Chapter 2

VEGETATION

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Abstract

The high priority accorded to the establishment of a major conservation reserve in the Lesueur area is largely attributable to its unique floristic values. Within the proposed reserve are found high levels of species endemism, a high degree of species richness, and a very fine scale and hence complex mosaic of vegetation types. The proponents' regional analysis covering other conservation reserves in northern kwongan failed to locate most of the vegetation types found at Lesueur. Our analysis showed that the proposed development will have a severe direct impact on at least eleven of the 38 vegetation types so far defined. Nine of these communities are not known from outside the project area.

We also considered the likely indirect impacts of the proposed mine and power station development on the vegetation of the region. The information provided in the ERMP is inadequate to allay serious concerns about the acute and/or chronic effects of the various stack emissions on the vegetation over a wide area. Given the high biological significance of the area, the possibility of retrogressive succession occurring in the area is of considerable concern. The impacts of some trace elements in both air and water effluent have not been considered in the ERMP, nor have the effects of groundwater drawdown or changes in surface drainage been adequately dealt with.

The combined direct impacts and indirect effects of the proposed development on the vegetation of the region are likely to be very significant.

2.1 INTRODUCTION

The flora and vegetation of the Lesueur area have long been recognized as having very high conservation significance (Drummond 1853, Gardner 1947, Speck 1958, Griffin *et al.* 1983). The conservation significance of this area stems from both the high species richness of the area (averaging 76 spp/100m^2) and a very fine scale mosaic of vegetation types. The reasons for this richness are not fully understood but may be related to habitat continuity since the Tertiary, migration barriers, nutrient poor soils and recurrent climatic stress (Hopper 1979, Griffin *et al.* 1983, Hopkins and Griffin 1984).

Only one quantitative regional floristic survey has been carried out covering the Lesueur area. This was the work of Griffin *et al.* (1983); it was restricted to the lateritic uplands and covered some 500 000 ha. This survey highlighted the distinctness of the Lesueur area, which contained vegetation types not found elsewhere in the region. Studies of the distribution patterns of the 259 regional endemic plant species of the northern kwongan reinforce this conclusion (Griffin *et al.* 1990).

In the guidelines to the preparation of the ERMP for the proposed power station and coal mine the EPA stated "... a detailed assessment of the area's conservation status will be required. This is to ascertain if the conservation values in the area proposed for mining are adequately represented and preserved outside the area to be mined. If there are suitable areas of other land which could be included into existing reserves to replace lost conservation values the appropriate replacement proposals should be made. Details of the following would be required to adequately determine the relative values of... the proposed reserve areas that may be affected by mining.
- distribution and description of vegetation types. ...
- conservation status of vegetation." (ERMP Attachment 1, p. 7).

In assessing the ERMP in light of these guidelines it was found that the vegetation section was most superficial. It was not possible to even broadly assess the local impacts of this proposal without first calculating areas of each vegetation type affected; this information was not contained in the ERMP. The section dealing with the regional significance of the vegetation of the Lesueur area was inadequate, the small amount of data provided (in consultants' reports, not the ERMP) indicate the high conservation significance of the proposed conservation reserve at Lesueur, yet are interpreted in precisely the opposite way.

2.2 DIRECT EFFECTS OF THE POWER STATION AND COAL MINES ON THE NATIVE VEGETATION

2.21 Local vegetation

The proponents commissioned detailed vegetation mapping over most of the uplands of the proposed reserve. This showed a complex mosaic comprising 38 basic vegetation types. These basic types were mapped in the eastern end of the proposed conservation reserve. However, in some areas the consultants were not able to map the basic type and instead mapped an amalgamated unit (e.g. in the project area Type A was mapped when the consultants could not allocate vegetation to A1, A2.1, A2.2, A4.1, or A4.2) or a mosaic unit (e.g. DEH was mapped when the vegetation appeared to be a complex of Type D (which has 3 sub-types), and Types E and H). These maps were not provided in the ERMP where the vegetation was discussed in terms of "seven basic vegetation types" (ERMP p. 4-17, figure 4.17). This level of simplification is inadequate to properly assess the impact of this proposal on vegetation of the proposed conservation reserve at Lesueur.

The 38 basic vegetation types were defined by the consultants from an analysis of data collected from 226 quadrats spread over the project area (Martinick and Associates 1988). This analysis was of a high standard although apparently spurious conclusions were drawn from it. In particular Martinick and Associates (1988, p. 6) stated that "there may be still a few undefined vegetation types, but these are likely to be very limited in area and unimportant".

Griffin and Hopkins (1990) showed the homotoneity of many of Martinick and Associates' floristic groups was low (their Table 4.3) and inspection of Martinick and Associates' (1988) two-way table shows that nine of their 38 groups were defined by only one or two quadrats. On this basis, the assurance that all major vegetation types are adequately defined must be seriously questioned. It is likely that the complexity of the vegetation is considerably greater than that suggested by Martinick and Associates' analysis.

The consultants used the floristic classification to produce a key based on landform, structure and indicator species which is used to define mapping units. Inspection of their two-way table indicates that this key is subject to some degree of misclassification (for example types A2.1 and A2.2, types B3.1 and B3.2 and C1, C2, C3). Hence the maps produced for the eastern section of the proposed conservation reserve at Lesueur are both simplifications and approximations of reality.

Table 2.1 shows the extent to which the various vegetation units will be affected by the proposed development. This table was developed by overlaying the impact zone (see Chapter 1, this publication) with the detailed vegetation maps of Martinick and Associates (1988). It was found that the degree of discrimination in the vegetation mapping was variable. In some areas vegetation was broken down into its basic units (i.e. one of the 38 floristic groups) while in other areas it was lumped into larger vegetation types (e.g. Sand heath (type A) cf. *Stirlingia - Adenanthos* Heath on sandplain (type A2.1)). It is important to note that these major vegetation types only refer to those areas which were not differentiated into the finer vegetation units. As a result of this lack of discrimination it was not possible to determine precisely the impact of the proposal on the 38 previously defined basic vegetation types; nonetheless general trends are clear.

Our analysis (Table 2.1) shows 11 of the 19 basic vegetation types, five of the ten amalgamated vegetation types and seven of the eight mosaic units will be impacted severely with more than 25% of their known extent in the eastern uplands being affected.

One of the most severely affected on a proportional basis is the drainage line vegetation (types L and M, subtypes L2 and L3, mosaic unit LM) which will be reduced by up to 50%. This will particularly affect the *Melaleuca* heaths.

Three sand heath units will be severely affected (A2.1, A2.2 and A4.2). Of these Martinick and Associates (1989a) have reported only the *Stirlingia - Adenanthos* heath (A2.1) from other conservation reserves in the region.

Two lateritic heaths will also be severely impacted (B1.4.1 and B3.2), although Griffin and Hopkins (1990) have reported *Banksia micrantha* heath (B1.4.1) from the Lesueur Dissected Uplands landform unit outside the project area.

Other vegetation types to be severely affected by the proposal include the *Gastrolobium spinosum* scrub (type I) which will suffer a 64% reduction, the *Petrophile seminuda* heath (type H) which will suffer a 40% reduction and the *Calothamnus quadrifidus* heath (type J) which will suffer a 30% reduction. Griffin and Hopkins (1990) note the unusual nature of vegetation type J. These authors also point out that the *Ecdeiocolea monostachya* heath (type E) occurs on two different substrates in the northern and eastern vacant Crown land blocks proposed for inclusion in the conservation reserve at Lesueur. Details available from Martinick and Associates' mapping does not

Table 2.1

Areas of the vegetation types in the direct impact zone (including the 100 m buffer) of the proposed power station and coal mine.

Vegetation type[1]	Area directly impacted[2] (ha)	Total area of mapped vegetation in proposed reserve[3] (ha)	Percentage impacted
Individual units			
A2.1	83.6	193.0	43.3
A2.2	2.8	11.0	25.5
A4.1	41.3	189.0	21.9
A4.2	143.2	327.0	43.8
B1.1	0.6	3.0	20.0
B1.2	0.4	51.0	0.8
B1.4.1	9.5	21.0	45.2
B1.4.2	15.5	73.0	21.2
B3.1	3.4	35.0	9.7
B3.2	134.2	426.0	31.5
C1	11.2	16.0	70.0
C3	9.1	30.0	30.3
E	54.4	79.0	68.9
H	45.3	114.0	39.7
I	3.2	5.0	64.0
K	9.1	644.0	1.4
L2	23.2	45.0	51.6
L3	1.9	9.0	21.1
M1	2.3	27.0	8.5
Amalgamated units			
A	63.0	1859.0	3.4
A1	2.7	31.0	8.7
B	72.4	731.0	9.9
B1	1.9	1.0	190.0*
B1.4	23.7	24.0	98.8
C	19.9	390.0	5.1
D	163.5	871.0	18.8
J	12.8	43.0	29.8
L	6.3	22.0	28.6
M	8.3	7.0	118.6*
Mosaic units			
AL	8.1	25.0	32.4
CDF	31.6	115.0	27.5
DEH	29.3	36.0	81.4
FG	6.6	70.0	9.4
FGH	341.5	851.0	40.1
FGHJ	60.0	117.0	51.3
JHL	11.7	30.0	39.0
LM	15.0	31.0	48.4

1 See Table 4.6 of the ERMP
2 Data calculated by CALM from digital information
3 Data from Martinick & Associates (1989b), refers to eastern portion of proposed reserve.
*Percentages > 100% result from minor differences in digitized data as calculated by CALM and Martinick & Associates (1989b).

allow the impact on these two subtypes to be assessed. Overall 69% of this combined vegetation type will be impacted.

In addition, two of the three sandstone heaths (C1 and C3) will be significantly affected by this proposal (70% and 30% respectively). The consequences of this proposal on the *Banksia tricuspis* scrub heath (subtype C1) are of special concern given the high conservation significance of this species and its demonstrated interaction with the local bird fauna.

The impact of the proposal on the wandoo woodlands is also of concern. Although only a relatively small area is involved (9.1 ha), this particular area contains the best stands of *Eucalyptus wandoo* with *Trymalium* understorey on deeply incised valley slopes in the region. Wandoo woodlands are known to be important for tree hole nesting birds. Such nest holes are a limiting resource in this area and any reduction in availability could have serious consequences (Hopkins and Saunders 1987).

From the available data it is clear that nine vegetation units (A2.2, A4.2, B3.2, C1, C3, E, H, I, L2), which are not known from outside the project area, will be severely affected by the proposal (Table 2.1). In addition the impact of the proposal on the wandoo woodlands is of serious concern.

2.22 Regional vegetation

Despite the requirement by the EPA (cited above) that the proponents assess the conservation status of the impact area in a regional context, the regional study provided in the ERMP was very superficial. The proponents stated in the ERMP that "it was not practical ...to carry out detailed quantitative studies of any vegetation on the regional reserves because of the large areas involved" (ERMP p. 4-15).

This large area defined by the proponents as some 50 000 ha (ERMP p. 4-15) was very much smaller than that studied by Griffin *et al.* (1983) in their regional survey of the vegetation on the lateritic uplands, which included the Lesueur area. It is much smaller than any of the normal quadrat-based regional surveys undertaken by CALM (e.g. Nullarbor (McKenzie and Robinson 1987) and kwongan of the wheatbelt (Brown 1989)) and smaller than detailed surveys undertaken of some single reserves (Cape Arid, Fitzgerald River). Clearly the proponents have not allocated the resources necessary to properly address this task.

Instead of a detailed regional floristic survey the proponents' regional survey consisted of attempting to identify the 38 Lesueur floristic groups (these were the basic mapping units in the project area) in selected conservation reserves in the region. These floristic groups were identified using a key based on landform, structure and the presence of indicator species. As indicated above this method is potentially subject to some degree of misclassification. This survey did not cover any areas outside existing or proposed reserves. No information is given either in the ERMP or in the consultants' reports of how many sites in each reserve were visited.

Of these 38 mapping units only two are definitely found outside the Lesueur region (types A1 and A2.1). (Martinick and Associates (1989a) state incorrectly that there are three - see their Table 2.) Of the remaining 36 units, similar but not identical vegetation has been recorded for another 10 units. This leaves 28 units not being recorded outside the Lesueur area. None of these statistics appear in the ERMP nor can they be derived from information presented there.

In the ERMP the proponents claimed that "the heaths on sandy slopes and valleys, the most common vegetation type in the project area, was also widely distributed in the region although there was some localised sub-types. Similar results were obtained for heaths on lateritic uplands and heaths and woodlands on gravelly hills and slopes, although the former were extremely variable" (p. 4-16).

Data from Martinick and Associates (1989a, Table 2) clearly show this not to be the case (Table 2.2). The proponents' statement that the vegetation types defined in the Lesueur area are widespread in the region is clearly not correct. The statement is based on their attempt to simplify the complex vegetation of the Lesueur area by amalgamating many of the basic vegetation types that are present there into only seven "basic" types.

All data presently available (including the proponents') clearly indicate the uniqueness of many of the vegetation units found in the project area (Griffin *et al.* 1983, Froend 1988, Griffin and Keighery 1989, Griffin and Hopkins 1990). According to the consultants' data only 5% of vegetation types mapped at Lesueur are found in existing or proposed reserves elsewhere. The consultants reported that similar vegetation is reserved for a further 26% of vegetation types, although the data presented are incomplete. The overwhelming majority of vegetation types (68%) have not been recorded in existing reserves or proposed reserves outside the proposed conservation reserve at Lesueur. These data clearly demonstrate the great importance of the Lesueur area for the conservation of the vegetation types of the region.

The proponents have failed to provide a detailed assessment of the conservation status of the vegetation found in the project area as requested by the EPA.

Table 2.2

Occurrence of the same or similar major vegetation types outside the Lesueur area.

Vegetation category	No. of subtypes	No. of same type found outside Lesueur	No. of similar type found outside Lesueur
Sand heaths	6	2	2
Lateritic heaths	8	0	2
Gravel heaths	5	0	0
Woodlands	1	0	1

Table 2.3

Impact on landforms in the proposed Lesueur conservation reserve.

Landform	Total area in proposed reserve (ha)	Impact area (ha)	%
Gairdner Dissected Uplands	2325	124	4
Banovich Uplands	1615	585	36
Bitter Pool Rises	1699	766	45

Further they have not been able to demonstrate alternative areas which could be reserved to protect the plant communities found in the Lesueur area. They appear to have attempted to play down the significance of the Lesueur area's vegetation.

2.23 Impact on Landforms

Table 2.3 provides data on the area of the three landforms that will be affected by the proposed mine and power station. These figures were calculated from digital maps prepared by CALM's Land Information Branch using data in the ERMP and Martinick and Associates (1989b).

The major impact of this proposal will be on the Bitter Pool Rises (45.1%) and the Banovich Uplands (36.2%) with a minor degree of impact on the Gairdner Dissected Uplands (3.6%).

The currently protected upper portions of the catchments of Cockleshell Gully, Munbinia Creek and Coomallo Creek would all be affected by the mine and would cease to be of value in "bench mark" studies to provide information for catchment management in the region.

The very high impact of the proposed development on the Bitter Pool Rises landform and its associated vegetation types is of particular concern. This unit is comprised mainly of heavy clayey soils and has a very sluggish (mature) drainage system feeding into Coomallo Creek to the east. The particular combination of low relief, heavy soils and poor drainage is unique in the region.

2.3 EFFECTS OF EMISSIONS FROM THE POWER STATION ON THE NATIVE VEGETATION

2.31 Model reliability

Calculations of predicted concentrations of aerial emissions to be produced by the power station are based on the mathematical model AUSPLUME. The proponents state that this model has been widely used in Australia despite its known limitations under certain meteorological conditions. These limitations are not discussed nor is any illustration of model versus actual emission presented for any currently operating power station. It is thus impossible to determine the confidence limits that can be placed on the output of this model. The adequacy of this approach needs to be determined by persons with expertise in this area. Since the release of the ERMP, another consultant's report has become available (Steedman Science and Engineering 1990a) that discusses the sensitivity and accuracy of the model.

2.32 Sulphur dioxide

There are few detailed data in the literature on the effects of either acute or chronic exposure to sulphur dioxide (SO_2) on Australian native vegetation. Data on these effects on the 821 species occurring in the proposed conservation reserve at Lesueur are almost entirely lacking.

Given this lack of data it is difficult to determine the potential area of vegetation that may be affected by either chronic or acute exposures. The proponents estimate (ERMP Figure 8.4) that 21 000 ha are likely to get at least a one hour exposure of 350 g/m^3/year, 9 000 ha will get at least a one hour exposure of 500 g/m^3/year and 2 000 ha will get at least a one hour exposure of 700 g/m^3/year. These data give some indication of the potential area that may be affected by SO_2 exposure.

The section of the ERMP dealing with this topic is both superficial and incorrect in matters of interpretation. The major data source considered by the proponents in their assessment of the effects on the vegetation in the project area are two papers by O'Connor *et al.* (1974, 1976) which look at the response of 131 Australian tree and shrub species to acute SO_2 exposure. Only one of these species occurs in the project area, but it is probably of a different genotype.

The proponents state that these data suggest "the decreasing order of susceptibility to SO2 in the study area can be broadly categorised into :

(a) Eucalypts - probably most susceptible
(b) Broad - leaved species
(c) Narrow - leaved species
(d) Acacias - probably the least susceptible." (ERMP p. 8-10).

Analysis of the data in the O'Connor *et al.* (1974) shows no such pattern. These researchers ranked SO_2 from 0 to 6 with 0 being most resistant and 6 being most susceptible.

An analysis of variance of these data broken down by the four classes suggested by the proponents showed -

Class	Mean sensitivity score
Eucalypts	4.02^a
Broad leaved spp.	1.75^b
Narrow leaved spp.	2.57^b
Acacias	2.26^b

This analysis showed only the eucalypts as significantly more sensitive to SO_2 than the other three classes ($P < 0.01$) while the trend in the

Table 2.4

Relative sensitivity of Australian native genera to SO_2 exposure. Number of species in each of seven classes shown. Classes range from 0 (most resistant) to 6 (most sensitive). (After O'Connor *et al.* 1974)

SENSITIVITY	0	1	2	3	4	5	6
CASUARINACEAE							
Casuarina	4	2					
CONIFERAE							
Callitris		2		2			
LABIATAE							
Prostanthera			1		1		
MALVACEAE							
Lagunaria	1						
MIMOSACEAE							
Albizia			2				
Acacia	1	8	9	5	1	2	1
MYOPORACEAE							
Myoporum		1					
MYRTACEAE							
Agonis		1	1				
Angophora				1			
Callistemon				5	2		
Eucalyptus	2	3	2	7	8	13	8
Eugenia		1					
Leptospermum		2	1			1	
Melaleuca		3	2	5		5	
Syncarpia		1					
Tristania		2					
PROTEACEAE							
Banksia		1			2	2	
Grevillea				1			
Hakea		1	1			1	
RUTACEAE							
Correa				1			
STERCULIACEAE							
Brachychiton		1					

remaining classes is not as suggested by the proponents. (Categories in the analysis with the same superscript are not significantly different from each other; categories with different superscripts are significantly different at the 1% level.)

Tabulation of the data from O'Connor *et al.* (1974) (Table 2.4) clearly shows that SO_2 sensitivity is highly variable within families and genera, and other data indicate that this variability in response also occurs within species and varieties (O'Connor *et al.* 1974, Thompson *et al.* 1980, Murray and Wilson 1988a).

As outlined in the ERMP, Murray (1988) has reviewed the impact of very high levels of SO_2 exposure for short periods on the vegetation around the Kalgoorlie nickel smelters. These emissions have had a surprisingly limited impact on the vegetation of the area (most visible damage restricted to within 2 km of the stack, severe damage limited to the NW quadrant). Similar resistance to SO_2 damage has been reported for species from the deserts of North America (Hill and Barrett 1974, Thompson *et al.* 1980).

What is not stated in the ERMP is Murray's conclusion that "...SO_2 concentrations around the Kalgoorlie Nickel Smelter would destroy most crop plants and most plants native to less arid areas of Australia..." (Murray 1988, p. 3). It is clearly not valid to compare the semi-arid to arid zone plants of the Kalgoorlie area with the Mediterranean climate plants of the Lesueur area. Data on the response of plants from Kalgoorlie cannot therefore be used to predict possible impacts on the plant communities found at Lesueur.

The proponents also fail to discuss the effects of chronic SO_2 exposure (i.e. low concentration, long exposure time) on the vegetation. Studies by Horsman *et al.* (1979), Ayazloo and Bell (1981) and Garsed and Rutter (1982) have shown a lack of correlation between acute and chronic sensitivity for a variety of taxa. As yet little work has been undertaken on effects of chronic exposure on Australian native species (Murray 1984, Murray and Wilson 1988b).

It is widely recognized that biochemical and ultra-structural changes may occur at concentrations well below that at which visible damage is apparent (Murray 1984). The SO_2-sensitive species of a community may show visible damage or may simply show reduction in growth rate and/or reproductive success (Murray 1984, Preston 1988). Either way such stress could eventually result in the elimination of such species, permanently changing the composition and structure of these communities.

Guderian (1977) shows a worst case scenario in an oak - beech forest where all plants are killed in the immediate area of the emission source. At a greater distances from the source there occurred a zone of highly resistant plants, a grass and scrub zone, a zone of dying trees and finally a forest zone. These patterns resulted from high level acute exposures to the pollutants. Such retrogressive successions have been reported in several different communities in the United States (Gordon and Gorham 1963, Westman 1985, Preston 1988). Much more subtle changes could be expected with long term chronic exposures.

If a proportion of the flora of the Lesueur area is sensitive to chronic exposures, then over the life of this project (30 years) significant changes may occur in the composition and structure of some or all of the 38 vegetation types found in this area. The effect of these changes on the fauna are likely to be profound.

In early July, some six weeks after the release of the ERMP, two additional consultants' reports became available which further assessed the potential impacts of SO_2 emissions on the local vegetation (Steedman Science and Engineering 1990b, Murray *et al.* 1990). These documents report on detailed studies on the SO_2 sensitivity of five species common in the project area. These five taxa were selected on the basis of their high sensitivity to SO_2 from "34 species of importance in the native flora" (Murray et al. 1990 p. 2). The other 29 taxa screened were not identified nor was the screening method specified.

The five taxa studied were *Acacia saligna, Banksia attenuata, Banksia menziesii, Eucalyptus wandoo* and *Hakea incrassata*. Steedman Science and Engineering (1990b) concluded that as a conservative estimate the SO_2 from the proposed power station would result in "areas of minor damage for E. wandoo up to 5 km for areas around the power station." and "minor damage to the sensitive species B. menziesii within 10 km of the stack for all directions, except the northeast quadrant where minor damage is likely to extend out to 20 km" (Steedman Science and Engineering 1990b, p. 6).

In their more detailed report Murray *et al.* (1990) showed that the growth response varied with SO_2 concentration and plant species. In the most sensitive species (*Eucalyptus wandoo* and *Acacia saligna*) there was no effect or a stimulation of growth at low concentrations of SO_2 exposure but growth inhibition occurred as toxicity developed at higher concentrations. In contrast the other three species showed no response or some growth stimulation. Murray *et al.* (1990) review the several possible mechanisms which may explain the variable results obtained.

These findings have important implications for the vegetation of the Lesueur area. The more resistant species tested showed a differing growth response at the levels of SO_2 exposures that can expected to be produced by the power station. Further, significant growth inhibition is likely in the two more sensitive species. Given this variation in response of the five taxa studied, it appears that significant changes in the composition and structure of the plant communities within a five to ten kilometre radius of the power station could be expected over the life span of this development (30 years). These five taxa represent only slightly more than half of one percent of the species that occur in the Lesueur area. More detailed assessments of the direction and rates of change can not be made until many more species have been similarly screened. O'Connor *et al.* (1974) point out that young plants (which were tested in the experiments of Murray *et al.* (1990), tend to be less sensitive to SO_2 exposure than mature plants. This implies that the above findings are likely to be conservative.

Given that the high biological significance of the proposed conservation reserve at Lesueur stems in part from its highly complex and species-rich plant communities, the possibility of retrogressive succession resulting from atmospheric pollutants is of major concern.

As a minimum requirement, the acute and chronic sensitivities of a wide range of the plant species occurring at Lesueur would need to be determined before the full ecological implications of the proposed power station on the highly diverse and species-rich communities in this area could be assessed. The endemic component of the flora would need special screening. The question of synergistic effects of SO_2 with other pollutants also needs to be addressed (Murray and Wilson 1988a, 1988b), as does the possible impacts on the fauna (e.g. potential loss of nest sites for Carnaby's Black-Cockatoo through tree loss).

2.33 Nitrogen oxides

Again there is almost a complete lack of knowledge of the sensitivity of Australian plant taxa to nitrogen oxides (NO_X). The overseas literature suggests that, as for SO_2, effects vary greatly within and between families, genera and species (Hill and Barrett 1974, Thompson *et al.* 1980). Most often NO_X have been tested in conjunction with SO_2; in some cases the resulting damage has been much greater than that seen when one pollutant is tested in isolation (Tingey *et al.* 1971, White *et al.* 1974, and others).

In light of the lack of data the proponents' statement that "it is believed that there will be no detrimental effects of NO_X on the native vegetation " (ERMP p. 8-14) can not be substantiated.

2.34 Hydrogen fluoride

The ERMP states that hydrogen fluoride (HF) emissions will not occur from the power station ("Many studies have tried to examine synergistic effects between SO_2 and NO_X or with substances that will not occur in the Hill River Project (e.g. hydrogen fluoride" ERMP p. 8-11). Since the ERMP was released a consultant's report has become available (Steedman Science and Engineering 1990a) that states "Very small amounts of chlorides, fluorides, carbon monoxide, hydrocarbons and trace metals will also be released." (p. 3). No amounts are given.

CALM sought from Canning Resources access to an earlier consultant's report by Burmot Australia, which was referred to by Steedman Science and Engineering and which we believed might give more precise data on fluoride in the flue gases. Canning Resources advised us that this report contained confidential commercial information and arranged for Burmot Australia to provide advice on fluorine.

Burmot Australia advised as follows:

"Burmot Power Station Stack Discharge Report 8842/4/2, dated July 1989, includes table 4 on page 12 which gives indicative quantities of constituents in typical coal and fly ash. Fluorine in coal ranges from 70 to 120 ug/g and in fly ash from < to 250 ug/g. We have conservatively estimated the maximum amount of fluorine in flue gas as 0.016 g/m3 on the basis of the following:

- Fluorine in coal 250 ug/g
- Fluorine in fly ash 100 ug/g
- Both generating units operating at maximum continuous rating

This maximum concentration is a factor of approximately three less than the NH&MRC standard of 0.05 g/m3." (Burmot Australia in litt. to Canning Resources, 27 July 1990).

It is clear that, contrary to the statement in the ERMP, there will be fluoride emissions. No estimates of ground concentrations of fluoride in the vicinity of the power station are available and the significance of these emissions on the native vegetation at Lesueur has not been addressed in the ERMP.

Fluoride is emitted by power stations in Victoria, Queensland and the Hunter Valley of New South Wales (Horning and Mitchell 1982). Data from 134 species of native Australian plants show that they have highly variable responses to HF exposure, indicating that the response of individual species is impossible to predict (Horning and Mitchell 1982, their Tables 1 and 2). Examination of their data indicates that only 0.5% of species, and species from 7.5% of genera and 23.7% of families occurring at Lesueur have been screened.

As with SO_2, significant internal injury may occur before visible symptoms are apparent (Doley 1981) and, furthermore, fluoride damage can occur at very much lower levels of emission than is seen for SO_2 (Mitchell *et al.* 1981). HF is also reputed to have synergistic effects with some other pollutants, at least for some species (Murray and Wilson 1988b).

Retrogressive successions have also been reported around fluorine emission sources both in Australia and overseas (Murray 1981, Treshow and Anderson 1982). As discussed above, such possible changes are cause for serious concern in the Lesueur area.

The question of fluoride emission by the power station obviously needs clarification. Since emissions will occur much more detailed data on their effects on the vegetation of the project area are needed.

2.35 Ash

The section in the ERMP dealing with ash emissions is both contradictory and incomplete. Of primary concern is the possible toxicity of the ash. The proponents state that, based on their analysis, the ash is non-toxic and contains many elements beneficial to plant growth. Examination of the data provided in Appendix E indicates that four trace elements (beryllium, boron, selenium and antimony) in the coal (Appendix E, Table 1) have not been analysed in their leachate studies.

The absence of data on boron is of particular concern. This element has been shown to reach toxic levels in Australian and Western Australian coals and is recognized as the major toxicity problem in utilization of ash for agricultural purposes in Australia (Aitken *et al.* 1984). Further, in glasshouse trials in the United States, it has been shown to cause growth depression and leaf necrosis in some taxa (Glaubig and Bigham 1985). Other work from the United States suggests that boron accumulates to very high levels in some woody species (Scanlon and Duggan 1979).

The failure of the proponents to consider possible boron toxicity makes their assurance of the non-toxic nature of the ash difficult to accept. Their assurance is further qualified by their discussion of ash burial methods within the overburden dumps. In Appendix E it is suggested the most appropriate way of disposing of the ash is straight burial without the use of barriers. Yet within the main body of the ERMP it is stated that "the ash would be placed in layers, compacted by rolling and, when at a designated depth, covered with a layer of impermeable clay to restrict natural moisture ingress" (ERMP p. 7-4). The reason for advocating a different ash disposal method to the one suggested by the consultants is not clear.

A further concern with regard to ash is the direct effect the emitted ash has on the vegetation in the general area close to the power plant. It has been shown that ash emitted from the Gladstone power station in Queensland has the potential to significantly damage plant cuticles (QEGB 1984). In a study on damage to a mango crop 5 km from the power station scanning electron micrographs showed ash particles embedded into the leaf surface. Spectrographic analysis of these embedded particles confirmed them to be fly ash. The effects of this leaf scarring, its possible effects on pollutant uptake and individual species sensitivity all need further study. Some work from the United States suggests that cuticle damage can facilitate fluoride (Chamel and Garrec 1977). None of these potential impacts of ash emissions on the local vegetation have been discussed in the ERMP.

2.4 EFFECTS OF WATER DISPOSAL AND DRAWDOWN ON NATIVE VEGETATION

2.41 Acid water disposal

The disposal of water collected in the various mining pits from rainfall, groundwater inflow and seepage from overburden dumps is inadequately dealt with in the ERMP. The proponents expect to deal with up to 1.5 million litres of waste water per day per pit. The suggested disposal method is to pump to lined surface holding ponds where it will either be treated to adjust pH and then discharged to sedimentation ponds or left to evaporate. The sedimentation ponds will be unlined due to the sediments having been previously caught in sumps. These sedimentation ponds will discharge into the natural drainage lines.

Acid mine drainage is recognized as a major water pollution problem (Letterman and Mitsch 1978). It forms whenever water containing oxygen comes in contact with sulphur present as sulphides (particularly pyrites) in coal or surrounding country rock. In addition to low pH, acid mine waters may have a large number of other contaminants (Barton 1978). Acid mine drainage could clearly be a problem with the high levels of sulphur in the Lesueur coal and the presence of iron pyrites.

The proposal that the waste water at Lesueur will only be adjusted for pH then discharged via an unlined sedimentation pond into the natural drainage lines is clearly inadequate. The proponents should, as a minimum, have discussed the likely contaminates of this effluent and outlined strategies to remove toxic materials before it is discharged into unlined ponds and natural drainage systems. Untreated discharge of waste water containing heavy metals, for example, has been demonstrated to cause heavy metal build up in plants, soils and animals in Victoria (Evans *et al.* 1977).

2.42 Water drawdown

There will be two major sources of water drawdown if this project proceeds: that surrounding the mine pits and that resulting from the bore field operations.

The proponents give no indication in their ERMP of the possible area affected by water drawdown around the mine pits but do comment "Drawdowns as a result of dewatering and depressurisation are expected to be limited to a distance of 2-3 km down dip of each pit, and should not adversely impact on the xerophyte vegetation (heath or agriculture) ..." (ERMP p. 5-8).

This assumption that the vegetation will not be impacted by radical changes in the water table by virtue of the xeromorphic anatomy of the component plants is not born out by other workers. Dodd *et al.* (1982) have shown that species comprising kwongan vegetation possess a variety of root morphologies, suggesting a wide range of responses to changes in water table depth. That xeromorphic kwongan vegetation is susceptible to changes in water availability was demonstrated by Hnatiuk and Hopkins (1980) who reported water stress in 124 native species at Eneabba in the second consecutive year of below average rainfall. They found differential responses both spatially and between different families. In addition, Heddle (1980), working in *Banksia* woodlands on the Swan coastal plain north of Perth, suggested that any long term decrease in water availability may result in a slow shift in floristic composition.

It is clear from these data that the changes in the water table due to the mine pits could be expected to have a significant effect on the surrounding vegetation. No attempt has been made to quantify the extent of these disturbances in the ERMP.

From the ERMP it is not clear to what extent the proposed bore field would affect the vegetation in the proposed Coomallo National Park. The proponents have not determined to what extent the abstraction of water from the Yarragadee Formation will affect the water table of the upper unconfined aquifers or semiperched aquifers, but appear again to rely on the "xerophytic" (ERMP p. 8-20) nature of the vegetation to ensure no adverse impacts. Given the very large extent of the proposed borefield this lack of detailed knowledge of the effects of drawdown on the local hydrology is a source of considerable concern.

A more recent consultant's report (Australian Groundwater Consultants 1990), which became available after the ERMP was released, states in relation to the surficial water aquifer "The maximum drawdown from a 30-year simulation was less than 5 m." (p. 21, see also Figure 41). The effect of even a three metre drawdown on the local vegetation is likely to be significant, given the studies referred to above.

This report also makes it clear that, on the basis of available information and studies, it is still not possible to predict whether trees and associated vegetation in the Hill River valley depend on artesian seepage for their water requirements. Thus, this vegetation may also be detrimentally affected by the operation of the bore field.

2.43 Drainage changes

Significant changes in surface drainage can be expected to result from the proposed development. As a consequence major changes in composition and structure of some communities must be expected. For example the *Calothamnus quadrifidus* heath associated with the clayey soils of the Bitter Pool Rises landform appears to be particularly susceptible to even small changes in soil moisture conditions. A similar *C. quadrifidus* heath has been severely impacted by changed hydrological conditions near the mineral sand mining separation plant at Eneabba. The question of such impacts or their likely extent has not been defined in the ERMP.