Widespread use of bauxite residue, Peel-Harvey Coastal Plain Catchment

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Western Australian Department of Agriculture

Report and recommendations
of the Environmental Protection Authority

Environmental Protection Authority
Perth, Western Australia
Bulletin 714
November 1993

THE PURPOSE OF THIS REPORT

This report contains the Environmental Protection Authority's environmental assessment and recommendations to the Minister for the Environment on the environmental acceptability of the proposal.

Immediately following the release of the report there is a 14-day period when anyone may appeal to the Minister against the Environmental Protection Authority's report.

After the appeal period, and determination of any appeals, the Minister consults with the other relevant ministers and agencies and then issues his decision about whether the proposal may or may not proceed. The Minister also announces the legally binding environmental conditions which might apply to any approval.

APPEALS

If you disagree with any of the contents of the assessment report or recommendations you may appeal in writing to the Minister for the Environment outlining the environmental reasons for your concern and enclosing the appeal fee of $10.

It is important that you clearly indicate the part of the report you disagree with and the reasons for your concern so that the grounds of your appeal can be properly considered by the Minister for the Environment.

ADDRESS

Hon Minister for the Environment
12th Floor, Dumas House
2 Havelock Street
WEST PERTH WA 6005

CLOSING DATE

Your appeal (with the $10 fee) must reach the Minister's office no later than 5.00 pm on **18 November 1993**

Environmental Impact Assessment (EIA)

Process Timelines in weeks

Date	Timeline commences from receipt of full details of proposal by proponent	Time (weeks)
	Proponent Document Released for Public Comment	
	Public Comment Period Closed	8
9 June 1993	Issues Raised During Public Comment Period Summarised by EPA and Forwarded to the Proponent	2
10 August 1993	Proponent response to the issues raised received	9
4 November 1993	EPA reported to the Minister for the Environment	12

ISBN 0 7309 5645 8
ISSN 1030-0120
Assessment No. 766

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Summary and recommendations

The Western Australian Department of Agriculture has agreed to be nominated as the proponent to facilitate the widespread use of bauxite residue in the Peel-Harvey Coastal Plain Catchment. The Department of Agriculture has pursued this proposal to fulfil its dual role in the Peel-Harvey Coastal Plain Catchment of developing sustainable agriculture and reducing phosphorus loads to the Peel-Harvey Estuary. In accepting a role as proponent the Department of Agriculture is expected to also have a role in marketing of bauxite residue and ensuring any environmental conditions set by the Minister for the Environment in response to this assessment are met.

Bauxite residue is a by-product of the alumina industry and when used as a soil amendment can significantly reduce phosphorus losses to the environment by soil absorption mechanisms. The success of bauxite residue in reducing phosphorus losses from agriculture to the Peel-Harvey Estuary will be monitored in accordance with environmental conditions set by the Minister for the Environment for the Peel-Harvey Estuary Management Strategy - Stage 2.

The Public Environmental Review document referred to a wide range of potential uses for bauxite residue. However, the Environmental Protection Authority considered that sufficient information to permit adequate environmental assessment was provided only for **broad-scale use as a soil amendment for existing agricultural and horticultural properties**. Accordingly this assessment only considers these uses.

This proposal was referred to the Authority in October 1992. Following consideration of the Public Environmental Review document and the proponent's response to public submissions which was received on 10 August 1993, the Authority has concluded that the proposal is environmentally acceptable.

Recommendation 1

The Environmental Protection Authority concludes that the proposal by the Western Australian Department of Agriculture for the widespread use of bauxite residue for existing broadacre agriculture and horticulture in the Peel-Harvey Coastal Plain Catchment is environmentally acceptable.

In reaching this conclusion the Environmental Protection Authority identified the main environmental factors requiring detailed consideration as:

- **the likely effects of bauxite residue based on the physical and chemical characteristics of bauxite residue, particularly alkalinity, salts, heavy metals and particle size;**
- **ensuring responsible use of bauxite residue**
- **potential impacts on flora;**
- **potential impacts on freshwater and estuarine wetlands;**
- **potential impacts from changes to soil permeability; and**
- **the need for monitoring and for monitoring results to be reflected in responsible use.**

The Environmental Protection Authority concludes that the environmental factors mentioned above have been addressed adequately by either environmental management commitments given by the proponent or by the Environmental Protection Authority's recommendations in this report.

Accordingly, the Environmental Protection Authority recommends that the proposal could proceed subject to:

- **the Environmental Protection Authority's recommendations in this Assessment Report; and**
- **the proponents commitments (See Appendix 1).**

The approach taken by the Environmental Protection Authority in this reaching this conclusion was to consider the physical and chemical characteristics of bauxite residue in association with research undertaken in respect of those characteristics, and then to consider the potential impacts that could result on a catchment level and on sensitive or important environments. These considerations are summarised below.

Characteristics of bauxite residue

Alkalinity

Bauxite residue which is dry enough for broad-scale agricultural use is quite strongly alkaline (it has a total soluble alkalinity of 25 to 35 g/L and has a pH in a fully carbonated state of 10.8). In contrast the soils and wetlands of the Peel-Harvey Coastal Plain Catchment are generally quite acid with a low pH.

The effect of this alkalinity on the pH of soil and water leaving the soil can be reduced by adding gypsum. However, adding gypsum causes an increase in Total Soluble Salts.

Total Soluble Salts

Research into Total Soluble Salt loads in leachate from bauxite residue indicates that loadings from the application of bauxite residue are not likely to be of concern, even with the addition of gypsum.

Trace elements and heavy metals

Bauxite residue contains a number of trace elements and heavy metals as do soils of the Darling Range. Most elements are tightly bound and would require exceptional circumstances such as immersion in concentrated acid to be released. However, there is an initial release of small amounts of some elements such as arsenic, fluoride and aluminium immediately after application. Aluminium levels in soil leachate appear to exceed the Australian Water Quality Guidelines for the protection of aquatic ecosystems whether or not amended with bauxite residue. Unless a large percentage of a catchment is treated at once the initial releases of elements would not cause unacceptable levels in the environment.

Reduced soil permeability and increased surface flow

The permeability of a soil decreases with the percentage of bauxite residue to sand. As mixing is not proposed (except for horticulture), the percentage of bauxite residue in the top layer could be quite high. Also, bauxite residue is mostly fine particles which can act like a silt and form an impermeable crust on the soil surface. Significant increases in surface water run-off volumes, from 550 to 800 mm of rainfall, were recorded in a catchment with soils amended at 80 t/ha with red mud gypsum.

Other characteristics

The fine nature of bauxite residue can cause dust, turbidity and staining. Experience has shown that the fine particles move down into pore spaces in the sand.

The cumulative application rate and degree of soil mixing are key factors which influence the potential environmental effects.

Code of Practice

The Department of Agriculture proposes to develop a Code of Practice to ensure responsible use of bauxite residue. The Code would address a wide range of issues. Environmental issues of concern are noted in the recommendation below.

Recommendation 2

The Environmental Protection Authority recommends that, prior to widespread use of bauxite residue commencing, the proponent prepare a Code of Practice, incorporating environmental issues, which includes but is not limited to consideration of:

- **dust control during transport and application;**
- **assessment of optimum application rate based on changes to pH;**

- **separation distance from soil amended areas to remnant vegetation or watercourses; and**
- **frequency of review of the Code of Practice to incorporate management recommendations gained from experience and monitoring of bauxite use;**

to the requirements of the Environmental Protection Authority.

The Environmental Protection Authority recommends that Department of Agriculture monitor, and seek to ensure, compliance with environmental aspects of the Code of Practice.

Use in Underground Water Pollution Control Areas

The Water Authority of Western Australia would like to monitor and if necessary control the use of bauxite residue in Underground Water Pollution Control Areas (UWPCAs). The Environmental Protection Authority considers that the Department of Agriculture should refer proposals for bauxite residue use within UWPCAs to the Water Authority. The Water Authority may then use or amend its by-laws to control bauxite residue use if needed. Proponents should be advised of referrals.

Potential catchment wide impacts

Research undertaken to date has concentrated on application rates of 80 t/ha or more and has not considered the effect of different land-use practices on soil mixing and the subsequent changes to soil permeability. This research should be undertaken to provide recommendations for the Code of Practice and provide a more detailed assessment of potential catchment wide impacts, particularly with respect to the impacts from repeated applications of bauxite residue to pasture.

Recommendation 3

The Environmental Protection Authority recommends that within six months of commencement of widespread use of bauxite residue the proponent develops and then implements a research program which evaluates the following potential environmental effects for a range of application rates and subsequent soil mixing scenarios:

- **changes to soil permeability;**
- **changes to surface water runoff flow patterns and volumes; and**
- **changes to pH of surface water run-off;**

to the requirements of the Environmental Protection Authority on advice of the Chemistry Centre of Western Australia.

The Environmental Protection Authority recommends that the results of the research program be made available to the public and the Authority.

Monitoring catchment wide impacts and important components of the environment

Important components of the environment in the Peel-Harvey Coastal Plain Catchment are remnant vegetation, freshwater wetlands and the Estuary.

A 10m separation between bauxite residue applications and remnant vegetation is proposed to be incorporated into the Code of Practice by the Department of Agriculture. The effectiveness of this measure should be monitored.

Potential impacts on freshwater wetlands from widespread use of bauxite residue include pH changes, increased Total Soluble Salts, increases in some trace elements, increased flow volumes through the wetlands and increased turbidity from red mud fines.

Changes in Total Soluble Salts and increased turbidity from suspended bauxite residue particles are not expected to be significant.

Changes in the pH of water in a wetland could occur if a large proportion of its catchment were amended with bauxite residue. Changes to the pH in wetland waters can affect vegetation composition, availability of micronutrients and the toxicity of substances such as ammonia and zinc. It is expected that some changes may already have occurred to wetland pH from other land management practices.

As noted above, aluminium levels in leachate from rainfall appear to exceed the Australian Water Quality Guidelines for the protection of aquatic ecosystems whether or not amended with bauxite residue and should therefore be monitored.

Changes to flow volumes would depend on a number of factors including the cumulative application rate and degree of soil mixing on individual properties and the extent to which soils in the catchment have been amended.

Significant changes to flow volumes could cause erosion and turbidity in drains.

The degree of change in any catchment would depend of the proportion of the catchment amended with bauxite residue. Monitoring of key catchments which have a high proportion of the catchment amended should be undertaken for each major soil system and for each of the potential environmental effects identified. Monitoring of freshwater wetlands would provide a warning system of potential effects on the Peel-Harvey Estuary.

Recommendation 4

The Environmental Protection Authority recommends that the proponent design and then implement a monitoring programme which includes, but is not limited to, addressing the following concerns for key sub-catchments and environments in the Peel-Harvey Coastal Plain Catchment:

- **adequacy of proposed measures to protect remnant vegetation;**
- **impacts from changes in pH and aluminium concentrations in the catchment on wetlands;**
- **changes to surface water runoff flow patterns and volumes, and the effect of this change on wetlands and drainage water quality;**
- **monitoring of ground and surface water quality parameters, including pH, heavy metals, turbidity and radioactivity, to confirm predictions in the Public Environmental Review document and this assessment report;**

to the requirements of the Environmental Protection Authority on advice of the Chemistry Centre of Western Australia.

The Environmental Protection Authority recommends the monitoring plan be reviewed every five years.

The Environmental Protection Authority recommends that the results of the monitoring program be made available to the public and the Authority.

Other issues

Traffic impacts could be significant and should be addressed by the Department of Agriculture in consultation with the relevant local authorities.

A number of health, occupational health, agricultural and economic issues associated with bauxite residue use are the responsibility of other agencies or individual landholders.

1. Introduction

The concept of using bauxite residue to reduce phosphorus losses from sandy soils been suggested or considered in a number of reports during the last decade as a possible strategy to assist in reducing nutrient input to the Peel-Harvey Estuary.

The Peel-Harvey Estuary is badly degraded because large quantities of nutrients have flowed into the Estuary from surrounding farm land, urban areas and point sources such as intensive animal industries. Algae live on the nutrients and multiply rapidly, stifling life in the estuary in warmer weather. The algae accumulate and rot on the shores of the estuary, causing odour problems, polluting the shore and killing wildlife and fish.

Following preparation of an Environmental Review and Management Programme in 1988, the State Government accepted strategies to improve the estuary's condition including the construction of the Dawesville Channel to improve flushing and catchment management to reduce nutrient input through controlling clearing, drainage and nutrient inputs. The Western Australian Department of Agriculture was one of the proponents and lead agencies in preparation of the Environmental Review and Management Programme.

Soil amendment with bauxite residue was discussed in the Environmental Review and Management Programme but discarded because at that time, the techniques used and tonnages involved made amendment extremely expensive and impractical. However, investigations into the use of bauxite residue have continued and the Department of Agriculture considers that economically viable techniques are now possible for a number of land-use situations.

Bauxite residue is a by-product of the alumina industry and is primarily finely ground bauxite and ironstone gravel from the Darling Scarp with most of the alumina content removed. The residue is very alkaline (it has a pH of about 10.8) because the alumina removal process uses caustic soda. Red mud is the fine fraction of bauxite residue.

This proposal was referred to the Environmental Protection Authority in October 1992 and a Public Environmental Review level of assessment was set. This level was set because bauxite residue use is likely to be of State-wide interest if proven to be successful in the Peel-Harvey Coastal Plain Catchment and because a Public Environmental Review would permit the level of public acceptance of bauxite residue use to be determined.

1.1 Role of Department of Agriculture

In the Public Environmental Review document the Department of Agriculture noted that it had a dual role in the Peel-Harvey Coastal Plain Catchment in furthering development of sustainable agricultural systems on the Swan Coastal Plain and as the State Government's lead agency for the Peel-Harvey Coastal Plain Catchment management program which primarily seeks a reduction of phosphorus loads to the Peel-Harvey Estuary.

The Public Environmental Review document did not contain details of any marketing structure. The Authority understands that a marketing structure will be negotiated between the Minister for Agriculture (or the Department of Agriculture on behalf of the Minister for Agriculture) and Alcoa of Australia Ltd following Environmental Protection Authority assessment. Any marketing structure established would need to ensure environmental conditions set by the Minister for the Environment (after consultation with the Minister for Agriculture) can be met.

Based on the above information, the Department of Agriculture may also have a role in implementing the environmental components of any marketing structure established.

2. Description of the proposal

The Department of Agriculture has referred to a wide range of potential uses for bauxite residue in the Public Environmental Review document. However, sufficient information to permit adequate environmental assessment was provided only for **broad-scale use of bauxite residue as a soil**

amendment for existing agricultural and horticultural properties. Other uses for bauxite residue noted in the Public Environmental Review, such as urban uses (e.g. in soil mixes), in effluent and waste management systems, in stormwater basins and drainage structures and in construction materials are not considered to form part of the proposal and have not been assessed.

The Department of Agriculture expects bauxite residue application rates to range from 20 to 100 tonnes per hectare (t/ha)for pasture and up to 250 t/ha for horticultural uses. Applications of over 100 t/ha would need to be mixed into the soil and gypsum addition considered to ensure the soil pH is suitable for agriculture.

Recommendations for re-application of red mud will be based on monitoring of key field trials by the Department of Agriculture. Based on current knowledge, applications of 20 t/ha would need to be re-applied after at least five years in order to maintain the desired reductions in phosphorus run-off. Whether this coincides with the optimum re-application time from the point of view of agricultural production is not known.

Bauxite residue would be transported by truck from one of three refineries owned by Alcoa of Australia to the paddock in which it is required. Conventional spreading equipment (multispreaders) can be used with only minor modifications to apply bauxite residue at application rates typically used for pasture.

Although the Public Environmental Review document suggests guidelines and recommendations for bauxite residue use, there is no commitment that they will be included in any Code of Practice or monitoring programme developed.

Other uses for bauxite residue, such as those suggested in the Public Environmental Review document, may need to be referred to the Environmental Protection Authority if they are likely to have a significant effect on the environment either individually or cumulatively.

The scope of the Public Environmental Review document, and hence the proposal assessed by the Environmental Protection Authority, limits bauxite residue use to existing cleared land in the Peel-Harvey Coastal Plain Catchment. Bauxite residue use for new land-use proposals was not considered to be part of this proposal. New uses could increase existing phosphorus loads to the Peel-Harvey Estuary, particularly if regular re-application is required to ensure applied phosphorus remains on-site and then re-application does not take place.

The Environmental Protection Authority understands that the Department of Agriculture wishes to commence distribution of bauxite residue this summer.

The proposal was limited to the Peel-Harvey Coastal Plain Catchment because it is only in this part of the State where the Department of Agriculture has overall land-use obligations resulting from environmental conditions set following the Environmental Review and Management Programme in 1988 and it is one of the catchments with a great need for phosphorus control measures.

3. Existing environment

The majority of the Peel-Harvey Coastal Plain Catchment is either Pinjarra Plain or Bassendean Dune and Plain (Wells, 1989).

The Pinjarra Plain is a broad, low relief plain west of the foothills on predominantly fluvial sediments and some alluvium associated with major active drainage systems. The soils are naturally poorly drained and many swamps occur.

The Bassendean Dune and Plain system has a very low relief, leached grey siliceous sand with intervening sandy and clayey swamps often underlain by iron organic hardpans or buried clay layers. The topography becomes more subdued from west to east.

Significant drainage works within the catchment permit rapid movement of nutrients from paddocks to the Peel-Harvey Estuary.

Despite extensive drainage works within the catchment, many parts of the Peel-Harvey Coastal Plain Catchment remain waterlogged or inundated for long periods during winter.

Most soil types in the Peel-Harvey Coastal Plain Catchment are strongly acidic or acidic (low to very low pH), as are a high proportion of wetlands. The pH of many soils has been influenced by past land-use and land management practices.

The majority of the Peel-Harvey Coastal Plain Catchment has been cleared. Little remnant vegetation remains.

Land-use in the catchment is predominantly rural, with an emphasis on grazing. About 400ha of the catchment is used for market gardens or similar intensive horticulture. A number of population centres exist within the catchment.

The Jandakot Public Water Supply Area and Underground Water Pollution Control Area extends into the northern part of the Peel-Harvey Coastal Plain Catchment.

4. Public submissions

The Environmental Protection Authority required that a Public Environmental Review be prepared for the proposal. The availability of the Public Environmental Review for comment over an eight week period was advertised in *"The West Australian"* and local newspapers and the document was circulated to relevant government agencies.

The Authority received eleven submissions from members of the public and community groups and a further six submissions from State and local government agencies.

A detailed summation of the points raised in the submissions and the proponents response to the submissions is presented in Appendix 2.

The most common theme in submissions was concern about cumulative effects which could become apparent in the long term.

In summary, the following topics were raised in the submissions:

- general comments ranging from qualified to unqualified support for the proposal, comments on the degree of government support for bauxite residue use, comments on the scope of the proposal and comments on the quality of the Public Environmental Review document;
- adequacy of commitments;
- control of and guidelines for bauxite residue use;
- comments on specific issues associated with the use of bauxite residue for soil amendment including:
    - potential phosphorus loss reduction from paddocks in the long term using low rates and re-application;
    - the applicability of research undertaken in other parts of the catchment;
    - economics of application;
    - issues associated with salts, gypsum, and increased pH; and
    - the benefits of and need to apply gypsum;
- long-term, cumulative and environmental impacts with particular reference to:
    - lack of information/comment in the Public Environmental Review document regarding this issue;
    - nutrient loads;
    - health and safety, particularly with respect to radioactivity;
    - salts and trace elements;
    - marine and freshwater impacts;

- impacts on flora; and
- impacts of haulage.

- comments relating to other uses suggested in the Public Environmental Review (i.e. effluent and waste management, stormwater drainage), as well as suggestions for alternative uses.

5. Characteristics of bauxite residue in the environment

The physical and chemical characteristics of bauxite residue provide an indication of potential environmental effects which may occur from its broad-scale use in agriculture. This section provides relevant background information to assess the likelihood of adverse impacts.

5.1 Alkalinity

Bauxite residue which is dry enough to be used for broad-scale agriculture has a total soluble alkalinity of 25 to 35 g/L (70% solids), and has a pH in a fully carbonated state of about 10.8. The alkalinity is mainly present as sodium carbonate with decreasing sodium hydroxide as it is exposed to air.

In contrast the soils of the Pinjarra Plain and Bassendean Dune and Plain are generally strongly acid, acid or neutral ,although some soils are weakly buffered (see Wells, 1989). The pH of soils in the region have been modified by application of fertilisers (which acidify the soil), gypsum (which is moderately alkaline) and the type of vegetation grown (e.g legumes can acidify the soil).

A study of wetlands in the Peel-Harvey Coastal Plain Catchment north of the Harvey River Diversion Drain found 50% of the wetlands had a pH of less than seven in contrast to the alkaline wetlands north of Perth (Wrigley, 1988).

The effect of the alkalinity in bauxite residue can be reduced or neutralised by adding a material such as gypsum. Although gypsum is alkaline, it can reduce the alkalinity of bauxite residue by converting the alkaline sodium carbonate in bauxite residue to sodium sulphate and calcium carbonate. The pH of calcium carbonate is lower than sodium carbonate. However, the combination of these materials causes an increase in soluble salts.

Analysis of leachate from simulated rainfall over areas treated with nil, 20, 40 and 80 t/ha red mud or red mud and gypsum found the pH of the leachate from nil application to be between 4.5 and 5.5 and from the 80 t/ha application to be between 6.4 with gypsum to 7.6 without gypsum (Summers *et al*, 1993b).

It is expected that for agricultural production, the landholder would seek a final soil pH suitable for the pasture or crop to be grown.

The application rate, the initial acidity of the soil and the incorporation of other materials such as gypsum influence the final change in soil and water pH. A change in soil pH from the addition of bauxite residue would be reflected in the pH of surface water runoff leaving the amended area. Unless applications are appropriately managed, bauxite residue could cause rapid or excessive changes in pH.

5.2 Salts

5.2.1 Increased total soluble salts

The analysis of bauxite residue provided in the Public Environmental Review document does not provide a clear indication of the elements which would contribute to the Total Soluble Salts which could be leached from the residue. The Authority understands that leaching of soluble salts from bauxite residue depends on both the addition of other ions such as occur in gypsum and the degree to

which soluble salts used in bauxite treatment to extract alumina (e.g. Sodium) have been removed from the bauxite residue.

The Australian Water Quality Guidelines for protection of aquatic ecosystems (Australian and New Zealand Environment and Conservation Council, 1993) and drinking water guidelines specify a maximum level of 1 000 mg/L Total Soluble Salts.

Experiments have shown that bauxite residue with gypsum incorporated at 10% by weight spread at 80 tonnes per hectare increased conductivity measured in stream-flow by 20 to 40 mS/m @ 25 °C (220 to 440 mg/L Total Soluble Salt). This is shown in Figure 1 (Summers *et al*, 1993a).

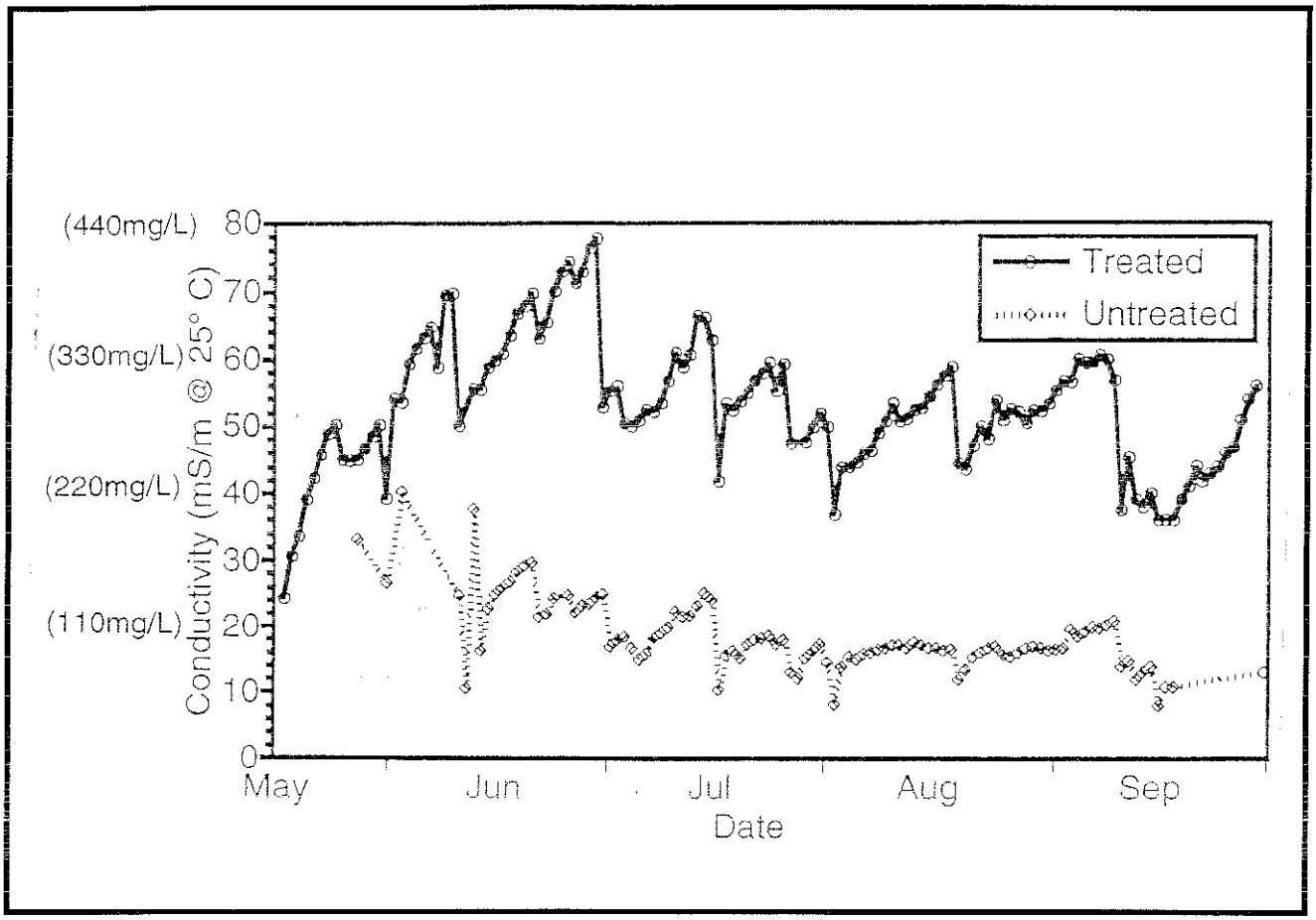

Figure 1: The increase in electrical conductivity (i.e. total soluble solids) caused by the application of red mud (From Summers* et al *1993a).

Analysis of leachate from simulated rainfall over areas treated with nil, 20, 40 and 80 t/ha red mud or red mud gypsum found that only leachate from the first simulated rainfall event exceeded 1 000 mg/L Total Soluble Salts and then only at the higher application rates. The highest level leachate was 1 210 mg/L Total Soluble Salts (Summers *et al* 1993b). This would be diluted rapidly to below 1 000 mg/L in the environment. Subsequent leachate concentrations from simulated rainfall were below 1 000 mg/L.

5.2.2 Trace elements and heavy metals

Bauxite residue, like soils in the Darling Range, contains traces of some elements which if mobilised could pose environmental risks. The Department of Agriculture considers that most of these elements

are tightly bound and require exceptional circumstances such as immersion in concentrated acid to be released. These circumstances are unlikely to occur in soil amended paddocks.

Appendix A of the Public Environmental Review document provides an analysis of trace element concentrations (including heavy metals) in bauxite residue and compares them with international criteria for rehabilitation of contaminated sites. The Department of Agriculture concludes that trace elements and heavy metals are well within acceptable levels.

Leachate from simulated rainfall over areas treated with nil, 20, 40 a 80 t/ha red mud or red mud gypsum were analysed for cadmium, aluminium, iron, arsenic, fluoride and sulphate, electrical conductivity, pH and phosphate (Summers *et al* 1993b). Leachate concentrations for Arsenic exceeded Australian Water Quality Guidelines only for the first simulated rainfall. Aluminium concentrations from leachates in both the untreated and treated areas exceeded recommended Australian Water Quality Guidelines for waters with a pH of less than 6.5. All the parameters tested were within the maximum limits for drinking water, except fluoride when gypsum was applied. Fluoride reached acceptable drinking water levels after 7 months simulated rainfall (Summers *et al* 1993b).

5.3 Reduced soil permeability and increased surface flow

For a sandy soil amended with bauxite residue, the permeability decreases as the percentage of bauxite residue to sand increases, as shown in Figure 2 (Reference).

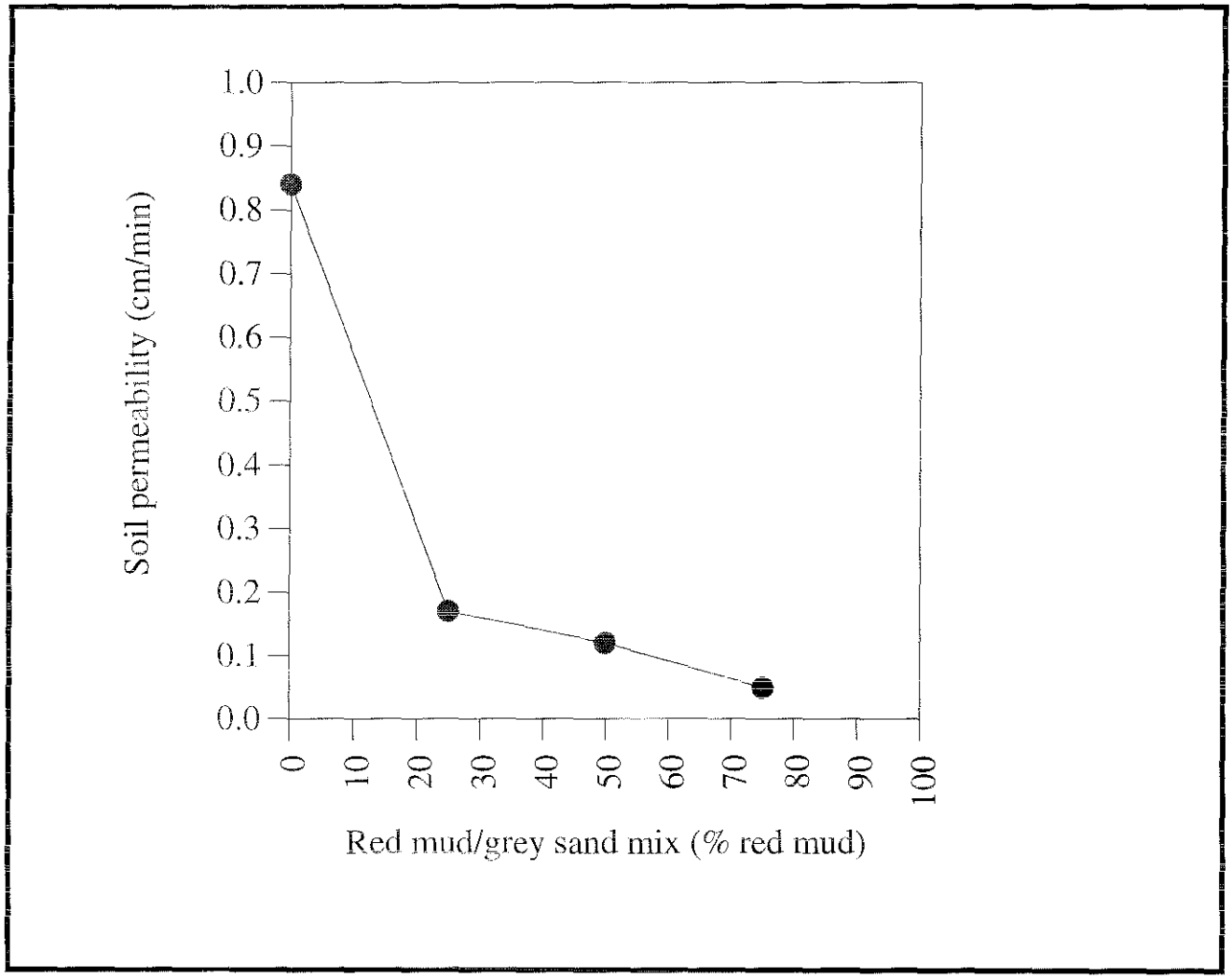

Figure 2: Permeability of a sandy soil amended with bauxite residue.

As bauxite residue applications for pasture do not involve mixing, the percentage of bauxite residue in the top layer of the soil may get quite high if several applications of 20 t/ha occur over time. However, if the bauxite residue is mixed deeper into the soil the percentage bauxite residue in the soil would be reduced with a corresponding improvement in soil permeability.

Because of the fine particle size of red mud it can act like a silt and can form a surface crust which can significantly increase water run-off rates.

Bauxite residue with gypsum incorporated at 10% by weight spread at 80 t/ha without mixing into the soil increased surface water run-off from 133,000 m^3 (550mm of rainfall) to 256 000 m^3 (800mm of rainfall). With broad-scale application, this increase could be significant at the catchment or sub-catchment level, especially since the increased run-off may change nutrient flow pathways.

The Public Environmental Review document does not provide specific information about reduced soil permeability. However the document states that the rates of red mud application proposed are not expected to significantly affect overland flow during winter, partly because much of the Peel-Harvey Coastal Plain Catchment is inundated in winter and because bauxite residue can improve the water holding capacity of the soil.

The Environmental Protection Authority considers that in the long-term, repeated application of bauxite residue throughout the catchment and consequent reduced soil permeability could significantly affect surface water run-off patterns and volumes.

5.4 Radioactivity

Bauxite contains radioactive elements. When bauxite is processed about one third of the material is removed as alumina which is low in radioactivity. Consequently there is a proportional increase in concentration of radioactive materials in the residue.

Bauxite residue is not defined as being radioactive by the Australian Code of Practice for the Safe Transport of Radioactive substances.

The Radiological Council advised that the application rates proposed by the Department of Agriculture will not result in radioactivity levels above that in bauxite ore and as such, are approved. Where application rates exceed that level the Radiological Council should be notified.

5.5 Particle size — increased turbidity and dust

Red mud is the fine fraction of bauxite residue with over 50% of the particles less than 10 microns in size and 15% fine sand. When first applied, the particles tend to be agglomerated and the material behaves like a silt.

Experience to date has shown that the fine particles move down into pore spaces in the sand and are not usually washed into drainage lines. However, if red mud is put directly into water channels turbidity could be a problem.

The fine nature of red mud means that dust is an issue during application and when dry on the surface if there is insufficient vegetative cover.

5.6 Colour — aesthetic effects

Bauxite residue is a dark red, and its application can initially change the colour of the soil. The application rate, degree of blending and vegetation cover affect the degree of colour change.

5.7 Conclusion

The effects of bauxite residue applications could vary significantly depending on a range of factors including:

- rate of application (affects pH outcome, mixing requirements);
- use of gypsum (depends on rate of application and affects salt loading);
- degree of soil mixing/blending by stock or other farm equipment (affects soil permeability); and
- number of applications (affects pH, salt loading and soil permeability as above).

Factors such as particle size, radioactivity and colour are expected to be relatively constant.

The rate of application would need to consider previous applications.

Based on consideration of the chemical and physical characteristics of bauxite residue the cumulative application rate and degree of soil blending are the key factors which influence the potential environmental effects.

Recommendation 1

The Environmental Protection Authority concludes that the proposal by the Western Australian Department of Agriculture for the widespread use of bauxite residue for existing broadacre agriculture and horticulture in the Peel-Harvey Coastal Plain Catchment is environmentally acceptable.

In reaching this conclusion the Environmental Protection Authority identified the main environmental factors requiring detailed consideration as:

- **the likely effects of bauxite residue based on the physical and chemical characteristics of bauxite residue, particularly alkalinity, salts, heavy metals and particle size;**
- **ensuring responsible use of bauxite residue;**
- **potential impacts on flora;**
- **potential impacts on freshwater and estuarine wetlands;**
- **potential impacts from changes to soil permeability; and**
- **the need for monitoring and for monitoring results to be reflected in responsible use.**

The Environmental Protection Authority concludes that the environmental factors mentioned above have been addressed adequately by either environmental management commitments given by the proponent or by the Environmental Protection Authority's recommendations in this report.

Accordingly, the Environmental Protection Authority recommends that the proposal could proceed subject to:

- **the Environmental Protection Authority's recommendations in this Assessment Report; and**
- **the proponents commitments (See Appendix 1).**

The following section details how the Department of Agriculture and Environmental Protection Authority consider the potential impacts should be managed.

6. Environmental assessment of the proposal

6.1 Effect of proposal on phosphorus loss to the Peel-Harvey Estuary

This assessment only examines the potential environmental impacts from the broad-scale use of bauxite residue as a soil amendment. Consideration of the positive effect of this proposal in reducing phosphorus loss from the Peel-Harvey Coastal Plain Catchment will be assessed in the context of auditing the environmental conditions for the Peel-Harvey Estuary Management Strategy — Stage 2, for which the Department of Agriculture is a proponent. In particular, environmental commitment 3.7 should ensure that the effect of this proposal in terms of phosphorus loss is monitored. Environment commitment 3.7 from the Peel-Harvey Estuary Management Strategy — Stage 2 is reproduced below.

Environmental commitment 3.7

The success of catchment management measures in reducing phosphorus losses to the estuary will be monitored by the proponents and audited by the Environmental Protection Authority. The social and economic effects of catchment management measures upon the catchment community will be closely monitored by the proponents. Current and proposed future monitoring studies are described in Section 13 of the ERMP and in Section 11 of the Authority assessment report. The catchment management plan will be regularly reviewed by the Authority.

6.2 Ensuring responsible bauxite residue use

6.2.1 Code of Practice

A Code of Practice is required to ensure bauxite residue application and use occurs in a responsible manner, particularly with respect to minimising the potential effects identified above. The Code of Practice developed would need to be reviewed regularly in response to new information from experience and monitoring gained through bauxite residue use. Although a code would not have the force of regulations, it is important that it be followed by users of bauxite residue.

The Department of Agriculture has made a commitment that a Code of Practice will be produced. The Public Environmental Review document suggests that the Code is intended to address a wide range of issues including environmental, agricultural, health and occupational health and method of application.

The code will probably become binding on contractors applying the bauxite residue through Clauses in their contracts.

Some public submissions expressed concern that a Code of Practice or similar mechanism should address the following issues:

- who may apply bauxite residue;.
- safety precautions for bauxite handling;.
- whether or not gypsum is applied based on an assessment of soil pH and application rate;
- the correct application and management of bauxite residue;.
- educational information to deter abuse of the amended soil advantage; and.
- proximity of bauxite residue application to watercourses and remnant vegetation.

The Department of Agriculture's full response to the above comments appears in Appendix 2. Key responses to environmental issues raised above include the following:

- "Cultural variations (which cause changes to soil acidity) will result in the need to assess each site for the potential for improvement by bauxite residue".

- As dust generation will be controlled by the Code of Practice the possibility of dust reaching surface waters is not an issue.
- A requirement for a 10m buffer to be kept between residue amended pasture and remnant vegetation will be included in the Code of Practice until more information has been derived from the monitoring program.

Another issue which warrants consideration is that of dust blowing from trucks during transport. As noted above, red mud has a very fine particle size and a pH of 10.8. Dust could remain suspended for long periods. This issue also has safety aspects for car drivers following bauxite residue trucks.

The Environmental Protection Authority considers that some of the issues raised above are key issues to the acceptability of widespread bauxite residue use and should be incorporated in the Code of Practice to the meet the requirements of the Authority.

The Authority considers that the Department of Agriculture should be responsible for monitoring and ensuring that the Code of Practice is implemented.

Recommendation 2

The Environmental Protection Authority recommends that prior to widespread use of bauxite residue commencing, the proponent prepare a Code of Practice incorporating environmental issues which includes, but is not limited to consideration of:

- **dust control during transport and application;**
- **assessment of optimum application rate based on changes to pH;**
- **separation distance from soil amended areas to remnant vegetation or watercourses; and**
- **frequency of review of the Code of Practice to incorporate management recommendations gained from experience and monitoring of bauxite use;**

to the requirements of the Environmental Protection Authority.

The Environmental Protection Authority recommends that Department of Agriculture monitor, and endeavour to ensure, compliance with environmental aspects of the Code of Practice.

6.2.2 Use in underground water pollution control areas

In its submission to the Environmental Protection Authority, the Water Authority of Western Australia expressed a desire to monitor and where necessary control the use of bauxite residue in the Jandakot Public Water Supply Area and Underground Water Pollution Control Areas. This was "noted" by the Department of Agriculture in its response to submissions.

The Environmental Protection Authority considers that the Water Authority of Western Australia should be kept informed of proposals to use bauxite residue in Public Water Supply Areas and Underground Water Pollution Control Areas. However, if the Water Authority considers it appropriate to control the use of bauxite residue in these areas, it could use or amend its Underground Water Pollution Control Area by-laws accordingly.

Where a proposal to use bauxite residue is within a Public Water Supply Area or Underground Water Pollution Control Area, the Department of Agriculture should refer the proposal to the Water Authority of Western Australia and inform the proponent that the proposal has been referred to the Water Authority.

6.3 Potential catchment wide impacts

The major use of bauxite residue in accordance with this proposal is likely to be for pasture improvement. There are about 400ha of horticulture in the Peel-Harvey Coastal Plain Catchment.

6.3.1 Potential effects in response to cumulative application rates and degree of soil blending

As indicated in Section 5.5, the potential environmental effects of bauxite residue depend primarily on the cumulative application rate and degree of soil blending.

The Public Environmental Review document referred to a range of studies in Western Australia which used application rates of 80 t/ha and upwards.

Recent research results from trials at 80 t/ha (See Summers et al 1993a) have provided valuable information on which to base an assessment of the likely environmental impacts. In particular the trials compared phosphorus loads, stream-flows and Total Soluble Salts from a treated and untreated catchment.

The Environmental Protection Authority considers that similar research to that noted above should be undertaken by the Department of Agriculture to determine the effects of lower rates of application which are either repeated every five years until the maximum recommended levels of 100 t/ha are reached or not repeated after an initial low application. The research should also evaluate changes to pH in water leaving the treated areas and investigate the effects of compaction and soil mixing by animals or farm equipment in changing the permeability of the soil and consequent change in surface water run-off patterns and volumes.

6.3.2 Effects of changes to soil infiltration rates

Section 5.3 of this report clearly indicates that significant changes to soil infiltration rates and surface water run-off volumes can be expected from areas which are not inundated in winter. Overall changes to surface water flows are expected to become more apparent in the long term as more of the Peel-Harvey Coastal Plain Catchment has bauxite residue applied and re-applied.

Ultimately the character of the catchment could be changed from one dominated by groundwater flow to one dominated by surface water flow. Figure 3 below provides a conceptual diagram of flow patterns which could result. If the surface water flow pattern shown for loams and clays becomes prevalent, surface run-off may become a significant factor in nutrient export pathways.

Erosion of drains could be stimulated by increased volumes of surface water flow which could carry sediment into the Peel-Harvey Estuary.

The Public Environmental Review document did not address this issue because the document states that changes to soil infiltration rates would not be significant. The Environmental Protection Authority accepts that this may be so for single applications of 20 t/ha at the paddock level, but considers the implications of repeated and/or catchment-wide application are yet to be shown.

The Authority considers that changes to surface water run-off should be monitored both at paddock and sub-catchment level. Results from the monitoring should provide recommendations for changes to the Code of Practice if appropriate.

Recommendation 3

The Environmental Protection Authority recommends that within six months of commencement of widespread use of bauxite residue the proponent develops and then implements a research program which evaluates the following potential environmental effects for a range of application rates and subsequent soil mixing scenarios:

- **Changes to soil permeability;**
- **changes to surface water runoff flow patterns and volumes; and**
- **changes to pH of surface water run-off;**

to the requirements of the Environmental Protection Authority on advice of the Chemistry Centre of Western Australia.

The Environmental Protection Authority recommends that the results of the research program be made available to the public and the Authority.

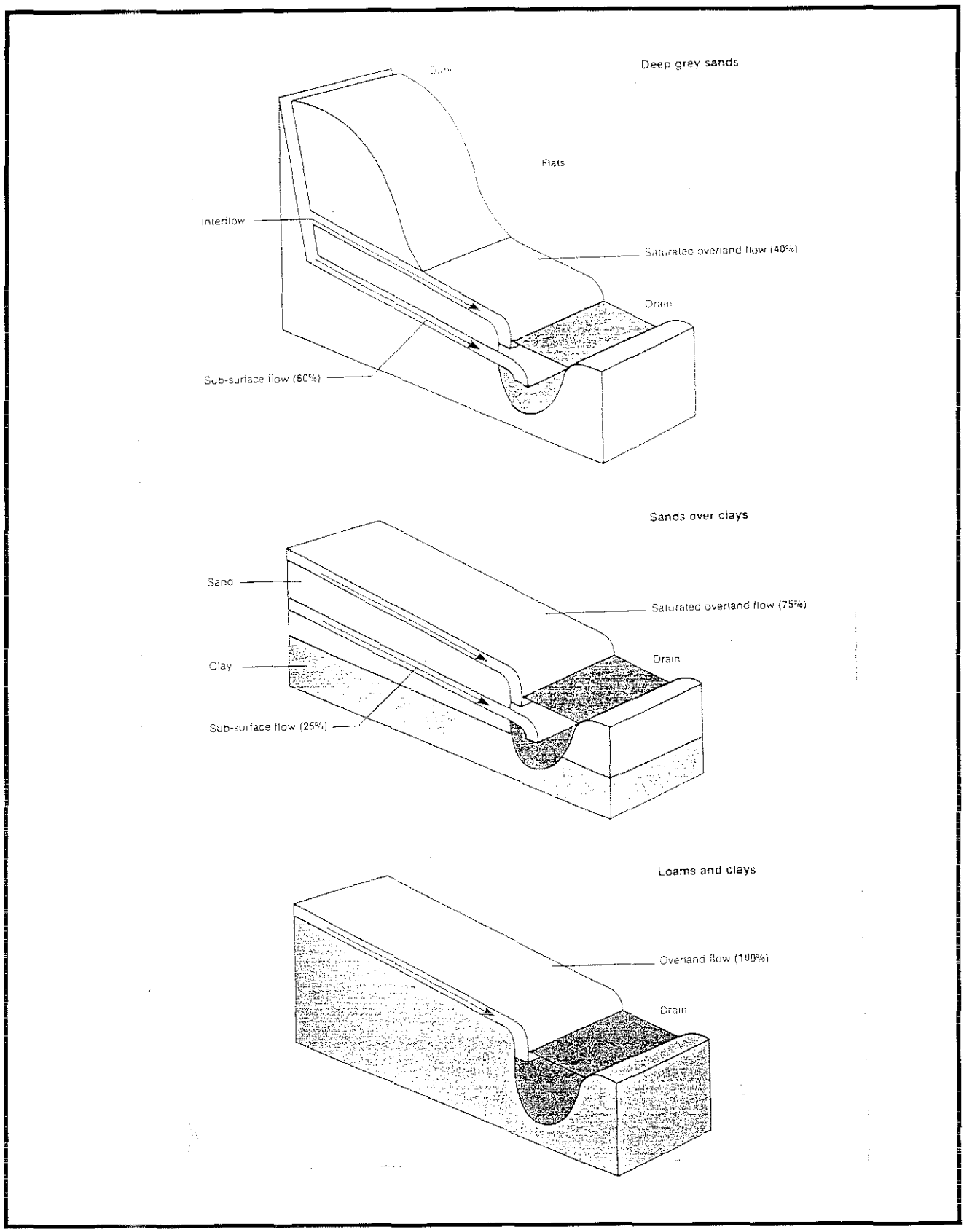

Figure 3: Conceptual diagram of phosphorus transport from the major soil groups.

6.3.3 Impacts on upland flora

As noted above, the Peel-Harvey Coastal Plain Catchment is largely cleared and few stands of remnant vegetation remain. As one of the measures to protect the Peel-Harvey Estuary from further degradation, there is a moratorium on further clearing of vegetation in the Peel-Harvey Coastal Plain Catchment. The remaining stands of remnant vegetation need to be protected.

The Public Environmental Review document stated that bauxite residue use would only be permitted on cleared areas. The alumina extraction process effectively sterilises bauxite residue, so the transmission of fungal diseases such as dieback is not a concern.

Concerns were expressed in public submissions that approval for the use of bauxite residue could encourage clearing of remnant vegetation and that physical and chemical changes to soil from bauxite residue applications could affect both the species composition of remnant vegetation and the ability of indigenous vegetation to re-establish.

The proponent replied that protection of remnant vegetation is a separate issue, that there is no documented evidence of the effects of bauxite residue on indigenous vegetation and that a 10 metre buffer between residue amended pasture and remnant vegetation would be incorporated into the Code of Practice. The proponent also noted that re-establishment of some species of indigenous vegetation had been observed on bauxite residue amended soil.

The Environmental Protection Authority considers that, provided the 10m buffer is incorporated into the Code of Practice, the application of bauxite residue in the Peel-Harvey Coastal Plain Catchment consistent with this proposal is unlikely to significantly affect indigenous vegetation. However, it would be appropriate to undertake monitoring to ensure the separation distance is effective.

6.3.4 Freshwater wetland and marine impacts

The Peel-Harvey Estuary and freshwater wetlands are environmentally significant parts of the Peel-Harvey Coastal Plain Catchment which have value for flora, fauna and people.

Based on the assessment in Section 5 potential changes to freshwater wetlands could include pH changes, increased Total Soluble Salts, increases in some trace elements, increased flow volumes through the wetlands and increased turbidity from red mud fines.

Changes to pH in wetlands can affect vegetation composition, availability of some micro-nutrients and the toxicity of substances such as ammonia and zinc which increase at high pH. Given the extent of rural development in the Peel-Harvey Coastal Plain Catchment it is likely that the pH in many wetlands has already been altered to some degree. The rate of pH change may be an issue.

The increase in Total Soluble Salts observed by Summers et al (1993a) when bauxite was applied at 80 t/ha are within the criteria for the protection of aquatic ecosystems in the *Australian water quality guidelines for fresh and marine waters* (Australian and New Zealand Environment and Conservation Council, 1991). The Public Environmental Review also notes that the salts which leach from bauxite residue are common in aquatic systems. On this basis, Total Soluble Salts are probably not of concern.

In terms of trace elements and heavy metals, aluminium may be of concern (See section 5.2.2).

The effect and likely increase in the volume of water passing through freshwater wetlands is unknown and would depend on the proportion of the wetland's catchment which has bauxite residue applied, and the factors which affect permeability.

Provided that the Code of Practice specifies a separation distance from watercourses, the fine particles are unlikely to reach wetlands.

A significant proportion of the Peel-Harvey Coastal Plain Catchment would need to have bauxite residue applied before the changes suggested above would be noticed in the Peel-Harvey Estuary. Appropriate monitoring of freshwater wetlands would provide a warning system of changes in the Peel-Harvey Estuary.

The Public Environmental Review document considered that marine and freshwater impacts would not be significant.

Concerns were expressed in public submissions that:

- there could be long term impacts on the health of waterways;
- heavy metals bound to the bauxite residue could be released in the marine/wetland environment and bioaccumulate;
- radiation levels could affect the aquatic ecosystem; and
- sulphate loading from bauxite residue/gypsum mix could accumulate in estuary sediments.

The Environmental Protection Authority considers the proponent's response, which appears in Appendix 2, to be adequate.

In response to concerns about the health of the waterways, the proponent would address these in the monitoring program. The Environmental Protection Authority considers any monitoring program developed should address concerns about pH and increased flow volumes.

6.3.5 Effects on groundwater

Based on the information in Section 5, impacts on groundwater quality are not considered to be significant. Although at the local level some water quality criteria in leachates could initially exceed desirable levels, this would not be of environmental significance unless an entire catchment were treated in the one year. The effects of reduced infiltration would depend on the proportion of the catchment amended with bauxite residue, the rate of application and the other factors which affect permeability.

6.3.6 Monitoring catchment wide impacts

The potential environmental impacts noted above should be monitored in some key sub-catchments and the monitoring results used to determine the continued acceptability of bauxite residue application and to modify the Code of Practice. Key sub-catchments should be identified on the basis of a high adoption rate by landholders in the catchment and major differences in the land systems such as occurs between the Pinjarra Plain and Bassendean Dune and Plain soil associations.

Recommendation 4

The Environmental Protection Authority recommends that the proponent design and then implement a monitoring programme which includes, but is not limited to addressing the following concerns for key sub-catchments and environments in the Peel-Harvey Coastal Plain Catchment:

- **Adequacy of proposed measures to protect remnant vegetation;**
- **impacts from changes in pH and aluminium concentrations in the catchment on wetlands;**
- **changes to surface water runoff flow patterns and volumes, and the effect of this change on wetlands and drainage water quality;**
- **monitoring of ground and surface water quality parameters, including pH, heavy metals, turbidity and radioactivity, to confirm predictions in the Public Environmental Review document and this assessment report;**

to the requirements of the Environmental Protection Authority on advice of the Chemistry Centre of Western Australia.

The Environmental Protection Authority recommends the monitoring plan be reviewed every five years.

The Environmental Protection Authority recommends that the results of the monitoring program be made available to the public and the Authority.

6.4 Traffic

The Environmental Protection Authority has been advised by the Main Roads Western Australia that the increase in traffic from this proposal could be significant.

The Department of Agriculture indicated in the Public Environmental Review document and its response to public submissions that it would consult with the Main Roads Western Australia and local government authorities regarding traffic impacts. In its response to public submissions the Department of Agriculture anticipates that monitoring of road use and any adverse impacts will proceed in conjunction with local government authorities.

The Authority considers that the management of traffic to reduce impacts on local roads and residents living near those roads is a matter for the Department of Agriculture to address with the relevant local government authorities.

6.5 Issues to be addressed by other agencies

There are a number of issues associated with this proposal which need to be addressed or considered by other agencies. These issues include:

- health issues such as accumulation of heavy metals/radioactivity in vegetables;
- occupational health issues associated with the handling and transport and spreading of bauxite residue;
- agricultural issues such as:
  - ensuring application rates do not cause pH changes which result in copper deficiency in ruminants; and
  - developing appropriate fertiliser rates for amended soils;
- economic issues which need to be considered by individual landholders.

One person has suggested that a residue management group could be established to oversee the above issues.

7. Conclusions

The Environmental Protection Authority concludes that the proposal by the Western Australian Department of Agriculture for the widespread use of bauxite residue in the Peel-Harvey Coastal Plain Catchment is environmentally acceptable.

In reaching this conclusion the Authority identified the main environmental factors requiring detailed consideration as:

- the likely effects of bauxite residue based on the physical and chemical characteristics of bauxite residue, particularly alkalinity, salts, heavy metals and particle size;
- ensuring responsible use of bauxite residue
- potential impacts on flora;
- potential impacts of freshwater and estuarine wetlands;
- potential impacts from changes to soil permeability; and
- the need for monitoring and for monitoring results to be reflected in responsible use.

The Authority concludes that the environmental factors mentioned above have been addressed adequately by either environmental management commitments given by the proponent or by the Authority's recommendations in this report.

Accordingly, the Authority recommends that the proposal could proceed subject to:

- the Environmental Protection Authority's recommendations in this Assessment Report; and
- the proponents commitments (See Appendix 1).

The Authority has established an implementation and auditing system which requires the proponent to advise the Authority on how it would meet the requirements of the environmental conditions and commitments of the project. The proponent would be required to develop a Progress and Compliance report for this project as a section of the recommended audit programmes.

The Authority's experience is that it is common for details of the proposal to alter through the detailed design and construction phase. In many cases alterations are not environmentally significant or have positive effects on the environmental performance of the project. The Authority believes that such non-substantial changes, and especially those which improve the environmental performance and protection, should be provided for.

The Authority believes that any approval for the proposal based on this assessment should be limited to five years. Accordingly, if the proposal has not been substantially commenced within five years of the date of this report, then such approval should lapse. After that time, further consideration of the proposal should occur only following a new referral to the Authority.

8. Recommended environmental conditions

Based on its assessment of this proposal and recommendations in this report, the Environmental Protection Authority considers that the following recommended environmental conditions are appropriate.

WIDESPREAD USE OF BAUXITE RESIDUE, PEEL-HARVEY COASTAL PLAIN CATCHMENT (766)

WESTERN AUSTRALIAN DEPARTMENT OF AGRICULTURE

1 Proponent Commitments
The proponent has made a number of environmental management commitments in order to protect the environment.

1-1 In implementing the proposal, the proponent shall fulfil the commitments (which are not inconsistent with the conditions or procedures contained in this statement) made in the Public Environmental Review and in response to issues raised following public submissions. These commitments are consolidated in Environmental Protection Authority Bulletin 714 as Appendix 1. (A copy of the commitments is attached.)

2 Implementation
Changes to the proposal which are not substantial may be carried out with the approval of the Minister for the Environment.

2-1 Subject to these conditions, the manner of detailed implementation of the proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the proponent to the Environmental Protection Authority with the proposal. Where, in the course of that detailed implementation, the proponent seeks to change those designs, specifications, plans or other technical material in any way that the Minister for the Environment determines on the advice of the Environmental Protection Authority, is not substantial, those changes may be effected.

3 Code of Practice
A Code of Practice will be developed to ensure responsible use and reflect management changes found necessary as a result of monitoring.

3-1 Prior to widespread use of bauxite residue commencing, the proponent shall prepare a Code of Practice incorporating environmental issues which includes, but is not limited to, consideration of:

- dust control during transport and application;
- assessment of optimum application rate based on changes to pH;
- separation distance necessary from areas where bauxite residue is applied to areas of remnant vegetation or watercourses to protect flora and water quality; and
- frequency of review to incorporate management recommendations gained from experience and monitoring of bauxite use;

to the requirements of the Environmental Protection Authority.

3-2 The Code of Practice shall be reviewed at a frequency determined in accordance with condition 3-1 to the requirements of the Environmental Protection Authority.

3-3 The proponent shall monitor and seek to ensure compliance with environmental aspects of the Code of Practice.

4. Evaluation of effects of application rate and land-use scenarios

An evaluation of the variation in environmental impacts which depend upon application rate and soil mixing scenarios is necessary.

4-1 Within six months of the commencement of widespread bauxite residue use in the Peel-Harvey Coastal Plain Catchment, the proponent shall develop a research program which includes, but is not limited to an evaluation of the following potential environmental effects for a range of application rates and subsequent soil mixing scenarios:

- changes to soil permeability;
- changes to surface water runoff flow patterns and volumes; and
- changes to pH of surface water run-off;

to the requirements of the Environmental Protection Authority on advice of the Chemistry Centre of Western Australia.

4-2 The proponent shall implement the research program required by condition 4-1.

4-3 Results from the research program required by condition 4-1 shall be made available to the public and the Environmental Protection Authority.

5 Catchment monitoring

Key catchments with a high proportion of their area bauxite residue amended and key environments shall be monitored to assess environmental impacts and confirm environmental impact assessment predictions.

5-1 Within six months of the commencement of widespread bauxite residue use in the Peel-Harvey Coastal Plain Catchment the proponent shall design a monitoring programme which includes, but is not limited to addressing the following concerns for key sub-catchments and environments in the Peel-Harvey Coastal Plain Catchment:

- adequacy of measures to protect remnant vegetation;

- impacts from changes in pH, and aluminium concentrations in the catchment on wetlands;
- changes to surface water runoff flow patterns and volumes, and the effect of this change on wetlands and drainage water quality; and
- monitoring of ground and surface water quality parameters, including pH, heavy metals, turbidity and radioactivity, to confirm predictions in the Public Environmental Review document and this assessment report;

to the requirements of the Environmental Protection Authority on advice of the Chemistry Centre of Western Australia.

5-2 Results from the research program required by condition 5-1 shall be made available to the public and the Environmental Protection Authority.

5-3 The proponent shall review and re-submit the monitoring program every five years to the requirements of the Environmental Protection Authority, until such time as the Environmental Protection Authority determines further monitoring is not required.

5-4 The proponent shall implement the monitoring program required by condition 5-1 and condition 5-3.

6 Proponent

These conditions legally apply to the nominated proponent.

6-1 No transfer of ownership, control or management of the project which would give rise to a need for the replacement of the proponent shall take place until the Minister for the Environment has advised the proponent that approval has been given for the nomination of a replacement proponent. Any request for the exercise of that power of the Minister shall be accompanied by a copy of this statement endorsed with an undertaking by the proposed replacement proponent to carry out the project in accordance with the conditions and procedures set out in the statement.

7 Time Limit on Approval

The environmental approval for the proposal is limited.

7-1 If the proponent has not substantially commenced the project within five years of the date of this statement, then the approval to implement the proposal as granted in this statement shall lapse and be void. The Minister for the Environment shall determine any question as to whether the project has been substantially commenced. Any application to extend the period of five years referred to in this condition shall be made before the expiration of that period, to the Minister for the Environment by way of a request for a change in the condition under Section 46 of the Environmental Protection Act. (On expiration of the five year period, further consideration of the proposal can only occur following a new referral to the Environmental Protection Authority.)

8 Compliance Auditing

In order to ensure that environmental conditions and commitments are met, an audit system is required.

8-1 The proponent shall prepare periodic "Progress and Compliance Reports", to help verify the environmental performance of this project, in consultation with the Environmental Protection Authority.

Procedure

The Environmental Protection Authority is responsible for verifying compliance with the conditions contained in this statement, with the exception of conditions stating that the proponent shall meet the requirements of either the Minister for the Environment or any other government agency.

If the Environmental Protection Authority, other government agency or proponent is in dispute concerning compliance with the conditions contained in this statement, that dispute will be determined by the Minister for the Environment.

9. References

Australian and New Zealand Environment and Conservation Council, 1992 *Australian water quality guidelines for fresh and marine waters* Australian and New Zealand Environment and Conservation Council, November 1992.

Summers R N, Guise, N R and Smirk, D 1993a Bauxite residue (red mud) increases phosphorus retention in sandy soil catchments in Western Australia *Fertiliser Research* **34**: 85-94

Summers R N, Smirk D D and Karafilis D 1993b Phosphorus retention and leachates of bauxite residue (red mud); Unpublished, to be submitted to *Fertiliser Research* .

Wells M R, 1989 *Land capability study of the Shires of Mandurah and Murray*, Land Resource Series No 2,Western Australian Department of Agriculture.

Wrigley T J, Chambers, J M and Mc Comb A J 1988 Nutrient and Gilvan levels in waters of coastal-plain wetlands in an agricultural area of Western Australia *Australian Journal of Marine and Freshwater Research* 39: 685-941

Appendix 1

Proponent's commitments

WIDESPREAD USE OF BAUXITE RESIDUE, PEEL-HARVEY COASTAL PLAIN CATCHMENT (766)

WESTERN AUSTRALIAN DEPARTMENT OF AGRICULTURE

The West Australian Department of Agriculture will accept commitments binding it to:

1 Commencing negotiations with Alcoa of Australia Limited which, if successful, will produce a Code of Practice and management structure enabling the widespread use of bauxite residue for nutrient control in the Peel-Harvey coastal plain catchment.

2. Maintaining, in conjunction with other agencies and institutions, and to the satisfaction of the EPA, a program of strategic monitoring of residue use and its benefits and impacts, under the program established through the Codes of Practice.

3. Providing the EPA and the general public with regular reports outlining the use and distribution of bauxite residue, under the program developed above and produce a major review of the program for EPA assessment within ten years.

Appendix 2

Summary of submissions and proponent's response

Widespread use of bauxite residue, Peel-Harvey Coastal Plain Catchment

Note: The Health Department of WA have given a commitment to complete their submission by 11 June 1993 and it will be forwarded directly to you by the Department. Issues raised by the Health Department of WA should be addressed in the Department of Agriculture response to submissions.

1 General comments

1.1 Broad overview comments

1.1.1 I fully support this proposal because it offers a solution to the cause rather than the symptoms. The Dawesville cut only affects the symptoms. This is part of the whole solution to the problems of the Peel-Harvey estuary.

1.1.2 Prevention is better than cure

1.1.3 The cooperative approach between industry and the environment is commended by this committee.

1.1.4 There is a natural counterpart to the proposal to apply bauxite residue on the coastal plain (ie the Pinjarra Plain soils).

1.1.1 to 1.1.4 noted.

1.1.5 The usefulness of bauxite residue should not be used as a justification for an expansion of bauxite mining.

Bauxite mining is covered by State Agreement Acts and existing EPA assessment procedures and this covers the disposal of the bauxite residue.

Within the scope of this PER only a small proportion of the annual production of 12 million tonnes of bauxite residue will be used.

1.1.6 Need to ensure that speculators will not use bauxite residue to promote the excessive use of horticulture and feedlots in inappropriate locations.

Proposals for horticultural and intensive animal industries are subject to a range of planning constraints, and to separate environmental assessment through being subject to the conditions of the Statement of Planning Policy for the Peel-Harvey Coastal Plain Catchment and the general requirements of the Environmental Protection Act. If the community wishes to control such developments, beyond ensuring that they meet existing nutrient targets and other environmental considerations, then land-use planning mechanisms need to be developed and used.

It is not intended that use of bauxite residue should over-ride existing land use planning mechanisms.

1.1.7 Appropriate publicity should be given to on-going improvement of the catchment.

The Western Australian Department of Agriculture is committed to improvement of the catchment and there exists an on-going publicity program bringing attention to that program and its performance.

1.2 Unqualified and qualified support for the proposal

1.2.1 After a trial on my property which extended the growing season and enabled greater survival of pasture plants I believe bauxite residue has great potential to help farmers and the environment.

1.2.2 The four trials which our group has been involved with demonstrate bauxite residue has the capability to significantly reduce nutrient discharge from a wide range of uses, including intensive animal industries, pasture and fodder.

1.2.3 Based on observations of other trials, I would like to register my name to use the bauxite residue on my farm/ dairy farm.

1.2.4 My study showed that the use of bauxite residue in the post-mining rehabilitation process for a mineral sands mine west of Serpentine would have major environmental and economic benefits to affected landholders.

1.2.1 to 1.2.4 noted.

1.2.5 With development of appropriate controls, a Code of Practice, and on-going monitoring the use of bauxite residue is unlikely to have adverse impacts on the environment.

1.2.6 Generally very supportive of the use of bauxite residue and a management tool to reduce nutrient runoff from the catchment, however there are several concerns which must be resolved before long-term permission is given. Suggest first stage approval should be granted until long-term issues adequately resolved.

1.2.5 to 1.2.6
The proponent agrees with the first stage over a period of five years during which time the longer term issues would be resolved.

The Department of Agriculture will develop a code of practice, and an ongoing monitoring program is outlined at the end of this document.

1.3 Comments on government support

1.3.1 There has been some reluctance to support use of bauxite residue by government agencies because of little formal support from the Environmental Protection Authority. I expect Environmental Protection Authority support would allow more frequent and innovative use.

1.3.2 A positive government response is required.

1.3.1 to 1.3.2 noted.

1.4 General and miscellaneous comments on the document

1.4.1 Is reminiscent of an advisory publication, but also seems to be a mix of a sales brochure and scientific review and so makes dogmatic statements based on fairly thin evidence.

1.4.2 Overall the document is considered to be a useful review and the relevant issues appear to have been addressed. It appears the document has been well researched.

1.4.1 to 1.4.2 noted.

1.4.4 Consideration of alternatives

1.4.4.1 Natural Zeolites (Clinoptilolite variety with cationic and anionic exchange capacities) provide a viable alternative and complementary product to bauxite residue. (Absorbs 5kg P & 15-18kg ammonia/potassium per tonne - several other benefits listed by submittor - copy of letter sent direct to Department of Agriculture).

Zeolites are a complementary product to bauxite residue, with niche markets. The use of zeolites in broadacre agriculture is not currently considered economically attractive, with the cost being 10 to 20 times that of residue when used in the Peel-Harvey catchment.

Bauxite residue is currently a waste material, and its use can be considered more environmentally desirable than the quarrying of new materials.

1.4.5 Scope of proposal

1.4.5.1 Why the use of bauxite residue is restricted to the Peel-Harvey Catchment is not adequately explained. Based on the Public Environmental Review document it would not be appropriate to restrict use of bauxite residue to this catchment.

It should be noted that there are no restrictions on the use of bauxite residue either inside or outside the Peel-Harvey catchment, and it is already being used in a number of locations. This PER results from a decision by the proponent to invite public and EPA comment on both existing and more widespread use.

However, EPA procedures are generally set for firm site-specific proposals and are not designed to endorse the use of materials or products (page 14, para 6). The formal EPA appraisal process is, in effect, being used as a mechanism to ensure there is open public discussion of bauxite residue use. As the proponent has a legal responsibility under the EP Act to implement nutrient reduction programs in the Peel-Harvey catchment, it was seen as appropriate to identify the catchment as the geographical boundaries of the proposal. This approach was considered acceptable by the EPA.

Additionally, it should be noted that the Peel-Harvey coastal catchment is the region of greatest need, and covers most of the area immediately adjacent to the bauxite residue stockpiles.

1.4.6 Adequacy of information about bauxite residue

1.4.6.1 Would have liked more information about source of bauxite residue and its chemical composition.

The information enclosed in the environmental review is the best available, and is considered more than adequate for the purposes of the PER. On-going analysis of the residue is currently being carried out by the Chemistry Centre of Western Australia.

2 Control of and guidelines for bauxite residue use

2.1 How will bauxite residue be applied and by who.

General techniques of application are spelt out in the PER (ie 5.1, 6.1.1.1, 6.1.2). Personnel involved in spreading residue, in the situations covered by this PER, will be determined after the EPA has commented on the general acceptability of widespread residue use. It is anticipated that ALCOA and the Department of Agriculture will jointly negotiate an arrangement which meets the EPA criteria established following their assessment of the PER.

Because the exact techniques of residue application have been improved drastically in recent years, it is considered important that precise techniques are not prescribed, and that flexibility is allowed. The important issue is seen as determining what environmental constraints, if any, may apply to residue application. Adjustment of techniques can be made, if necessary, to meet those constraints.

2.2 Who is responsible to ensure the blending and application of bauxite is done in accordance with any Code of Practice and not applied in excess.

The Western Australian Department of Agriculture will maintain, in conjunction with other agencies and institutions, and to the satisfaction of the EPA, a program of strategic monitoring of residue use, established through the Code of Practice for

the use of bauxite residue (as committed in section 12 of the Public Environmental Review).

2.3 Concerned that when bauxite residue not mixed with gypsum, pH of residue can cause minor burns. Suggest should only be applied with gypsum (to control pH).

The concern about pH is recognised. However, bauxite residue does not fall into a hazardous category for transport set down by the Department of Mines, and its use, as set out in the PER, will meet Occupational Health and Safety requirements.

Additionally, mixing with gypsum in the dry state may only reduce the pH of a small proportion of the bauxite residue particles, that is it gives a false impression of the nature of the alkalinity in bauxite residue. Without gypsum the natural neutralising effect of the air and organic matter in the soil is sufficient, and much more effective in reducing pH.

In recent trials by the Chemistry Centre (Bob Jeffery pers. comm.) bauxite residue without gypsum was analysed for its alkalinity. The bauxite residue was prepared for removal to be used in soil amendment (without gypsum). This work has shown that there is about 3% sodium carbonate in the bauxite residue. This shows that the alkali has converted from sodium hydroxide to sodium carbonate on exposure to air, even on lumps as large as 10 cm.

Sodium carbonate is a common constituent in clothes washing powders which is enjoying a return to popularity over phosphate based washing powders. The level of sodium carbonate in washing powders is much higher than in bauxite residue used for soil amendment.

For these reasons the addition of gypsum to bauxite residue for safety reasons in broadacre agriculture is not considered necessary. People should follow standard safety procedures for eye and respiratory protection (p11 para 2) when spreading bauxite residue.

In some cases, such as with soil blends for domestic gardens and septic systems, the use of gypsum may be beneficial in adding calcium ions to a much diluted mixture to reduce the pH. The main emphasis however is on the thorough mixing and use of the natural buffering capacity of the mixtures to reduce the pH, and not on the gypsum alone.

2.4 Areas with acid soils where bauxite residue without gypsum is to be applied should be identified and the manner in which it is implemented should be determined.

The final decision on whether bauxite residue is to applied on a property will be made by individual landholders. This will be in consultation with the appropriate agencies, and generally follow consideration of a range of agronomic and other issues.

The soils of the catchment have been mapped, and this provides some general guidance to the areas where amendment is most applicable. The degree of acidification of these soils is primarily due to the effect of the vegetation growing on it and the way it is managed. Specifically soil which has had legumes growing on it for a number of years becomes acidic, and this is increased if hay is cut and not fed out on the area from which the hay was cut. Some forms of nitrogenous fertilizers also have an acidifying effect. As a consequence the level of acidity of soil cannot be identified simply from soil maps as these cultural components that have to be taken into account.

The sandy soils which are most likely to benefit from bauxite residue to improve their phosphorus retention are those which have little iron and aluminium oxides. These oxides give the more fertile soil a colour from brown through red to yellow. Sometimes these retentive soils are deceptively grey on the surface with the coloured oxides below the surface. If the sandy soil has had a long history of phosphorus application, it may become phosphorus "saturated" and may benefit from application of bauxite residue. Again, soil mapping has limited applicability.

A very broad guide for the identification of those sandy soils which have potential for improvement of nutrient retention from bauxite are those which have a grey sandy surface. More accurate mapping of the potential soils can be seen from the land resources maps produced by the Western Australian Department of Agriculture (Van Gool (1990), Wells and Hesp (1984), Van Gool and Kipling (1993)). Similarly, broad indication of these soils is shown in this mapping by the pale yellow areas. There are other soils besides these and closer scrutiny of the map legend should show these.

Aside from this identification of the potential areas it is important to reiterate that cultural variations will result in the need to assess each site for the potential for improvement by bauxite residue. Bauxite residue is not a cure all and it must be used in a measured and considered manner.

2.5 All precautions should be widely publicised and implemented to minimise environmental and public health effects (short and long term).

Noted. Ensuring that this happens is one of the purposes of this PER.

2.6 The State government should assist farmers in the correct application and management of bauxite residue (ie fund Land Care groups).

The Western Australian Department of Agriculture already provides considerable support to Land Care groups, with a major component of funding in the Peel-Harvey catchment being directed towards this. The department is committed to ensuring that adequate information and advice on residue application is available to landowners.

2.7 What management strategies are in place to educate land users and to prevent abuse of the amended soil advantage (Eg over application of fertilisers/pesticides to gain productivity).

The Department of Agriculture has already established major long term trials aimed at producing the information needed by farmers to "re-calibrate" their fertiliser application rates to suit amended soils. Results will be fed into existing Departmental programs which are aimed at assisting farmers and market gardeners to apply only the fertilizers that they need. This advice is generally based on site specific on soil tests. However, it needs to be recognised that fertiliser application rates is a decision made by individual landowners, and is not subject to any controls.

Amendment with bauxite residue will increase the efficiency of fertilizer use and is expected to reduce the application of fertilizers. The main soil types which suit bauxite residue application are low in production value, and do not produce returns that would support the cost of excessive nutrient application. With the "cost-price squeeze" very few farmers can afford to waste fertilizer.

Over-application of insecticides is not expected to be a side issue of the advantage gained from bauxite residue application.

2.8 Concerned that if not applied properly, dust from bauxite residue application may contaminate surface waters.

Although the application of bauxite residue will be subject to a Codes of Practice developed by the Western Australian Department of Agriculture, and this will act to limit the production of dust, the possibility of dust reaching surface waters is not seen as an issue. The environmental impacts of dust are centred around either leachates or the physical effects of the particles. Both of these aspects have received attention in the PER (page 33 section 9.4.3, page 34 section 9.6) and are not considered to be a potential problem.

2.9 Concerned that high application rates (250 t/ha) may have a significant impact from heavy metals, fluoride and salts, particularly sodium and sulphate. At 100t/ha impacts from salts would be minimal.

As mentioned in the PER, bauxite residue application has been studied at rates of up to 2000 t/ha where these concerns were addressed (page 32, 33, 34, section 9.4.3).

Long term monitoring will be carried out.

2.10 In the event that availability of bauxite residue is restricted, distribution should be determined on the basis of site suitability and corresponding environmental benefit.

Noted.

2.11 Note that a rezoning proposal at Kwinana may result in a portion of currently available bauxite residue becoming unavailable.

Noted. However the production of bauxite residue, over and above the present reserves, exceeds 12 million tonnes per year. This is far in excess of current expected needs.

3 Soil amendment

3.1 Bauxite residue by itself will not remove the need for programs to minimise fertiliser and nutrient losses.

Bauxite residue is only one of many tools and techniques for the reduction of fertilizer and nutrient loss. The Department of Agriculture is committed to many other methods of minimising nutrient losses (page 13 para 4). The use of bauxite residue alone cannot meet the targets of reducing nutrient loads. Bauxite residue only improves the nutrient retention of sandy soils and more than a quarter of the catchment has clay surfaced soils. Other techniques are necessary to reduce the loss of nutrients from these soil types. Programs aimed at the development and application of other techniques are underway, and will continue.

3.2 How is economic level of application determined? (See Page 18, paragraph 6 & Page 19, paragraphs 3 & 4).

Within the parameters set out in the PER, the final decision on economic application rates will be set by landholders and any others involved in bearing the costs of application. Economic analysis of application rates, as referenced in the PER, related purely to current grazing enterprises. This analysis has been conducted by the Department of Agriculture. The statement on page 19 states that probably the most economic rate, for broadacre landholders, is between 10 and 20 t/ha.

Trials by the Western Australian Department of Agriculture has shown that improvements in pasture production, levels-off (plateaus) between 40 and 80 t/ha. The steepest point in the response curve occurs between 10 and 20 t/ha. Applying more bauxite residue results in a diminishing return. The cost of application at this point will provide the most return for pasture production. Coincidentally the retention of nutrients follows a similar curve and the best retention of nutrients over an extended leaching (equivalent to five years rainfall) lies somewhere between 10 and 20 t/ha.

The improvements in growth and cost of use will vary depending upon the enterprise, however, based on normal grazing operations the application of bauxite residue in the order of 10 to 20 t/ha is economically viable. With horticultural enterprises it is not considered that factors other than economic will determine the heaviest rate of application used by growers.

There are many other land uses in the catchment where the cost of residue will be a relatively minor consideration, such as in horticulture, recreational areas, and in effluent treatment. In these situations application rates of 250 t/ha or above may well be economically justified.

It is expected that inclusion of broad environmental benefits in a cost/benefit analysis would show that financially supporting residue application is an effective means of gaining improvements in estuarine health.

3.3 Public Environmental Review should have given more consideration to the relative merits of five-yearly applications of 'low' rates of bauxite residue compared with less frequent applications at higher rates.

The PER is concerned predominantly with outlining possible environmental issues. Adjustment of application rates, within the parameters determined as acceptable to the EPA, will be an ongoing process. The Department of Agriculture already has a programs of trials and assessments in place to provide information to landholders on the relative merits of a range of application techniques and rates.

Page 22 of the PER gives the context within which application of lower rates can be viewed. In the earlier trials, bauxite residue was applied at up to 2000 t/ha. It was discussed in the Peel-Harvey Environmental Review and Management Program at 200 t/ha, and rejected for economic reasons. The application rates of 10 to 20 t/ha are low rates and it is currently thought that reapplication will be necessary. The exact time span is not known but it has been estimated through trials that the initial application should last at least five years.

The application of 10 to 20 t/ha is based on the achievement of both reductions in phosphorus loss rates and improvements in growth and it is expected that reapplication will occur. The upper level of 250 t/ha is expected to be warranted and viable only in situations where high inputs and outputs occur.

3.4 How frequently would re-application be required to continue the benefits with respect to erosion?

Exact measurement to determine any benefits of residue application in reducing soil erosion have not been made, although the improved pasture cover following amendment can be expected to reduce erosion to some extent. The major factor in the decision to re-apply is expected to be exhaustion of the capacity for phosphorus retention.

3.5 I wish to lodge a formal protest about this proposal until I receive a satisfactory explanation about issues associated with the amount of salts produced and gypsum, and the increased pH associated with its use making areas unsuitable for cereals and natural grasses.

In one major trial the use of bauxite residue at 40 t/ha increased the pH of a pasture paddock from 3.5 to 4.5, which is well within the desirable range of cereals and natural grasses. Other field trials have shown that clover and grasses grow well where red mud has been applied; better than where it has not been applied. Clover is more susceptible to salts than grasses and cereals. Where studies have considered results from application rates in excess of 250 t/ha, the salts leached were not considered likely to cause problems. The PER recommends rates below 250 t/ha.

3.6 On what basis is the statement made that soil phosphorus levels in the catchment are now such that further reductions in fertiliser efficiency are unlikely unless improved fertilisers become available (Page 12, paragraph 3).

Fertiliser use has generally been declining for a number of years, mainly due to the reduced profitability of farming and high cost of fertiliser, and to programs by the Western Australian Department of Agriculture which assist farmers to fertilize on the proven requirements of soil tests.

Data collated in 1991 showed significant drops in phosphorus levels on a range of soil types (PHCSG, 1991) and Departmental advisory experience in the past two seasons has been that phosphorus levels have generally reached the point where the majority of recommendations based on soil tests are for increases in application rates.

Modified slow release fertilizers show considerable promise. Currently, coastal superphosphate is considered to be the best alternative to normal superphosphate as a slow release fertiliser. However, paired catchment trials over several years comparing coastal superphosphate with normal superphosphate were unable to show a reduction in phosphorus loss from coastal superphosphate. The catchment treated with coastal superphosphate lost slightly more phosphorus than the normal superphosphate treated catchment (Silberstein and Schofield, 1990). Development work is proceeding.

3.7 The slightly increased salinity is unlikely to be a problem in high rainfall areas.

Noted.

3.8 The reference summaries quoted in the PER did not cover the retention of organic P by bauxite residue.

Most of the trials in the reference summaries measured "total phosphorus", which has a component of both inorganic and organic forms of phosphorus. The aim of these trials have been to reduce the total amount of phosphorus leaving the land. The exact partition or component of phosphorus is not as important due to the labile nature of phosphorus between organic, inorganic and with particulate association.

There is an exception to this in the work of Hofstede and Ho (1992) who found increased stability of organic matter through the addition of bauxite residue during the composting process.

3.9 Section 5.3.1 and Page 22, paragraphs 6 & 7 describe research work but do not provide enough information about site conditions (Eg. how important was surface runoff compared with vertical leaching, how well mixed was the bauxite residue). Also the

research was done on soils with a low pH (about 3.5) and therefore I am concerned that many other soils would not respond to the addition of lime, and therefore possibly not bauxite residue, at the rates promoted in the Public Environmental Review.

3.10 With respect to soil acidity and pasture production Public Environmental Review document gives impression that yield increases with bauxite residue application are assured (See Page 13, paragraphs 6 & 7). Concern here is promotion of bauxite residue as a fix-all.

3.9 and 3.10. Extensive references covering these factors are contained in Section 13 of the PER. Agronomic performance of bauxite residue is covered by research at a wide range of sites, with a range of pH.

The research work refers to field trials on areas where there is an impermeable hardpan below the surface. At the beginning of the season there is some vertical leaching to the hardpan layer. During this period there is no visible runoff. After the dry depressions begin to fill, the water reaches a level where streamflow begins. The source of the streamflow is from a combination of vertically leached water and surface runoff water that is from inundated and very flat areas close to the surface expression of the water table. The bauxite residue was only lightly mixed into the surface using harrows.

The response to bauxite residue in the short term is clearly pH dependant initially, and the relationship between pH and the amount of bauxite residue needed for short term improvement in growth has been approximated- this was stated exhaustively in the review. The long term improvement in growth is due to the increase in plant available phosphorus which is less dependant upon pH. This improvement in plant available phosphorus has also been ascertained. Despite this it is suggested that those wishing to use bauxite residue for an agronomic response first run some test strips. It is also recommended (page 8) that the soil be tested to avoid the effects of overliming.

The aspect of mixing appears to have been confused due to early reports of the belief that a high level of mixing in pasture is necessary. However, the large scale, broad-acre field trials (80 t/ha and below) have shown that mixing the bauxite residue is not as important for nutrient retention and improved production as expected. These trials were designed to mimic the techniques readily available to landholders, with minimal mixing (only harrowing) and were quite successful in reducing phosphorus loss and improving nutrient retention.

As well as the trial on soil with a pH of 3.5, referred to in 3.9, trials have been repeated at the higher pH's (4.5 to 5) more commonly found on the sandplain, and similar improvements were demonstrated.

For higher application rates (up to 250 t/ha) in other, more intense, land uses mixing is more important because the bauxite residue could form a physical barrier and is too concentrated on the surface. In urban uses the PER recommends extensive mixing, or use of pre-mixed soil blends.

The PER does not promote the use of residue as a fix-all, and the Department of Agriculture is involved in the development and application of a range of other techniques aimed at achieving environmental improvements in the coastal catchment and its estuary. The PER gives no guarantee on pasture production increases (ie p13, para 6 "shows considerable potential for reducing sub-soil acidity", p13 para 7 "offers the prospect of significant improvements in pasture production").

3.11 At application rates < 100t/ha gypsum has been found unnecessary. However, gypsum has additional benefits apart from neutralising acid, such as improving the Sodium Adsorption Ratio, important for functioning of roots of plants.

The gypsum is not used to neutralise acid. The role of gypsum is to reduce pH but not substantially reduce alkalinity. It does this by converting the sodium carbonate which has a high pH to calcium carbonate which has a lower pH.

The application of gypsum as mentioned was found unnecessary in field trials at application rates < 100 t/ha. These trials showed no further improvement in growth when gypsum was added to the bauxite residue. In fact there was a slight (but not significant) reduction in the pasture production when gypsum was applied at the lower rates (below 40 t/ha). As a consequence the effect on the sodium adsorption ratio was not sufficient to justify the use of gypsum. Similarly there was no improvement in phosphorus retention with the application of gypsum when bauxite residue was tested below 100t/ha. In this case there was a slight (but not significant) reduction in phosphorus retention from the addition of gypsum at the lower rates (below 40 t/ha).

4 Effluent and waste management

4.1 Bauxite residue may be able to be used along the same principles as synthetic rutile processing waste is for dairy waste. (See Masters, B K, 1993 Management of dairy waste: A low cost treatment system using phosphorus adsorbing materials *Wat. Sci. Tec* Vol 27 No 1 159-169).

Noted.

5 Stormwater, drainage and wetlands

5.1 On what basis is the statement made that the most effective wetland filters are those that have bauxite residue mixed into their soils. There are many other ways in which wetlands filters can be designed to reduce nutrient flow. Concern here is promotion of bauxite residue as a fix-all (Page 13, paragraph 5).

The statement was based on experience in the Peel-Harvey coastal catchment. Bauxite residue has very high phosphorus adsorption capacity. Adsorption is a physical and chemical process by which these dissolved pollutants adhere to suspended particulates or onto bottom sediments. Adsorption of phosphorus is dependant on the sediment type (Stockdale, 1986). Richardson (1985) found that the phosphorus adsorption capacity of a wetland soil can be predicted by the extractable aluminium content of the soil. Richardson and Davis (1987) also concluded soil adsorption chemistry is one of the keys to storing phosphorus in wetlands.

Residue use is not being promoted as a fix all, merely as an extremely efficient tool when used in the right situations and with the right mix of other techniques. The Department of Agriculture is involved in other developmental work involving the use of plant species, such as Sudax and various reed species, to scavenge phosphorus from drainage sumps and rehabilitated wetlands.

5.2 There is insufficient data on the impact of using modified bauxite residue as a filter medium, particularly in relation to drainage structures and infiltration basins.

The work referred to in the PER by Ho *et al* (1985), Ho *et al* (1986a,b), Ho *et al* (1987), Ho *et al* (1989), Ho *et al* (1991), Ho *et al* (1992a,b), Kayaalp *et al* (1988), McAuliffe and Evangelisti (1991),Vlahos *et al* (1989) covers the removal of nitrogen and phosphorus by bauxite residue as a filter medium, removal of viruses and bacteria, the leachates from bauxite residue and the design of stormwater quality control basins. The data from these were obtained from laboratory column trials, field lysimeters and full scale effluent treatment systems.

Further research is being carried out by the Western Australian Water Authority and Murdoch University on an sewage treatment filter at Pinjarra as a long term trial.

5.3 The Public Environmental Review document does not address issue of contamination of water from heavy metals that may leach from bauxite residue due to low pH conditions resulting from acid spillages or illegal discharges to drains.

Although these are unlikely events, the discharge of acid to drains is worthy of consideration. Also worthy of consideration is what would happen if the discharge occurs where there is no lining in the drains. If there is no bauxite residue, the heavy metals would not be held and would contaminate the water. There are very few heavy metal absorbing materials that will not liberate the heavy metals on reaction with acid. The acids themselves would become pollutants and the bauxite residue would act to neutralise them.

5.4 We hope that Councils will insist on using bauxite residue to catch nutrients and heavy metals in the hundreds of stormwater sumps in the catchment.

Noted.

6 Other uses for bauxite

6.1 I support the use of Bauxite residue for other uses such as modified domestic septic tanks.

Noted.

6.2 Research into other uses for bauxite residue should be supported. (Eg. for piggeries and dairies, stormwater runoff, its use in compost, for wastewater treatment plant effluents).

Noted.

6.3 The use of bauxite residue for silviculture should be investigated.

Noted.

6.4 Any legislation advocating the use of bauxite residue should set out the need for controls on uses apart from broad acre and point sources.

Legislation advocating the use of residue is not envisaged, or likely. All the PER seeks is open public discussion, and assessment by the EPA of any possible environmental impacts. Following the PER it is likely that Government will seek an arrangement with Alcoa that enables the widespread use of residue. The nature of this arrangement is currently under discussion. If this arrangement were to include legislation, it would be "enabling" legislation, advocacy of use is a totally separate issue.

The PER contains extensive reference to the use of bauxite residue apart from broad acre and point sources.

7 Long-term, cumulative and environmental impacts

7.1 General comments

7.1.1 Despite the copious amount of work which has been carried out, the long-term impacts cannot be defined with certainty. Suggest first stage approval should be granted until long-term issues adequately resolved.

7.1.2 Prior to long-term permission being granted, at least two sites should be monitored for at least 5 years for the movement and loss of heavy metals, radioactive elements and salts. Suggest that Pinjarra Treatment Plant Red Mud Ponds could be one such site.

7.1.3 Concerned bauxite residue may not be the final solution because of need to repeat applications.

7.1.4 Prior to long-term permission being granted, monitoring to assess the effectiveness of low rate applications with a view to determining when re-applications are necessary should be undertaken.

7.1.5 State government should fund research in the long term monitoring of bauxite residue applications.

7.1.1 to 7.1.5
Bauxite residue is not to be considered a final solution or fix-all, and this is stated in the PER. It is one of many tools to reduce the algal blooms in the Peel-Harvey. On it's own, bauxite residue will not control the problem, but may be capable of reducing the phosphorus load by up to 30% (page 30 para 7). This only part of the way to the targeted 50% reduction set down by the ERMP and consequently residue use must be seen as an integral part of the whole program.

It is proposed that the residue program will be subject to ongoing assessment and adjustment. This is particularly appropriate given the speed at which the current technologies have been developed, and are being refined.

The proponent is already committed to a program of strategic monitoring of residue use, in conjunction with other agencies. The Water Authority is already committed to monitoring the Pinjarra Sewage Treatment Plant effluent irrigation field in conjunction with Murdoch University. The proponent has already committed funds to this project. The proponent will also monitor a large catchment treated with red mud for five years. Monitoring to establish the possible need to re-apply residue is seen as primarily an agronomic issue, not an environmental one. Research on this aspect is already underway.

7.2 Nutrient loads

7.2.1 Suggest that P concentration in water leaving bauxite residue amended soils should be used as the criterion for effectiveness and to determine frequency of re-application.

As outlined in the PER, environmental effectiveness, and hence benefit to the wider community, is largely achieved through the "happy co-incidence" of both environmental and economic benefits being derived from residue use. Unless residue is applied through a massive state funded program, initial application and subsequent frequency of application will largely be determined by the economic judgement of individual landholders. The PER is merely seeking environmental approval for widespread use to proceed within certain gross parameters.

Whilst P concentration may be the ideal measurement of the environmental effectiveness of bauxite residue, it is very difficult and expensive to measure in practice. Additionally very few sites which drain into a measurable point. There are other methods to determine the effectiveness of bauxite residue to retain nutrients, and these have been described by the Chemistry Centre (Allen, D. G. and Jeffery, R. C.,1990). There are also other factors not relating to phosphorus retention that need to be taken into account such as pH, plant species, soil type, fertilizer history and amount of fertilizer added since application of bauxite residue.

The monitoring of benchmark sites that mimic the general practice of fertilizer application for the area will also aid in determining the frequency of reapplication.

7.3 Health and safety

7.3.1 Lack of radiation levels, loss of salts from amended soils and the level of fluoride should be assessed by the Health Department of WA, particularly with respect to long term impacts.

Significant benchmark data was collected on these factors for the PER. The Department of Agriculture is keen to collaborate on any initiative by the Health Department to establish base line levels of water quality, though this would be possibly most efficiently achieved in conjunction with the range of agencies that already function in this area. The Department of Agriculture, on advice from the Radiological Laboratories, will monitor key sites to determine the background level of radioisotopes in groundwater and the effect red mud has on that level over the monitoring period.

7.3.2 The use of bauxite residue in application rates proposed (100-250 t/ha) will not result in radioactivity levels above those in bauxite ore and are approved. Where application rates exceed that level the Radiological Council should be notified and an assessment of the radiological impact made. Other uses of bauxite residue where high human occupancy may result, such as for construction material, may need individual approval from the Radiological Council.

Noted

7.3.3 Concerned about heavy metals and radioactivity in bauxite residue. Consider that extreme caution should be used at first (Eg. monitor food products for contamination for several years, ensure people applying bauxite residue wear respiratory protection & monitor before and after radiation levels).

Food products have been monitored for some years and monitoring is continuing. No problems have been recorded.

The need for respiratory protection (page 11, 19 and 31) was repeatedly emphasised in the review.

There has been exhaustive studies into the before and after radiation levels which has been verified by the statement in the previous statement (7.3.2) from the Radiological Council.

7.4 Salts and trace elements

7.4.1 Research is required to understand the long-term leaching of salts from the catchment to the estuary. Expect few problems. This research would help determine acceptability of use elsewhere (Eg. Jandakot Mound).

Long term research is being carried out on the Pinjarra Waste Water Treatment Pond facility which should provide this information.

7.4.2 Use of gypsum and the long term effect in the balance between minimising initial leaching of salts and achieving improved Sodium Adsorption Ratio should be investigated.

The application of gypsum as mentioned was found unnecessary in field trials at application rates < 100 t/ha. These trials showed no further improvement in growth when gypsum was added to the bauxite residue, in fact there was a slight (but not significant) reduction in the pasture production when gypsum was applied at the lower rates (below 40 t/ha). As a consequence the effect on the sodium adsorption ratio was not sufficient to justify the use of gypsum. Similarly there was no improvement in phosphorus retention with the application of gypsum when bauxite residue was tested below 100t/ha, in fact there was a slight (but not significant) reduction in phosphorus retention from the addition of gypsum at the lower rates (below 40 t/ha).

7.5 Marine and freshwater impacts

7.5.1 Concerned about long-term impacts of wide scale use with respect to the health of the waterways (Eg. potential of bio-accumulation in the food chain, on water quality and peripheral vegetation). Commitments to address these impacts should be made.

These aspects will be addressed in the monitoring programme.

7.5.2 Concerned that impurities/heavy metals bound to the amended soil washed into the estuary/marine environment may then be released. Would these impurities concentrate in the food chain or have adverse effects on estuary/marine life which may ingest soil.

The PER provides references to the lack of heavy metal contamination caused by residue. It also provides references as to the ability of residue to reduce the mobility heavy metals in soils (Hofstede and Ho, 92). Any heavy metals likely to be bound to red mud would need to come from materials already being applied to the catchment. If there is no material retaining the heavy metals (ie. if soil amendment does not proceed) then they are even more likely to wash into the estuary.

7.5.3 Will minor variations relating to radiation levels have an adverse effect on the estuary aquatic ecosystem.

Although it has been shown that radioisotopes do not leach from bauxite residue, this aspect will also be monitored as part of monitoring for heavy metals.

7.5.4 How important is sulphate loading from the ocean compared with the catchment in the sediments of the estuary, and how will this proposal affect sulphate loadings. How will this proposal affect the long term accumulation of H_2S in the estuary sediments.

Bauxite residue contains minimal amounts of sulphates. It is only when it is mixed with gypsum that sulphate levels can become significant. The use of gypsum will be limited for most low rate applications. In a recent trial the total level of salts (only

a proportion of these were sulphate) leaving a sub-catchment (30 ha) treated with 80 t/ha bauxite residue amended with 10% gypsum were at the very worst 200 mg/L (at the most 140 mg/L of sulphate) more than the untreated catchment. This is not a great level when one considers that upper limit of sulphate for potable water is 400 mg/L. The level recorded for the 30ha catchment will be many times the level expected because gypsum will not be used in most bauxite residue, and the application rate will largely be about 20 t/ha.

The concentration of sulphate in seawater is 2700 mg/L and the contribution of seawater to the sulphate in the estuary is dominated by seawater exchanged with the ocean. This will be more so after completion of the Dawesville channel. As a consequence the sulphate contribution of the bauxite residue is expected to be negligible.

7.5.5 The use of bauxite residue adjacent to Water Authority drainage structures, infiltration basins and drainage catchment areas should be monitored to;

- ensure heavy metal contamination is not occurring;
- ensure dust does not reach drains; and
- ensure superficial groundwaters and receiving waters are protected.

Monitoring to meet these criteria will largely be addressed through monitoring being undertaken at the Water Authority Waste Water Treatment Pond at Pinjarra. The possibility of dust reaching drains is not seen as being of concern. Considerable documentation is cited in the references where drainage structures constructed wholly or partly from residue were evaluated.

7.5.6 The Water Authority is opposed to the use of bauxite residue in a Priority 1 source protection area. Proposals to use bauxite residue in the Priority 2 part of the Jandakot Underground Water Pollution Control Area should be referred to the Water Authority for assessment. The Water Authority is discouraging further establishment of horticulture in the Priority 2 part of the Jandakot Underground Water Pollution Control Area

Noted, but it is suggested that there be ongoing appraisal of these constraints in the light of the measured performance of residue, and evaluation of the consequences of the nutrient and heavy metal pollution that is currently occurring on the Jandakot Mound, and which could be reduced through the use of residue.

7.5.7 Existing background levels of chemical constituents and radioactivity should be determined for groundwater in the areas where bauxite residue is to be distributed so that long term changes can be determined. This is important in view of the expansion of residential areas on Special Rural and Rural properties in the catchment.

It should be noted that the chemistry of groundwater in many areas is already changing due to various land-use impacts, and attributing any changes to a single factor is often difficult. It is anticipated that widespread use of bauxite residue would reduce the changes occurring to groundwater due to organic and chemical/heavy metal pollutants.

Leaching studies by the Western Australian Department of Agriculture have shown that red mud at rates of 250 t/ha produce leachates with undetectable increases in levels of radioisotopes. This is because the only radioactive element soluble enough to leach from red mud is Radium^{226} which is a daughter product of Uranium. The total level of uranium in red mud is very low and the amount of radioactive uranium is only a proportion of this. Even if Radium^{226} was produced it has a high affinity

for clays (Dames and Moore, 1989) and would remain in the red mud. The concern about long term leaching of radioisotopes also has a limited basis because the half life of Radium^{226} is only five years. Residue use has been assessed by the Radiological Council.

Aside from this information, the Department of Agriculture will sample bores from beneath long term trials to ascertain the level of radioisotopes and will monitor before and after levels of radioisotopes at key sites.

7.6 Impacts on flora

7.6.1 Removal of existing vegetation in wetlands and drains so that bauxite residue can be applied is unacceptable. Vegetation removed would take decades to re-establish during which time aesthetic and wildlife values are adversely affected, and there may be a temporary increase in nutrient discharge before vegetation establishes successfully.

7.6.2 Have a major concern that farmers may be able to/encouraged to clear existing areas of remnant vegetation as bauxite residue could be used to prevent erosion. All remnant vegetation should be protected.

7.6.3 Remnant vegetation needs to be protected from ill effects of bauxite residue.

7.6.4 Prior to long-term permission being granted, monitoring to discern any impacts on native vegetation adjacent to amended paddocks - with a particular view to changes in species composition and mortality of nutrient-poor sediment associated plants (Eg. Banksia) should be undertaken. This could also address mycorrhizal and general rhizosphere concerns for native vegetation.

7.6.5 Will amended soils have soil conditions which do not favour the growth of vegetation native to the area.

7.6.1 to 7.6.5
Bauxite residue is only intended for use on cleared land, although separate EPA approvals have been given for residue use in compensation basins constructed on previously vegetated land subject to urban development and freeway construction.

Protection of remnant vegetation *per se* is a separate issue. Through its various agency and parliamentary processes the State of WA has in place controls on vegetation clearance only as it relates to land degradation as defined in the Soil and Land Conservation Act, as it affects rare flora and fauna, where specified through the statutory planning process, or as otherwise assessed as damaging by the EPA. A Statement of Planning Policy exists for the Peel-Harvey catchment. This document controls clearing on proposals being assessed through the planning process. There is regular discussion with the EPA on the relative effectiveness of these mechanisms in the Peel-Harvey coastal plain catchment.

It should also be noted that, as part of the catchment management program of which residue use is a part, the Department of Agriculture is actively promoting the values of remnant vegetation, actively promoting strategic revegetation of the catchment, and actively assisting landholders to protect and rehabilitate remnant vegetation. This will continue.

In most existing cleared farmland residue use will assist in returning soils to their original pH, and restricting the movement off-site of soluble P, which is known to affect species such as banksia. Bauxite residue has been used to culture native species in pot trials, and on residue areas as part of revegetation programs.

There is no documented evidence of the effects of bauxite residue on the vegetation native to the Peel-Harvey catchment. There is anecdotal evidence of Zamias

(*Macrozamia reidlei*), Woody Pears (*Xylomelum occidentale*) and Jacksonia germinating or emerging and growing well on early pasture trials using over 1000 t/ha of bauxite residue (Ward Pers Comm).

The Department of Agriculture will include in the Code of Practice a requirement for a 10 metre buffer to be kept between residue amended pasture and remnant vegetation until more information has been derived from the monitoring program.

7.7 Impacts of haulage

7.7.1 The Public Environmental Review plays down the potential impact of truck haulage. Up to 10 000 truck movements could occur over a single autumn spreading season from and around three refineries. This needs further consideration.

This amount of trucking is not considered excessive, particularly in relation to existing truck movements. The trucking would occur over both summer and autumn because the spreading does affect the pasture. The major interruption to transport of bauxite residue is wet weather causing trafficability problems on paddocks. This represents at least six months of the year available to transport. The 10 000 truck movements (which is probably an upper limit figure) would be spread over three refineries and over nine shires. The 3 000 truck movements per refinery over six months represents about 30 a day. The South Western Highway at Pinjarra carries 4000 vehicle movements per day (MRD). If this is considered as a percentage it equates to 0.8% increase, while the projected growth in traffic for the area is 2.65% per year. It has been estimated that there are a minimum of 4 000 truck movements in the catchment each year due to cattle production alone.

It is recognised however, that some significant increase may occur on specific local government authority roads, as the result of an amendment program by a landcare group or a large landowner.

7.7.2 State government should assist (fund) local governments in road maintenance for roads used for bauxite transportation.

Once the EPA has clarified its views on the environmental acceptability of widespread residue use, the proponent is committed to establishing, in conjunction with other agencies and Alcoa, a "framework to facilitate more extensive use of residue" (p16, 2nd para). This framework will necessarily involve discussions with local government authorities, and it is anticipated that monitoring of road use and any adverse impacts will proceed in conjunction with local government authorities.

8 Adequacy of commitments

8.1 Management commitments are very general and should be tightened to the standard required for most environmental impact statements. A management and monitoring program should be prepared.

As set out in the PER (Section 2) the Department is seeking an indication from the EPA of the general acceptability of more widespread use of residue, within certain gross parameters. While this does not fit the normal pattern for a PER, it was considered by the EPA to be the appropriate pathway for the proposal to proceed. Once the overall environmental acceptability of widespread residue use is established, then the department will have a basis from which to establish with Alcoa a more detailed management and monitoring program.

Notwithstanding this, the PER did document a number of long-term monitoring sites already established by the Department. Six sites are currently in place, and a further three sites will be established. These sites are being utilised to cover a range of attributes, including impact on water quality run off (nutrients, heavy metals, salts and possible radioisotopes), possible impact on native vegetation, and improvements or other impacts on groundwater quality.

It is anticipated that these sites will be monitored as benchmark sites for the duration of the Department's active involvement in a bauxite residue program, and certainly for the next five years.

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Appendix 3

list of submittors

State and local government

Health Department of Western Australia & Radiological Council

Peel Inlet Management Authority

Water Authority of Western Australia

Shire of Harvey

Town of Kwinana

City of Mandurah

Members of the public and conservation groups

Conservation Council of Western Australia

B K Masters and Associates

S McCoy

Dr G Ho, Murdoch University

L Mullins

Meredith Land Conservation District Committee

B S Pink

Peel Preservation Group Inc

K Thorn

H B Watts

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