline to a rate which was consistent with general market growth in user industries, as the scope for further substitution by aluminium was reduced. Such a falling off in market growth would be accelerated by any price rises. In some uses there could be a movement away from aluminium if its price were to increase significantly. This pattern of diminished rate of usage in developed countries is compensated in demand projections by an assumed increase in GDP in the under-developed nations.

The need to conserve energy has opened growth opportunities for aluminium in automobiles, transport containers, and insulation. However, the motor industry to date has been slow in initiating large scale substitution of aluminium for steel. Without such penetration into new markets the rate of growth for aluminium will tend to decline.

## Recycling

It requires far less energy to produce secondary metal from scrap than primary metal from ore. (Kellogg, 1978). For aluminium the ratio of energy involved is of the order 1:20. In 1972 16.9% of US aluminium was produced from recycled scrap. However, only 3.4% was from "obsolete" scrap aluminium, the remaining 13.5% being turnings, offcuts, imperfect products, etc, from the aluminium fabricating industry. The recovery of obsolete scrap aluminium is made difficult because of the need to separate metal impurities before reprocessing. In 1969 only 13% of available obsolete aluminium scrap was recycled. The future will certainly see improvements in scrap recycling technology with consequent energy savings and reduction in demand for alumina for smelting to primary aluminium.

## Industry Competition

Bauxite is not a rare material. Vast reserves of bauxite occur in many countries, being particularly abundant in the Caribbean, Australia, South America and Africa. The future growth of bauxite mining and alumina refining in Western Australia cannot be considered to be independent of plans for growth in other Australian States and overseas. Indeed, the development of the Mitchell Plateau bauxite deposits and plans for the Alwest refinery are contingent on both world markets and Alcoa's future plans.

No significant addition to western world alumina refinery capacity occurred during 1977, and existing plants operated at about 87% of their production capacity. (Engineering and Mining Journal, March 1978). However, expansion of existing refineries and establishment of new refineries is planned for the early 1980s in many South American, Caribbean, European, African and Asian countries. (Edwards, 1977; Engineering and Mining Journal, January, 1978). Completion of these projects will maintain competition for expanding world markets.

## Conclusions

The aluminium industry appears to be assured of continued growth into the future. Growth rates will be below those experienced in the past and will depend on a return to more normal economic activity in developed countries, establishment of new markets in developing nations and increased usage of aluminium in, for example, transport-related industries.

High energy demands of the industry will continue to be a problem as conventional fuels become depleted and more expensive. Higher prices for aluminium will favour recycling of scrap, and may restrict market penetration.

Projections for future aluminium demands have been demonstrated to be unreliable. As Malenbaum (1977) has said — "It seems hard to believe today that only a few years back (during 1965-73) demand projections for raw materials were based on average GDP growth rates in the 5-6% range for a 30 year time frame."

## APPENDIX IV

### NATURAL GAS RESOURCES AND ALUMINA REFINING

#### Introduction

Western Australia possesses nearly 60% of Australia's estimated  $746 \times 10^9 \text{ m}^3$  recoverable natural gas reserves. (Urie *et al.*, 1977). The resource comprises two fields — the relatively small Dongara field 240 km north of Perth, and the larger fields of the Carnarvon Basin on the North West Shelf.

Gas from the Dongara field is piped to Perth for residential supply, alumina refining and other industrial use. Demand currently exceeds supply and existing contracts will be progressively terminated from 1982 until gas production ceases in 1987 (Kirkwood, 1977).

The recoverable natural gas reserves from the three Rankin Trend fields of the North West Shelf have been estimated at  $350 \times 10^9 \text{ m}^3$  (Kirkwood, 1977). North Rankin with reserves of  $240 \times 10^9 \text{ m}^3$  is the largest field followed by Goodwyn,  $70 \times 10^9 \text{ m}^3$  and Angel,  $40 \times 10^9 \text{ m}^3$ . Total "proven and theoretical" reserves of the Carnarvon Basin could be up to 30% higher (McGarry, 1977), and potential exists for further discoveries.

Total natural gas reserves of Australia comprise only 1.4% of the total world reserves (Anderson and Daniels, 1977), and impending problems of local supply have been indicated (Urie *et al.*, 1977). Natural gas supplies in Queensland are small. Gas from the Cooper Basin field is used to supply Sydney and Adelaide, but is barely adequate for Adelaide alone. Gippsland fields have sufficient gas to supply Victoria until after the year 2000, but peak demands are expected to exceed supply by the early 1990s.

The allocation of Australia's remaining natural gas reserves is clearly a subject of national importance.

At present, Australia imports about 30% of her petroleum supply and, in the absence of major new discoveries, this figure is expected to increase to about 70% by 1985. In units of energy, the annual petroleum shortfall by then is expected to be about  $1300 \times 10^{15}$  joules which is more than twice the anticipated production rate of the North West Shelf gas. The annual cost of importing this amount of oil has been variously estimated at between \$2,000 million and \$3,000 million. Esso Australia Ltd has recently reported ("The West Australian", 27 July, 1978) that Australia could face an oil import bill of \$7,200 million by 1990.

Western Australia's reserves of fossil fuels other than gas are limited. Crude oil reserves at Barrow Island are only 9% of the remaining Australian recoverable reserves of  $224 \times 10^6 \text{ m}^3$ . These Australian reserves represent only one-quarter of one per cent of the world reserves and at the end of 1976 amounted to only nine times the local production rate for the same year (Urie, *et. al.*, 1977). Despite the fact that the Collie field is small (less than one percent of Australia's total reserves) and of low grade, it will be sufficient for industrial use and electricity generation in Western Australia for at least 40 years. (DID, 1978b). Further coal reserves are being investigated in the Perth Basin.

#### Energy Demands in Western Australia

The SEC has forecast the demand for fuel usage in Western Australia during the period 1978-1988, with a long range prediction for 1998. Energy use is expected to increase at the rate of 6.1% to 1988 and then at 4.1% to 1998. Expected fuel requirements are as follows.

**TABLE 1. PROJECTED FUEL DEMANDS FOR WESTERN AUSTRALIA 1978-1998**

Form of Energy	Units	1978	1988	1998
Petroleum Liquids	tonnes x 10 <sup>6</sup> joules x 10 <sup>15</sup>	4.7 218 (70%)	6.1 283 (50%)	9.1 420 (50%)
Gas	m <sup>3</sup> x 10 <sup>9</sup> joules x 10 <sup>15</sup>	.9 34 (11%)	4.3 163 (29%)	6.3 241 (28%)
Coal	tonnes x 10 <sup>6</sup> joules x 10 <sup>15</sup>	3 60 (19%)	6 120 (21%)	9 185 (22%)
<b>TOTAL</b>	joules x 10 <sup>15</sup>	<b>312</b>	<b>566</b>	<b>846</b>

Based on SEC Report RP68, March, 1978.

Whilst the use of solar energy is expected to increase during the review period, its contribution will be mainly in the domestic sector, where it may provide up to 3.7% of the expected residential energy demand of  $43 \times 10^{15}$  joules by 1998.

Nuclear power generation was not considered in the SEC report, but it would have a significant influence on the future allocation of energy resources. As discussed below nuclear power may be inevitable if energy demands of current and planned industrial development are to be met.

### **North West Shelf LNG Proposed Development**

A number of reasons have been given to support the proposed North Rankin project. These include the following:

- Exploration for oil and gas on the North West Shelf is expensive and difficult. Approval of the North West Shelf project is a clear indication to companies that there are tangible rewards for discovery. This is expected to provide incentive for continued exploration.
- At a time of high unemployment and economic stress the project will provide job opportunities and industrial contracts for Western Australians.
- Western Australia depends on imported oil for nearly 70% of its energy requirements. Development of the natural gas resources will reduce our dependence to about 50%. Local industry will benefit from guaranteed supply for at least 20 to 25 years, and there will be a positive effect on the national balance of payments, at least in the short to medium term.
- Supplies of gas from the Dongara Field will be exhausted by 1987. Major changes in residential and industrial energy usage patterns would have to be effected if a replacement gas supply was not made available.
- The decision to develop the North West Shelf gas reserves to supply both export markets and Western Australian demands was made after consideration of alternative schemes based on limited and/or progressive development of the resource.

The planned North West Shelf project involves the construction of two gas-producing platforms, each capable of producing 19.3 million cubic metres of gas a day from about 20 wells. Gas would be piped ashore via a 130 km pipeline to a LNG processing plant. The capital cost of the project has been estimated to be in excess of \$3 billion. Firm contracts with prospective consumers are to be written prior to development and in common with most recent LNG projects will be on a 95% take or pay basis, over a 20-25 year period. Approximately two-thirds of the gas production is to be processed to LNG for overseas contracts and one-third is destined for the Western Australian market.

**TABLE 2. PLANNED NORTH WEST SHELF LNG PROJECT**

Market Sector	Yearly Production	Energy Equivalents (joules)	
Export LNG	$6.5 \times 10^6$ tonnes	327	$\times 10^{15}$
SW Pipeline	$3.1 \times 10^9 m^3$	118	$\times 10^{15}$
Pilbara	$0.7 \times 10^9 m^3$	28	$\times 10^{15}$
Condensate	$1.0 \times 10^8$ tonnes	45	$\times 10^{15}$
<b>TOTAL</b>			
<b>PRODUCTION</b>	$14.1 \times 10^9 m^3$	$538^{(1)}$	$\times 10^{15}$

Note: <sup>(1)</sup> The total energy of the marketable products is  $518 \times 10^{15}$  joules.

## South West Pipeline

The SEC will take delivery at Dampier of up to  $3.8 \times 10^9 m^3$  of natural gas per year. Gas will be used to supply the growing residential, industrial and mineral processing requirements forecast by the SEC.

**TABLE 3. ANTICIPATED WESTERN AUSTRALIA GAS DEMAND 1978—1998**

Gas and Energy Demand	1978	1988	1998
Residential $m^3 \times 10^9$ /year joules $\times 10^{15}$	.07 2.5	.18 6.7	.35 13.2
Commercial $m^3 \times 10^9$ /year joules $\times 10^{15}$	.02 0.8	.05 2.0	.11 4.1
Industrial $m^3 \times 10^9$ /year joules $\times 10^{15}$	.19 7.1	.64 24.4	1.00 38.0
Mineral Industry $m^3 \times 10^9$ /year joules $\times 10^{15}$	.62 23.4	3.39 129.4	4.87 185.9
<b>TOTALS</b>	$m^3 \times 10^9$ /year joules $\times 10^{15}$	.89 162.6	6.32 241.2

About 80 to 85% of the expected gas demand will come from Perth and the South West. To service this need the State have designed a pipeline capable of carrying  $3.1 \times 10^9 m^3$  of natural gas per year. The pipeline is expected to cost about \$400 million and should be in operation by 1984-1985.

## Alumina Refineries

Alcoa's 1977 alumina production was 3.45 million tonnes.

The refineries at Kwinana and Pinjarra currently use both imported fuel oil and Dongara natural gas for energy requirements. The Company's future energy demands can similarly be met by fuel oil or gas alone or in combination with coal or nuclear energy.

Approximately  $300 m^3$  of natural gas ( $11.5 \times 10^9$  joules) are used to refine 1 tonne of alumina. If both the Kwinana and Pinjarra refineries operated entirely on natural gas they would consume about  $1.04 \times 10^9 m^3$  of natural gas per year at the present production level. This is about one third of the planned Dampier to Perth gas supply.

Bauxite mining and alumina refining dominate mineral processing fuel demand in the South West (SEC, 1978). Because of the vast Darling Range bauxite resource and the expected increase in world demand for aluminium, Alcoa is favourably placed for expan-

sion of refining capacity. The State Government have given enthusiastic support to expansion of the alumina refining industry as part of an integrated development proposal with the North West Shelf natural gas project. This approach, however, has introduced the problem that assessment of the environmental impact of the proposed Wagerup refinery can no longer be viewed in isolation. The acceptance or rejection of the Wagerup project impinges strongly on the State's plans for gas supply to Perth and indeed the whole North West Shelf natural gas project.

Calculations based on a supply rate of  $3.1 \times 10^9 \text{ m}^3$  of natural gas to Perth and the South West and an anticipated 1988 demand of about  $2.9 \times 10^9 \text{ m}^3$  for the South West mineral processing industry (based on 85% of the SEC's 1988 demand projection), suggests that Alcoa's projected usage will be in the range  $1.5\text{--}2.0 \times 10^9 \text{ m}^3$ . This equates to alumina production of between 5 and 7 million tonnes per year. Even allowing for the possible energy requirements of integrated electricity generation, aluminium smelting and caustic soda production the increase in alumina refining capacity will have to be substantial to justify the SEC's projected natural gas supply undertakings. **Further growth of the alumina industry is anticipated in the SEC's projections to 1998, but the proposed gas supply would not be able to meet these increased requirements without eroding supplies to other gas customers (see below and Fig. 1).**

*If the State has entered into preliminary agreements with the North West Shelf joint venture partners on the one hand and Alcoa on the other for supply and purchase of gas at the levels suggested above, it could be construed as anticipating or pre-empting both the Wagerup ERMP and the present arrangement to constrain growth of the Pinjarra refinery. This could result either in acceptance of growth of the alumina industry regardless of environmental impacts or re-negotiation of gas supplies at a level that may put the viability of both the North West Shelf project and Dampier to Perth pipeline at risk.*

There is no doubt that alumina refining, even at the present level of production, provides a substantial market for North West Shelf gas, and gives the State a strong economic justification for building the Dampier to Perth pipeline. The large, and immediate gas requirements of the industry will ensure the most economic transport of gas to Perth, and will assist in minimising the transport component of gas costs for South West consumers. This impact on cost structure will be slight for residential consumers, but it could be a significant factor in determining the final cost of natural gas relative to imported fuel oil for industrial consumers.

## Other Demands for North West Shelf Gas

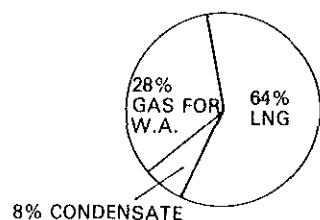
The SEC has pledged (Kirkwood, 1977) "top priority" treatment for residential, commercial and non-mineral processing industrial users of natural gas. If this undertaking is honoured, the amount of gas available for alumina refining, integrated electricity generation, aluminium smelting and caustic soda production may be severely limited. Other mineral processing projects, such as nickel refining, will also be restricted in their possible future use of natural gas. Failure to give top priority to consumers outside the alumina industry could result in shortages in supply over demand similar to those currently being experienced for Dongara gas.

Demand for gas for residential, commercial and non-mineral industrial use in Western Australia has been estimated to reach  $1.46 \times 10^9 \text{ m}^3$  per year by 1998. Assuming 85% of this demand is in Perth and the South West, this will constitute a natural gas requirement of  $1.24 \times 10^9 \text{ m}^3$  at about halfway through the projected life of the North West Shelf gas project.

Figure 1 is a bar diagram showing projected gas demands for Western Australia relative to natural gas supply from the North West Shelf gas project. *It is apparent that the planned supply cannot produce more than about 6 million tonnes of alumina and still satisfy the projected 1998 requirement for residential, commercial and industrial gas.*

NORTH-WEST SHELF RESERVES  
 $350 \times 10^9 \text{ m}^3 = 13400 \times 10^{15} \text{ Joules}$

→  
 25 years at  
 $14.1 \times 10^9 \text{ m}^3$



ENERGY DISTRIBUTION

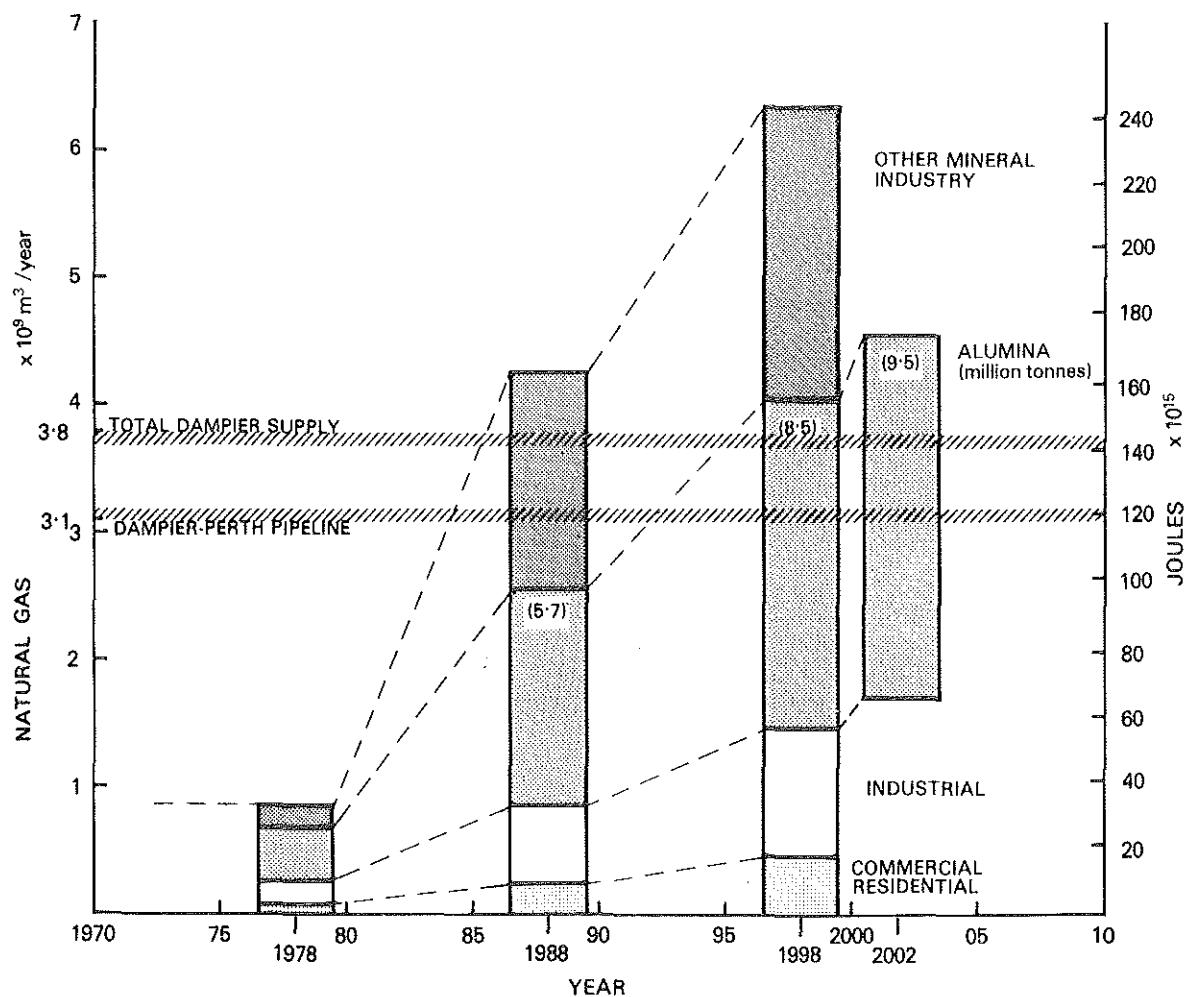


Fig. 1: Projected use of natural gas in Western Australia (SEC 1978) in relation to proposed North West Shelf natural gas development.

As demand continues to grow in the non-mineral processing sector after 1998 the amount of gas in excess of residential, commercial and industrial requirements would be smaller still.

It has been argued (DID 1978b) that use of natural gas in the alumina industry will reduce the imported fuel oil requirements and hence have a positive effect on balance of payments. This assertion is certainly true for the alumina refining industry when considered in isolation. However, it is only true in a general sense if alumina refining does not create a shortfall in gas supply for other competing users. In such cases, alumina refining would force other industrial or domestic users into having to accept the costs and uncertainties of imported oil supplies

*It has been calculated (E.H. Nickel pers. comm.) that alumina refining requires about 50 times as much energy per worker as the manufacturing industries. One is forced to question whether alumina refining is an effective use of energy at a time when the country's long term energy problems remain unsolved and there is a high rate of unemployment.*

Additional supplies of natural gas might become available to Perth and the South West in the future. These supplies would be contingent on demand, market conditions and economics of development at the time, and would depend on the discovery of new gas reserves. The existing pipeline would be able to transmit the greater volumes by increasing the number of compressor units.

## Future Energy Requirements for the State and the Alumina Industry

Alcoa anticipates that the life of its bauxite mining and alumina refining projects in Western Australia will be in excess of 70 years (WERMP, p. 2). Energy requirements of the industry might be expected to be within the range of  $66 \times 10^{15}$  joules (5.7 million tonnes of alumina) to  $110 \times 10^{15}$  joules (9.5 million tonnes of alumina). This requirement may last until the middle of the twenty-first century. Implicit in the Government's approval of such a large long term project is the assumption that adequate provision has been made for the future energy requirements of both the State and the alumina industry.

The SEC have presented a synopsis of the possible sources of energy supply to meet the expected increase in demand in Western Australia from  $312 \times 10^{15}$  joules in 1978 to  $846 \times 10^{15}$  joules in 1998. In making their assessment, the SEC appear to have assumed that Alcoa's planned rate of development will take place, and that Alcoa's major fuel source will be North West Shelf natural gas.

Western Australia is almost totally dependent on fossil fuels (Figure 2). Coal production from Collie is assured for 40 years or until about 2020. Present reserves of natural gas from the Rankin Trend are sufficient to guarantee production until 2005. The remaining fuel requirement is met by largely imported liquid petroleum products. If substantial discoveries of recoverable oil and gas are not made during the next 20 years, Western Australia will become dependent on imported fuels for nearly 80 percent of the anticipated energy demand. Prices for liquid petroleum products are expected to rise as world reserves become depleted. Our increasing dependence on overseas oil will make fuel supply potentially uncertain and will erode profitability of Western Australian industries.

Exploration activity on the North West Shelf, Exmouth Plateau and offshore Perth Basin has increased to a high level, largely in response to the restoration or introduction of a number of Federal Government incentives. In the six years to 1984 exploration companies have commitments to spend in excess of \$400 million and to drill some 102 new wells. It is probable that new gas resources will be indicated during the exploration and possible that new oil fields will be found. Difficulties of recovery from the deepwater Exmouth Plateau will demand the discovery of a large oil field and improved technology before development can occur. The existence of the Dampier to Perth gas pipeline could facilitate development of gas fields discovered in the southern section of the North West Shelf.

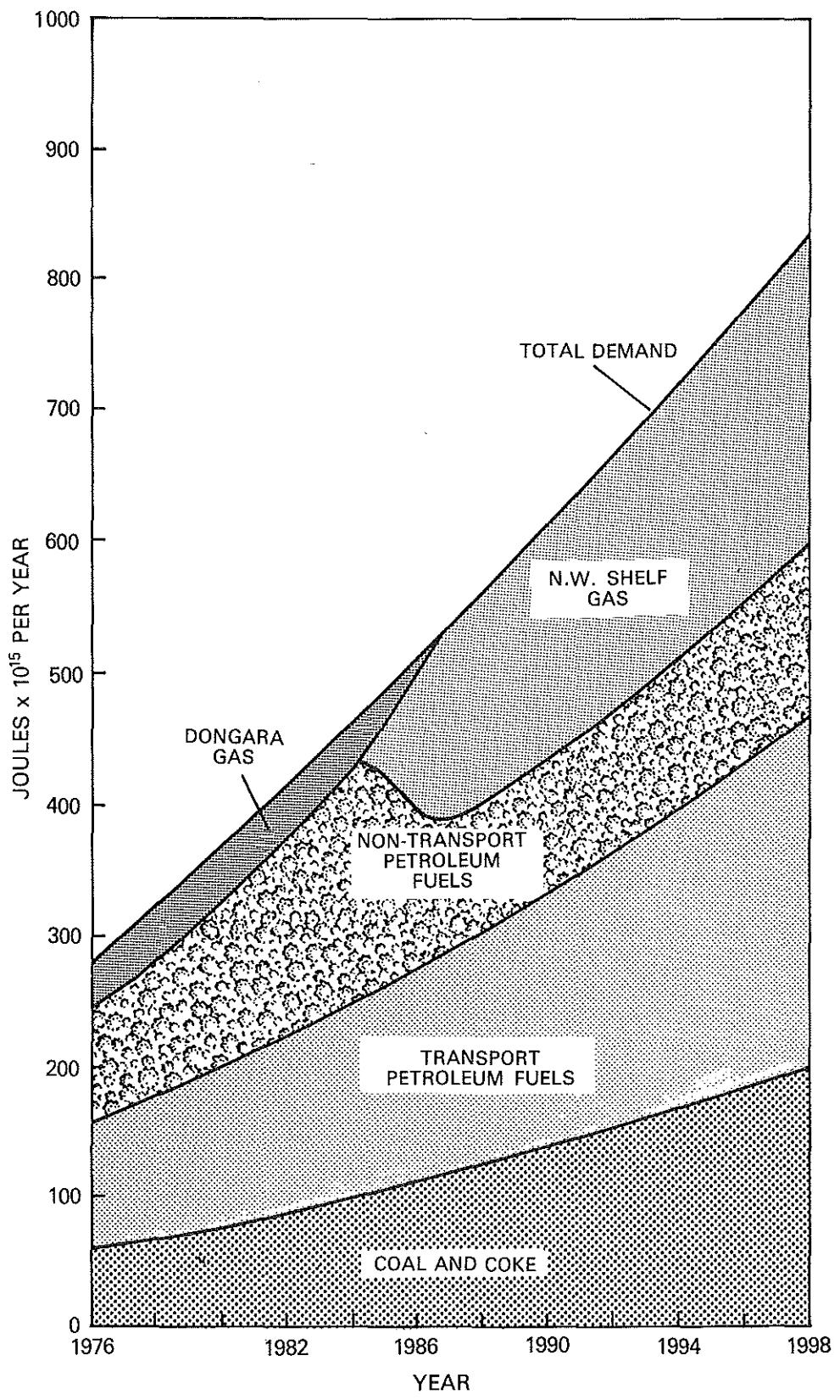


Fig. 2: Total fuel demand for Western Australia 1976-1998  
(based on SEC Report RP 68 1978).

*There can be no doubt that the Government will be in a much better position to judge the magnitude of our natural gas and oil resources in 1984 than at present. It would seem to be irresponsible to fully commit existing resources before further careful evaluation and planning have taken place.*

If the current oil and gas exploration is unsuccessful the Government may find that its proposal for a nuclear electricity-generating facility will become an early necessity in order to maintain energy requirements for planned and existing Western Australian industrial development. The cost of such a venture, or the cost of imported fuel oil, will be critical in determining whether Alcoa will be able to compete successfully against countries with alumina industries based on cheaper methods of power generation.

## **Alternatives to the Proposed North West Shelf Project**

The North Rankin project is dependent on the joint venture partners securing overseas contracts for LNG. A combination of economic uncertainty in Japan and the United States and competition from other LNG projects may make contracts difficult to secure. Alternatives to the proposed development scheme include —

- a reduced scale of project to provide gas for local consumption. This would be dependent on a market of sufficient size being developed in Western Australia. Alumina refining, probably at an expanded capacity, is the only planned or existing industry with sufficient energy demand to support the production from one platform
- a reduced scale LNG project to satisfy a small overseas market and supply LNG for Perth and the South West by tanker
- deferred development of the North Rankin project. This would necessitate import of LNG to satisfy Western Australia's future gas demand, and import of LNG or fuel oil for existing or planned alumina refining.

*Reduced or deferred development will result in a short term loss of employment and industrial opportunities. The long term result may be to conserve a rapidly dwindling Australian resource that may assume an even greater economic significance in the future.*

## APPENDIX V

### MINING COSTS AND ALTERNATIVE MINING STRATEGIES

#### Introduction

This Appendix provides a background to the Section of Chapter 4 entitled "Mining Location and Production Costs: Their Relation to Public Policy", and is in three parts. First, data are presented which help to identify the cost structure of bauxite mining and alumina refining in Western Australia and elsewhere. Second, the cost structure of the mining operation itself is considered. This prepares the way for the third part, which shows how bauxite mining costs would be affected by adopting an alternative, environmentally conservative strategy in the Wagerup medium term mining area.

#### Mining and Refining Cost Structures

A study of alumina and bauxite production costs was recently conducted by Commodities Research Unit (1978). They give production costs for an average alumina refinery in the USA in 1976, and contrast this with a new Australian project (see Table 1).

TABLE 1 — COST OF PRODUCING ALUMINA IN 1976.

(A) USA Average and (B) New Australian Project Using Low-Grade Bauxite.

Cost Item	(A) USA Average			(B) A New Australian Project		
	Units required per tonne of alumina	Unit price \$	Cost per tonne of alumina \$	Units required per tonne of alumina	Unit price \$	Cost per tonne of alumina \$
Bauxite	2.5 tonnes	28.00	70.00	2.75 tonnes	8.50	23.38
Caustic soda	88 Kg	0.15	13.20	60 Kg	0.15	9.00
Electricity	150 Kwh	0.029	4.35	160 Kwh	0.029	4.64
Fuel oil	265 litres	0.09	23.85	275 litres	0.09	24.75
Natural gas	1.25 m K.Cal	7.90	9.88	1.25 m K.Cal	7.90	9.88
Labour	2 man-hrs	5.38	10.76	2 man-hrs	4.30	8.60
Maintenance			15.00			19.50
Overheads			12.88			14.05
Delivery			nil			11.0
Total operating cost			159.92			125.30
Capital servicing	\$500/annual tonne at 10% for 20 yrs		58.73	\$650/annual tonne at 10% for 20 yrs		76.35
Total production costs			218.65			201.65

Source: Commodities Research Unit (1978)

Commodities Research Unit suggest that in 1976 the relative costs of bauxite mining and alumina refining (including capital servicing) were as follows:

TABLE 2 — SUMMARY OF ALUMINA PRODUCTION COSTS: USA AND AUSTRALIA IN 1976.

Project Location and Type	Production Costs (US\$/tonne)		
	Bauxite Mining	Alumina Refining	Total
USA Average	70.00	148.65	218.65
New Australian Project	23.38	178.27	201.65

Source: Commodities Research Unit (1978).

In the USA, the cost of bauxite represents US \$70/tonne of alumina, or 32% of alumina production cost. However, this estimate includes cost of transport to the USA and assumes that bauxite is purchased at market rates from an independent supplier. In the "new Australian project" bauxite accounted for only 12% of alumina production cost.

It would appear that the proposed Wagerup project is expected to achieve much lower production cost levels than the examples quoted above. The WERMP gives estimates for some of the mining and refining costs of the Wagerup project (page 406.). This data has been expanded to include an estimate of operating costs and gross margins, shown in Table 3. The calculation suggests that production costs including mining and refining at Wagerup have been assumed by Alcoa to be of the following order of magnitude:

1987	150 \$/tonne
1995	100 \$/tonne
2004	75 \$/tonne

The costs of production fall over the life of the proposed project, and at all times are well below the levels suggested by Commodities Research Unit for a new Australian project in 1976. The provisions for labour cost and imports (mainly caustic soda), for which data are given in the WERMP appear to be comparable in magnitude to those assumed by Commodities Research Unit. This suggests that in three remaining cost categories the production costs assumed by Alcoa are substantially lower than projects elsewhere, namely:

- maintenance and overheads.
- energy.
- bauxite mining.

There are good reasons for expecting maintenance and overhead costs to be low in Wagerup. The refinery will be brand new and its design should help to minimise maintenance costs. Overhead costs will be minimised by use of existing Alcoa staff and facilities. However, the implied cost assumption for energy is surprisingly low: while this does not concern us further in this appendix, it should be of concern to energy planners. Bauxite mining costs are considered below.

TABLE 3 — ESTIMATED COST STRUCTURE OF THE WAGERUP PROJECT  
(MINING AND REFINING COMBINED)

Year	(1) Wages and Salaries	(2) Depreciation Interest and Capital Repayments	(3) Operating Costs	(4) Payments to Government	(5) Gross Margin	(6) Total Revenue	(7) Production Cost
\$ at 1977 prices							
1987	7	44	21	10	-3	80	74
1995	19	80	84	81	56	320	199.2
2004	26	68	168	189	189	640	299.8
\$/tonne at 1977 prices (8)							
1987	14	88	42	20	-4	160	148
1995	9.5	40	42	40.5	28	160	100
2004	6.5	17	42	47.2	47.3	160	75

NOTES TO TABLE 3

- (1) WERMP p. 406
- (2) WERMP p. 406
- (3) Operating costs comprise imports (10% of revenue, WERMP p. 406), plus purchases of fuel and power, lime, maintenance, and local supplies. In 1977, when no major new plant construction was taking place, Alcoa spent \$65 million in payments to Western Australian contractors and suppliers (Department of Industrial Development, 1978b), including approximately \$12 million for energy. This represents \$18.6/tonne of their alumina production in that year. However, the Wagerup project is based on 100% local supply of energy (Imports, at 10% of revenue, p. 406, would not cover energy requirements). If Alcoa had obtained all its energy locally in 1977 it would have spent approximately \$65 + \$24 = \$89 million, or \$25.43/tonne. Thus, operating costs comprise imports, costing 10% of \$160/tonne (WERMP p. 404) plus domestic purchases of \$25.43/tonne, giving a total of \$41.43/tonne. Note, that this calculation makes no allowance for cost escalation, in for example energy.
- (4) WERMP p. 406.
- (5) Equals total revenue (6) minus ((1) + (2) + (3) + (4)). It is noted from the WERMP (p. 406) that cash flow to Alcoa does not become positive until 1988. Also, column (5) bears a relation to column (4), since the major part of Alcoa payments to the government sector are in respect of company taxation.
- (6) WERMP gives alumina production rates (p. 406) and revenue of \$160/tonne (p. 404).
- (7) The sum of columns (1), (2), (3) and 20% of (4).
- (8) Derived from upper half of the table using production levels given in WERMP (p. 400).

## Mining Cost Structure

It would appear that the cost of the bauxite mining operation in the western part of Alcoa's lease area is very much lower than the figure of US\$23/tonne of alumina quoted by Commodities Research Unit for a new Australian project in 1976. From visits to the mine sites at Del Park, Huntly and Jarrahdale, information supplied by Alcoa on conveying costs, and enquiries on equipment and labour costs, mining costs are estimated to be around \$3/tonne of bauxite (see Table 4); this is equivalent to approximately \$10/tonne of alumina. The estimate is, if anything a little on the high side, being based on the early stages when conveyor costs are higher.

**TABLE 4 — ESTIMATED COSTS OF BAUXITE DELIVERED TO  
THE WAGERUP REFINERY FROM THE WESTERN ZONE  
(1977 PRICES)**

Cost Item	\$/tonne
Crusher	
Roads, Dozers, Trucks	0.9
Conveyor	0.5
Blasting, Maintenance, Fuel, Labour	1.3
Total	2.7

This calculation strengthens our view that Alcoa derives a major advantage from the close proximity of its refineries to the bauxite deposit in the Darling Range. The small proportion of total production costs attributable to mining (about 8% in the first 15 years) supports our suggestion that there is considerable flexibility, from the company's point of view, to adopt alternative mining strategies.

From Table 4 it is also apparent that a substantial element of mining cost is fixed, regardless of mining location. For example, the costs of the crusher, roads, dozers, trucks, blasting, maintenance, fuel and labour are likely to be very similar from location to location. The main item which varies with alternative mining strategies is the cost of the conveyor. Some additional labour costs for manning conveyor junction points could be required in some mining plans, and there may also be a small additional element of downtime if the crusher has to walk longer distances between crusher sites. Overall, however, it seems that the cost items which vary with mining location only account for about a third of total mining costs.

### Costs of Alternative Mining Plans: Worked Example

In Chapter 4 of this report it is suggested that the appropriate measure of cost to the company from avoiding certain bauxite deposits (in the interest of other objectives of land utilisation in the Darling Range), is the difference in cost of bauxite supplied to the refinery. In order to demonstrate the small magnitude of cost difference involved in the selection of alternative mining strategies, we have considered, as an example, the exclusion of two areas from the proposed medium term mining area (WERMP, Fig. 3).

Figure 1 of this Appendix shows a possible network of crusher sites linked by a conveyor system in the medium term mining area. Alcoa confirmed this as being a plausible mining strategy during our field investigations. It is based on the available details of refinery capacity levels (WERMP p. 406) and approximate bauxite locations (Figure 3 of the WERMP and pers. comm. Alcoa). It appears reasonable to assume that all mining costs other than those associated with the conveyor are constant at each mining pod. Thus the difference in cost between two mining strategies will be equal to the difference in conveyor costs, which run at \$0.5 million per kilometre at 1977 prices. (Alcoa pers. comm.)

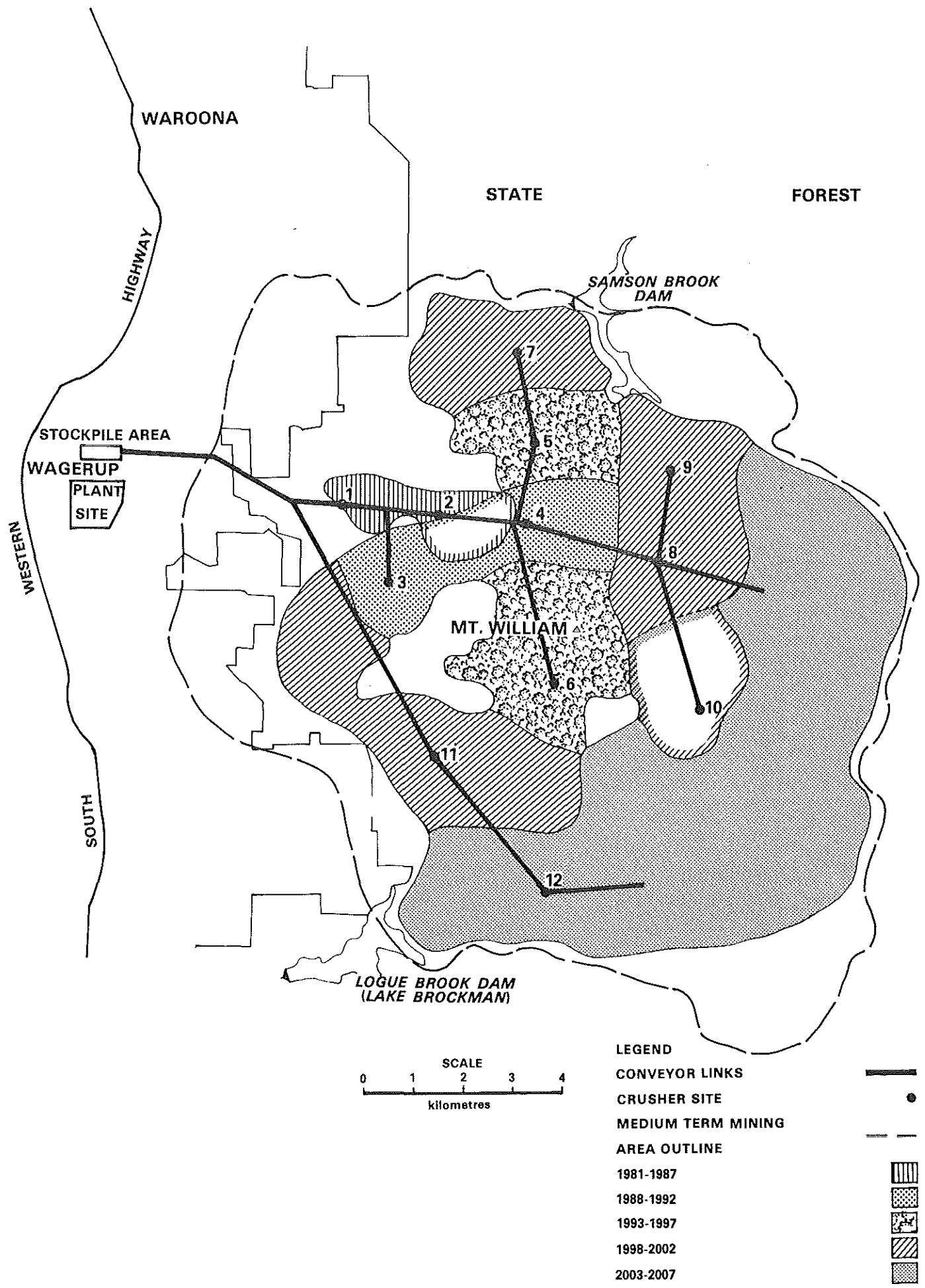


Fig. 1: Possible conveyor system, in the medium term mining area.

The two strategies compared in this example are:

- (A) the strategy preferred by Alcoa (WERMP Fig. 3)
- (B) a strategy devised to ensure the same production schedule as Strategy (A), but excluding the Samson area (crusher site No. 9) and the Mount William area (crusher site No. 6). See Fig. 1.

Table 5 shows distances and estimated capital cost of the conveyor for each possible link in the network. There is negligible operating cost, as the downward incline presents a zero net energy demand. Cost of labour required to man junction points on the conveyor has not been included in this analysis, but its omission is very unlikely to be significant in this particular example.

**TABLE 5 — ESTIMATED NETWORK OF POTENTIAL CONVEYOR LINKS AND THEIR COST: WAGERUP MEDIUM TERM MINING AREA**

Link (1)	Distance km	Estimated Cost (2) \$ x 10 <sup>6</sup>
0, 1	5	2.5
1, 2	2	1
1, 3	1.8	0.9
2, 4	2	1
4, 5	2	1
4, 6	3	1.5
5, 7	1.8	0.9
4, 8	2.5	1.25
8, 9	2	1
8, 10	3	1.5
0, 11	10	5
11, 12	4	2
12, 13*	2	1
13, 14*	2	1
14, 15*	2	1
8, 16*	3	2
16, 17*	2	1
17, 18*	2	1

**NOTE TO TABLE 5**

- (1) Each link refers to a stage between two crusher sites shown in Figure 1; Site No. 0 is the refinery.
- (2) At 1977 prices

\* These links are not shown in Figure 1.

Table 6 shows the estimated conveyor costs for the strategy preferred by Alcoa, discounted at 10% (WERMP p. 405 gives 10% as Alcoa's preferred discount rate). Table 7 gives a comparable schedule for the alternative strategy. Links (4,6) and (8,9), being spurs from the main conveyor route to the proposed Mt. William and Samson mine sites, are now omitted. In order to maintain the same level of alumina production at each date, some crusher sites are now needed earlier in the time frame (crusher sites 8, 10 and 12) and some new crusher sites enter the time frame (sites Nos. 16 and 17). However, the alternative mining plan imposes a very small extra conveying cost, the total discounted cost in Strategy B of \$6.0 million being a mere \$0.2 million larger than in Strategy A.

It is thus apparent that the effect on total project costs of adopting such an alternative mining plan would be very small indeed. The above calculations indicate that variable mining costs might be increased by 3% in the alternative plan. This represents just 1% of total

mining costs, and about 0.1% of the total cost of producing alumina. It is not necessary to enter any detail of sensitivity testing to prove that quite large errors in the above estimates of mining and refining costs would be unlikely to affect this general result. The main area of sensitivity would lie in the ability of the mining strategy designers to provide some mine sites close to the refinery in the early years of the project: note that in the worked example, Strategy B is identical to strategy A for the first 13 years.

**TABLE 6 — ESTIMATED CONVEYOR COSTS 1980-2004  
MINING STRATEGY (A) — (PREFERRED STRATEGY  
IN WAGERUP ERMP)**

Link (1)	Date	Discounted Cost (2) \$ x 10 <sup>6</sup>
0, 1	1980	2.28
1, 2	1984	.62
1, 3	1988	.38
2, 4	1989	.39
4, 5	1993	.26
4, 6	1995	.33
5, 7	1998	.14
4, 8	1999	.19
8, 9	2000	.14
8, 10	2002	.17
0, 11	2000	.70
11, 12	2003	.20
<b>Total Discounted Cost</b>		<b>5.80</b>

**NOTES ON TABLE 6**

- (1) Link refers to stage between each crusher site shown in Figure 1.
- (2) Discount rate assumed = 10% per year; cost of each link obtained from Table 5.

**TABLE 7 — ESTIMATED CONVEYOR COSTS 1980-2004  
MINING STRATEGY (B) — (EXCLUDES SAMSON  
AND MOUNT WILLIAM MINE SITES)**

Link (1)	Date	Discounted Cost (2) \$ x 10 <sup>6</sup>
0, 1	1980	2.28
1, 2	1984	.62
1, 3	1988	.38
2, 4	1989	.39
4, 5	1993	.26
4, 6	omitted	
5, 7	1988	.14
4, 8	*1995	.28
8, 9	omitted	
8, 10	*1995	.33
0, 11	2000	.70
8, 16	*2000	.28
16, 17	*2001	.12
11, 12	*2002	.22
<b>Total Discounted Cost</b>		<b>6.00</b>

**NOTES ON TABLE 7**

- (1) and (2) See Table 6.
- \* Links and dates which differ from Strategy A

It is easy to envisage that negotiated variations in Alcoa's reclamation expenditure could counterbalance cost differences between alternative strategies. At present, Alcoa plan to spend around \$10,000 per hectare on mine site rehabilitation. Thus if, by avoiding environmentally sensitive areas, average reclamation costs could be reduced, it would not require a very large amount of low cost rehabilitation to fully recover any additional conveying cost. For example, a saving of \$2,000 per hectare in discounted rehabilitation costs over 100 hectares would fully compensate the company for adopting Strategy B rather than A.

Thus, we are led to the general conclusion that at little or no cost to Alcoa, bauxite mining could be directed away from areas which yield environmental benefits to the community as a whole.

## APPENDIX VI

### JARRAH DIEBACK RESEARCH

#### Department of Soil Science and Plant Nutrition

DATE: 31st May, 1978.

Memo to: Dr. M.J. Mulcahy,  
Convenor,  
Supervisory Panel on Project 8 (Jarrah Dieback)  
For the Steering Committee on Research into the Effects of  
Bauxite Mining.

Subject: Report on Jarrah Dieback with special reference to the causal  
agent, the fungus *Phytophthora cinnamomi*.

The working party on *P. cinnamomi* was asked to consider what research is most urgently required to better understand the biology and spread and possible control of this soil-borne pathogen. This we have done, and our conclusions are summarised in the attached report.

This report deals almost exclusively with *P. cinnamomi*, pointing up areas of study which we think are necessary and urgent. However, I wish here to register my personal view that an ecosystem operates as a whole, and to neglect any major part of it will result in defective or misleading results.

The biology of the forest litter layer is of great importance, (a) because the litter constitutes an important reservoir of plant nutrients, as well as modifying the micro-climate of the soil surface, (b) because active populations of soil fauna and soil micro-organisms are responsible for mineralising this litter, releasing its nutrients for plant growth.

The soil fauna are important in the initial comminution and digestion of the more indigestible parts of the litter. As well, some members 'graze' on the bacteria and fungi which continue the 'digestive' process to the point where ammonia, phosphorus, calcium etc. are made available to plants. The larger soil animals may in turn be eaten by birds and other vertebrate fauna, and these, of course have their special roles in the system.

Forest management practices, such as firing, can greatly reduce the biota of the litter layer, and the faunal population may take several years to recover (see Dr. J.A. Springett's published research in W.A.).

From the foregoing, I think it can be seen that we ignore the biology of the litter layer at our peril, and I hope that funds can be found to maintain sustained research into this key part of the forest ecosystem. Such work would be integrated with that of scientists working on forest nutrient cycling, and with work on *Phytophthora* itself.

(C.A. Parker)

Memo to: Dr. M.J. Mulcahy,  
Convenor,  
Supervisory Panel on Project 8 (Jarrah Dieback)  
For the Steering Committee on Research into  
the Effects of Bauxite Mining.

#### Report on Jarrah Dieback, with Special Reference to the Causal Fungus

The working party on *Phytophthora cinnamomi* was asked to consider priorities for research into the problem of the jarrah dieback disease. This we have done, and our con-

clusions are summarised below. This Report deals almost exclusively with *P. Cinnamomi*, pointing to areas of study which we think are necessary and urgent.

### I. The Situation Now — a Summary of Major Knowledge

- (i) Jarrah Dieback is caused by a soil-borne fungal pathogen, *P. cinnamomi*, first elucidated by Podger, Zentmyer and Doeppel 13 years ago. It was almost certainly introduced into Western Australia and is not an indigenous organism.
- (ii) It is transported to disease-free areas by movement of soils carrying (probably) chlamydospores, a resting spore phase, also, by running water which would transport both chlamydospores and zoospores.
- (iii) For these reasons (in ii) it spreads naturally downhill rapidly, uphill very slowly by mycelial growth. It is clear that virtually all new separate focal points of infection arise from human activity.
- (iv) Certain soils favour the disease organism and plant infection, e.g. sandy surfaced, lateritic soils, especially those subject to seasonal waterlogging. Other soils, e.g. the richer valley soils, appear to contain or suppress the disease. It seems likely that jarrah may be less susceptible to infection in the richer soils, and there is evidence that these soils are also more "suppressive" to the fungus.
- (v) The dense population of micro-organisms on the roots, known as the rhizosphere population, has a protective effect. Thus marri is effectively protected, jarrah is less so, remaining susceptible. The protection is probably derived in part at least from the symbiotic mycorrhizal fungi, which have not yet been grown in the laboratory. This means they cannot be tested, alone, as protectants against *P. cinnamomi*. It is known that the mycorrhizas of pine trees, which can be grown in the laboratory, can confer resistance to the fungus.
- (vi) There is evidence that some "fire" legumes such as *Acacia pulchella*, whose seeds germinate after hot burns, make their soil suppressive to the dieback fungus (Shea and Malajczuk). Similar suppressive action was obtained from *Casuarina* spp. by Titze and co-workers at Kelmscott.
- (vii) The nutritional status of forest soils appears to be important in containing the dieback disease — there is less dieback in the more fertile soils both in Western Australia and in eastern Australia. Liming the soil has undoubtedly reduced disease in pots, a result gained in Western Australia in 1977 by Jan Titze and his associates, who are following this lead in the field, and by Robson, Boughton and Malajczuk. The latter group has also obtained growth responses by jarrah seedlings in the field.

### II. Suggested Priorities for future Microbiological Research into Jarrah Dieback.

The microbiology of jarrah dieback is not well understood. By this is meant the biology, ecology and epidemiology of the pathogen, as well as its interaction with other microbial elements in the soil. There is also a dearth of mycological work in this state, where the problem seems to be substantially different from the eastern states. Thus extrapolation of results from eastern Australia to the Western Australian situation could be dangerous.

Priorities for research are listed in descending order of urgency:

#### (i) Detection Problem

Even in areas where trees and shrubs show severe and obvious dieback symptoms there is often great difficulty in detecting and isolating the pathogen. Is this due to our different soil types in Western Australia, with their different microbial populations? Can the pattern of soil infectivity be related to the pattern of plate isolations, or of trap host infections? Is the fungus ephemeral in soil, or does it require special conditions to grow out in laboratory media? These are important questions which cannot yet be answered.

- (ii) **The Biology of the Organism**
- Although something has been learned about the fungus by American, New Zealand and Australian workers, there is still much about the pathogenic fungus that we do not understand.
- (a) **Strain variation** — We know little about variation in the *P. cinnamomi* population in the jarrah forest, although CSIRO Forestry Division Officers do have some unpublished work on such strains.
- They could be important because of differing ability to grow in soil; or to form resistant propagules; or to infect host plants.
- The potential for production of hypovirulent strains which might protect susceptible plant roots by cross-infection (a little understood phenomenon akin perhaps to immunity in animals) has not been examined. In the USA the chestnut blight disease, caused by a different pathogen to *P. cinnamomi*, can be cured by inoculation with hypovirulent strains of the virulent pathogen.
- (b) **The life cycle of the organism** — This is quite complex and the soil factors affecting it are far from fully understood. The conditions for the production and germination of the various propagules need more clarification.
- (c) **Survival of propagules in soil** — The ability of propagules to survive in different soils or under different soil conditions requires further examination. At this stage we still do not know what constitutes the major infective agent in the jarrah forest soil, though present evidence favours motile zoospores. The role of the chlamydospore is uncertain and reports of mini-chlamydospores need closer examination. These potential infective agents (propagules) need further study to establish their relative importance. The chlamydospores may well be the principal agent of spread of the disease into new areas.
- (d) **Infection** — Little is known about the infection process in soil, or about the mechanisms enabling *P. cinnamomi* to invade the tissues of so many hosts belonging in different Orders, Families, Genera and Species.
- (e) **Interaction with other soil micro-organisms** — It is known that certain soil microbes have profound effects on the formation of various kinds of spores by *P. cinnamomi*. In addition, some soil bacteria cause hyphal lysis and sporangial degradation. This area of research needs to be consolidated and expanded. In particular, the possibility that the fungus may have a saprophytic phase in the soil needs careful investigation.
- (f) **Effects of seasonal variation** — The pathogen is known to respond to major seasonal variations, and this should be further examined in relation to the effects of different soil types. Such information should be valuable when formulating quarantine regulations.

(iii) **The Role of Mycorrhizas**

Several reports indicate increased resistance to *P. cinnamomi* by mycorrhizal roots. Dr. Malajczuk has local knowledge of this phenomenon, and would be interested to continue. Little has been done in this area apart from Dr. Malajczuk's own work, and this approach deserves support as a possible means of protection. Apart from any effect on *P. cinnamomi*, the mycorrhizas are important in their own right as nutrient gathering symbionts for the plant hosts.

We have not closely considered the possibility of developing "suppressive" soils by encouraging certain leguminous understorey shrubs in the jarrah forest. Nor have we emphasised research on the mineral nutrition of jarrah trees. Both these areas of research are promising and will deservedly attract much work and interest. This report emphasises the importance of increasing the study of certain basic microbiological problems.

There is no more complex biological problem than root disease, and there are no short cuts to control. Basic information about the fungal pathogen and the factors affecting its behaviour is essential if we are to understand and hopefully control this disease.

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5th June, 1978

## APPENDIX VII

### PREDICTIONS OF THE EFFECT OF BAUXITE MINING ON STREAM SALINITY

Predictions of the effect of bauxite mining on stream salinity are particularly important for long term planning of water resources and other related land uses in the Darling Range. The techniques currently available are briefly described below, together with some of their limitations and their use by Alcoa for the assessment of the environmental impact of their Wagerup Refinery proposal.

The simplest predictions developed by Peck (1976) are based on the following basic concepts:

- that the groundwater systems can be lumped together over a catchment and characterised by a simple average groundwater salinity
- that water previously transpired by forest vegetation recharges the groundwater system and is discharged to the surface stream system within the same annual cycle
- that the additional salt carried by the stream following clearing is a product of the additional water discharging from the groundwater system and the salinity of the additional discharging groundwater

An estimate of the final salinity is simply calculated by taking the ratio of the initial plus additional salt discharge divided by the initial plus additional volume of flow. No changes are assumed to occur in the surface runoff component but total streamflow is increased by the additional groundwater discharge. Alternative predictions can be made by assuming that the additional groundwater flow is lost to evaporation and does not contribute to any additional streamflow.

This model was originally developed to simulate the effects of permanent removal of vegetation and therefore takes no account of the effect of rehabilitation in the bauxite mining case. The assumptions are clearly very crude and involve either gross over simplification or are simply not true. For example, it is known that the groundwater system often has a significant relatively fresh perched water table in porous (lateritic gravel) soils above a deeper more saline groundwater system in pallid zone clays. Significant changes have been observed in these shallower groundwater systems following mining (see chapter 8) but no means of accounting for these changes have been developed as yet.

It is simply not true that additional groundwater recharge is discharged to the surface stream system within the same annual cycle. The hydraulic properties of the clay aquifers indicate very slow lateral movement (hydraulic conductivities are of the order  $10^{-2} \text{m}^3/\text{m}^2 \text{ per day}$ ).

A more detailed model (Peck *et al*, 1977) to account for the time response of groundwater is discussed later. No account (in a predictive sense) can be made of the effects of salinity in wet or dry years or between high or low flow periods within a year.

Despite such obvious limitations the technique provides a formalised structure to assess the relative importance of the major factors known to contribute to the severity of salinity problems. Accepting the above limitations only four sets of data are required to enable prediction, namely:

- current stream flow volume
- current average streamflow salinity
- the estimate of the groundwater salinity
- an estimate of the additional recharge following clearing.

Estimates of the increase in recharge following agricultural development have been made using the assumption that catchments were in an approximate salt balance before clearing (Peck and Hurle, 1973). Estimates are relatively reliable in low rainfall areas (800 mm per annum or less) where salt balances have been significantly disturbed and where recent drilling programmes have provided independent estimates of additional recharge following clearing. Recent attempts to confirm estimates of around 400 mm per annum of additional recharge in high rainfall areas (1150 mm plus) have emphasized the uncertainty in the estimates based on the salt balance approach. Data from groundwater observations (Hurle, pers. comm.) and a general review of streamflow yield changes in the American forest hydrology literature (Anderson *et al*, 1976) suggest that changes are unlikely to be in excess of 250 mm-300 mm in the high rainfall areas.

Estimates of the salinity of the additional groundwater flows can be made from:

- surface stream base flow salinities
- salinities of deep groundwaters as measured from observation bore holes, and
- the salinities of moisture held in the complete soil profile. That is the total stored salts divided by the total stored water.

Base flows from surface streams contributed to by local perched waters can significantly underestimate groundwater salinities. Further there is considerable evidence that all salts held within the soil profile are not mobilised following clearing. Because of these factors groundwater salinities from bore holes are currently considered the best estimate of the likely salinities of the additional discharging groundwaters following clearing.

Given this background the approach taken in the WERMP (p. 314) to predict the effects of clearing in the first 30-35 years are considered to be sufficient within the limits of our current understanding. Because a high recharge figure following clearing was used in the WERMP and no rehabilitation was assumed, Alcoa's estimates if anything are on the high side.

The predicted increases in stream salinity are very small (less than 20 mg/l and would be very difficult to detect from the natural variation in salinity from year to year).

To account for both the spatial, temporal and transient nature of bauxite mining, Peck *et al.*, (1977) developed a model for predicting the effect on the salinity of inflow to South Dandalup Dam. Essentially the model uses scale parameters of the clay aquifer and associated parameters of the location and area mined to provide some estimate of the time delay between the upslope vegetation disturbance and the stream response. Various limitations of the model have been discussed in the original paper and within the WERMP (p. 398-400) and will not be reiterated in detail here. Additional points which may tend to increase the predicted salinity include:

- responses of groundwater are considered to cause an underestimate of peak salinities because of limitations in the assumed boundary conditions for the groundwater flow calculations (Byrne, pers. comm.)
- further salinity data from groundwater drilling (Herbert pers. comm.) indicate higher levels than used in the original calculation.

Decrease in the predicted streamflow salinity would be caused by:

- the adoption of lower estimates of groundwater recharge (based on additional salt and water balance, calculations and additional drilling data), and
- a different strategy of mining to minimise the mining of saline areas at a time which would accentuate the salinity peak (WERMP, p. 435).

Many other limitations remain, both within the structure of the model and the input data. For example, the multiplier affect between mining and dieback is a vital factor in the prediction. Cases for both a reduction of the 3:1 ratio in the west and an increase to 4:1 in the

eastern zone could be made (Chapter 7). The crude concept of the presence of one ground-water system with no consideration for the role of perched water tables and surface runoff should not be overlooked. Also concern has been expressed about how different ground-water mounds might interact between pits and produce different responses from the model (Byrne, *pers. comm.*).

Despite major inadequacies, the two predictive models for salinity estimation can, using broad regional data, serve to indicate the order of magnitude of the salinity threat. In the context of broad scale land use issues these models are considered to be of considerable value. Research must be aimed at improving these estimation techniques in the long term. Additional refinements may well require far more accurate data and more detailed analysis.

In the context of mining through the eastern, potentially saline region, it is considered that Peck *et al.*'s (1977) conclusions still stand, namely that:

- bauxite mining alone without dieback will have negligible effect on South Dandalup salinities
- that in conjunction with dieback significant increases in salinities are likely, and
- that substantial control should be achieved by a successful programme of reforestation.



## APPENDIX VIII

### WATER RESOURCE PLANNING, WATER QUALITY CRITERIA AND BAUXITE MINING

As discussed in the introduction to Chapter 8 substantial problems of supplying Perth's metropolitan water demand from the study area will develop by the turn of the century. Some of the important planning options involve the development of water resources with salinities in excess of 500mg/l TDS, the highest desirable limit set by the World Health Organisation (WHO, 1971). Two questions immediately arise:

1. What criteria should be adopted for planning of future potable water supplies?
2. Does a small and possibly temporary increase in salinity within an acceptable level constitute a serious degradation of the resource through its reduced capacity for blending with other more saline resources?

Answers to these questions clearly have a major effect on both the long term planning of our water resources and of the strategies which the State should develop for bauxite mining in the eastern zone.

Discussion of water standards has usually centred on the 500 mg/l and 1,500 mg/l TDS highest desirable and maximum acceptable levels respectively set down by WHO (1971). These criteria are based primarily on palatability and presuppose that other constituents are not limiting. In the Western Australian context the proportions of chloride ion and sodium ion are particularly high on a world scale. While international standards have been set for chloride ion concentrations no level has been set for sodium. However a range of sodium levels has been suggested, based on the need to restrict the sodium intake of patients suffering from various heart and kidney diseases (EPA, 1972).

These criteria are summarised in Table 1 following. The table also shows an approximate equivalent TDS concentration for the sodium and chloride criteria based on typical proportions of ions found in surface waters in the Darling Range and artesian groundwaters beneath the coastal plain.

It is clear that the chloride and sodium levels are the critical constituents rather than just the Total Dissolved Solids (TDS). Sodium is the most critical component particularly for artesian groundwaters where its proportion is around 35% of the Total Dissolved Solids.

Recent press releases by the Campaign to Save Native Forests (10/7/78) and their supporting documentation (Bartholomaeus and Holt, 1978) have precipitated public debate on the issue of an acceptable sodium level for drinking waters in W.A. While there are differences of opinion within the medical profession about the seriousness of high sodium levels in drinking waters, the debate has re-emphasised the need to supply water of the lowest possible sodium concentration within reasonable economic constraints. Therefore any permanent increase in salinity, particularly in the sodium concentration, should be considered as unacceptable (Chapter 8).

TABLE 1 — WATER QUALITY CRITERIA RELEVANT TO WESTERN AUSTRALIAN WATERS

Water Quality Standard	Highest Desirable mg/l			Maximum Acceptable mg/l		
	Constituent Concentration	Approx. TDS Equivalent for W.A. waters		Constituent Concentration	Approx. TDS Equivalent for W.A. waters	
		Surface	Artesian Groundwater		Surface	Artesian Groundwater
TDS	500	500	500	1500	1500	1500
Cl <sup>-</sup>	200	400	500	600	1200	1500
Na <sup>+</sup>	20	80	60	270	1080	810

NOTES TO TABLE 1

1. Water Quality Standards for chloride ion and TDS (Total Dissolved Solids) are World Health Organisation Standards (WHO, 1971)

Standards listed for sodium are not internationally accepted but represent concentrations allowable for patients on "strict" and "moderate" sodium free diets who drink an average of two litres per day (EPA, 1972).

2. The equivalent TDS values have been estimated from average proportions of ions recorded in surface waters and from artesian groundwater bores after flocculation treatment.

Observed ranges are:

Surface waters:	50% to 60% Cl <sup>-</sup>
	25% to 30% Na <sup>+</sup>
Artesian Groundwater:	40% to 50% Cl <sup>-</sup>
	33% to 37% Na <sup>+</sup>

3. The lower percentage of each ion was used to calculate the equivalent TDS value.

However bauxite mining in the eastern saline susceptible areas, in conjunction with the spread of dieback will cause some temporary measurable increase in stream salinity (Peck *et al.*, 1977; Appendix VII). We do not consider that specific criteria should be set to define acceptable or unacceptable temporary increases in salinity caused by bauxite mining at this stage for the following reasons:

Such criteria would be dependent on:

- the adopted permanent water quality criteria
- long term development plans as they affect the proportion of more saline groundwater relative to surface water development
- the flexibility of the distribution system to enable adequate mixing between waters of different quality
- the deterioration of one particular supply relative to others in both location and time.

*Rather we consider that controls over the possible increase in salinity caused by mining can be more effectively ensured by restricting mining to the relatively low salinity risk zone west of the 1150 mm isohyet. (See recommendation 8.7).*

Perth's water demand is expected to double (increase by over  $200 \times 10^6$  m<sup>3</sup>) by the year 2000 (MWB, 1977). Increased percentages of groundwater (both shallow, unconfined and artesian) relative to surface water supply are planned by the MWB to meet this demand. Over 50% of the additional demand could come from groundwater supplies, with an increasing percentage coming from artesian wells. If this strategy is adopted, the supply salinity within the metropolitan area will increase. The MWB has foreshadowed investigations on the effects of raising their desirable water quality standard from 500 mg/l to either 750 or 1,000 mg/l TDS (MWB, 1978).

*It must be realised that the strategies adopted for the development of Perth's water supply in the future may well have a larger impact on the overall quality of supply than bauxite mining restricted to the western low salinity risk areas.*



## APPENDIX IX

### **NATURE RESERVES, NATIONAL PARKS AND CONSERVATION MPAs IN WAGERUP REVIEW STUDY AREA**

#### **1. Existing National Parks and Nature Reserves**

RES. No.	MAP REF.	VESTING	PURPOSE	AREA (Ha)
John Forrest National Park	Pth 2000 24.33	National Park Authority	National Park	1578
10233	1/20 NN	Not vested	Cons. Flora	4.0
Greenmount National Park	1C/20 NW	National Park Authority	National Park	56.0
20765	Pth 2000 — 25.27	Shire of Mundaring	Rec. and bird Sanctuary	4.0
Gooseberry Hill National Park	M119.4	National Park Authority	National Park	33.0
Kalamunda National Park	1C/20 NW	National Park Authority	National Park	374.0
Lesmurdie National Park	1C/40	National Park Authority	National Park	35.0
30142	M226/4	Shire of Kalamunda	Cons. Flora	3.7
22576	Kalamunda Townsite	Shire of Kalamunda	Public Park Protection of Flora	4.0
30667	2A/40	W.A.W.A.	Cons. Flora and Fauna	59.0
30681	Swan Loc. 3042	Not vested	Cons. Flora	24.3
32064	K82	Shire Gosnells	Wild Life Sanctuary	5.0
24504	K82 K98	Shire Gosnells	Wild Life Park	16.0
32352	Serpentine Townsite	Not vested	Preservation Flora	2.0
32202	341 C/40	Not vested	Cons. Flora Fauna	302.0
Serpentine National Park	341 C/40 D.3 and 4	National Park Board	National Park	635.0
22797	383 C/40	Not vested	Conservation Flora and Fauna	301.0
22690	411/C4D-E3	Not vested	Conservation Flora and Fauna	2.2
28926	Collie Regional	Not vested	Conservation Flora and Fauna	7.0
<b>TOTAL 19</b>				

**2. Proposed Changes of Existing Reserves to Conservation of Flora and Fauna (Sytem 6 — Conservation Reserves and National Parks Committee Report)**

RES. No.	MAP REF.	VESTING	PURPOSE	AREA (Ha)
12453	Pth 2433	Not vested	Parks and Rec.	22.0
12085	M149.4	Not vested	Education Endowment	65.0
34103	M151.4	Not vested	Government requirements	55.0
18130	M151.4	Not vested	Timber	20.0
30797	2A/40	Not vested	Government requirements	14.8
25033	2A/40	Not vested	Government requirements	121.0
30363	2A/40	Not vested	Government requirements	234.0
32727	M165.4	Not vested	Parks and Rec.	57.0
1847	M163.4	Shire of Mundaring	National Park	7.0
22865	1C/40	Shire of Kalamunda	Parks and Rec.	36.0
20641	M243.4	Min. for WSSD	Water	59.0
10601	1C/40	Not vested	Timber	20.0
21172	1C/40	Min. for WSSD	Water	283.0
19662	341 B/40	Not vested	Timber	49.0
32728	Kelmscott NW	Not vested	Government Requirements	53.0
5704	341 B/40	Not vested	Timber	253.0
14629	380/80 B/D1	Not vested	Timber for settlers	110.0
19413	380/80 B/D1	Not vested	Timber	40.0
21038	380/80 D1 & 2	Not vested	Parks and Rec.	61.0
22977	383 D/40	Not vested	Common Water	361.0
15515	383 C/40	Min. for WSSD	Common Water	273.0
14564	383 C/40	Not vested	Timber for settlers	61.0
25727	383 D/40	WSSD	Water supply	308.0
<b>TOTAL 23</b>				

### 3. MPAs in Wagerup Review Study Area

MPA	STUDY AREA	AREA CORE & BUFFER	AREA CORE
2.3	Gunapin	13497	5882
2.4	Sullivan	6335	3300
2.5	Russell	5702	2658
2.6	Dale	6272	2968
8.1	Eagle Hill	4338	1590
8.4	Gooralang	705	232
8.7	Serpentine	1496	475
8.2	Cooke	4695	1750
8.5	Boyagarring	1480	1480
8.6	Windsor	4225	1910
8.8	Lupton	2770	2770
3.8	Karnet	3688	1247
3.5	Duncan	9935	4542
3.4	Gyngorda	3453	2025
3.10	Wandering	4334	4334
3.7	Teesdale	1728	1095
3.6	Plavins	3495	2195
10.4	Federal	1412	1412
10.5	Samson	1035	1035
10.3	Bell	2590	495
10.6	Surface	15125	5480
10.7	Nalyerin	10375	2912
10.8	Stene	4487	1664
4.1	Trees	7837	2532
4.2	Lennard	6562	2379
4.3	Westralia	2129	1090
4.5	Goonac	5211	5211
4.6	Muja	3411	2227
4.7	Bennelaking	5635	4487
5.1	Preston	2707	660
5.2	Noggerup	3387	2473



## APPENDIX X

### EXTRACT FROM FORESTS DEPARTMENT LAND USE MANAGEMENT PROGRAMME (1978)

The Forests Department is quite confident that it has put forward a sensible and workable plan as the following quotation shows.

"The land uses recommended in this study have been welded with the inherent site potential of each area and are in harmony with the environment and the reasonable requirements of various sectors of society. All current land uses have been considered and have been allocated their appropriate place in the landscape.

In addition, a number of options are possible in the future, for example:

- bauxite mining could be permitted in a conservation of flora and fauna MPA if the State decides, in 20 or 30 years, that this course of action would be desirable. The reverse is not possible. Once the area is mined it loses its indigenous value and can no longer be useful as a Conservation MPA.
- a valley which remains undammed (for example the Murray valley) can always be dammed at a later date. Once this valley is dammed, parts of its valley, its flora, fauna and recreational appeal are destroyed or changed forever.
- bauxite mining could be extended into the eastern parts of the catchments once research has conclusively shown that certain environmental disbenefits can be reversed quickly and effectively.
- recreation could be permitted on existing catchments and even reservoirs, but only when it is proved that these activities will not affect the health of the water users, or if costly treatment is undertaken.

The great concern in land use planning is that land may be committed irrevocably to activities which promise short term benefits and which may cause long term harm. The advantage of reserving options is future flexibility. Decisions of great consequence and with possible long term disbenefits need not be made now from a position of ignorance. Planning must therefore be periodically reviewed as new information becomes available.

The reservation of options is a sensible course of action only when the current land users have been adequately catered for. The Forests Department's proposal has done this.

- The areas recommended for bauxite mining are considerable. They are closer to refineries and ports and present the least environmental problems. They contain a very considerable proportion of the total resource. (They appear to approximate to a large proportion of the State Forest west of the 1150 mm Isohyet, TAG note.)
- The existing water supply catchments are protected (primarily from pollution by salt, human faecal matter, dieback and fire). Yield increases through forest manipulation are being investigated.
- Recreation pressures are channelled away from existing utilised catchments for many recreational pursuits. In some areas the mined over land can be rehabilitated to a recreational end point. In others, it may be possible to cater for some of the more environmentally damaging forms of recreation.
- Conservation areas to cover the complete range of species types have been selected. These will be protected from dieback and managed for the conservation of the plant, animal and other resources.
- Timber production will continue (with appropriate safeguards) in all areas other than the cores of the Conservation MPAs.

- The needs of apiarists, science, education, aesthetics etc. have also been catered for.
- Consistent with other multiple use requirements, the proposal takes into account the public requests for access to key areas — the scarp, the Murray and lower Helena valleys, the monadnocks. Management prescriptions along major and tourist roads cater for public needs and activities."

Certainly the Forests Department's submission was prepared only after a great deal of discussion. To assist the Department in its formulation of a Multiple Use Plan the following steps were taken:

- All public submissions to the System 6 Study were reviewed.
- All Government and private submissions to System 6 from organisations which use the forest area were reviewed.
- The Forests Department Policy Statement, General Working Plan No. 86 (Part I) and Planning Perspective formed the background to these detailed planning proposals. These documents were made available to Interested Departments and organisations and subsequently to the public for comment. All comments were considered, considered.
- Other relevant planning documents were assessed.
- Talks were given to cover 100 Departmental employees (4 talks) and over 80 Government and private company employees (these included personnel from Alcoa, MRD, PWD, MWB, Agriculture, DID etc.). At each of these 7 talks the Department's framework land use plan was explained and questions were answered.
- the document is currently being disseminated for comment to over 30 Government bodies and will eventually be made public.

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