PASTURE & TREE ESTABLISHMENT ON SAND MINING RESIDUES

AT CAPEL - AN APPRAISAL AFTER SIX YEARS

SUMMARY

Revegetation of the mining residue surface by pasture and crop legumes and grasses, and success of establishment and growth of tree species were studied in relation to variations of rainfall-evaporation balance over time, to different site types and to species.

A possible effect of climatic variation associated with the time of,and consequently affecting, vegetation establishment and growth was not demonstrated by the study, although both monthly rainfall in the growing period of pasture and mean annual rainfall over the period were below long term averages.

The four site types recognised produced significantly different growth rates of both surface cover plants and trees. For grasses, the finely textured substrates, particularly the freely drained sites, promoted better cover percentages than the coarsely textured substrates. The legume component was not significantly affected by different site types, and inclusion of weed species data eliminated significant differences. Tree growth was better on the coarsely textured, water gaining sites and the finely textured, freely draining sites than on the coarsely textured, freely draining sites or the finely textured, water gaining sites.

Overall proportions of recorded quadrats covered by different vegetation groups were legumes 26%, grasses 11%, veldt grass 9% and other weeds 8%, leaving 46% unvegetated.

One of the sixteen tree species gave significantly higher growth rates than the lowest nine of the remainder, and growth rates of a further seven appeared to be acceptably high.

Although both pasture and tree growth were effective in preventing erosion by wind, their potential for building up humus levels to an approximation of a natural soil was not impressive. Changes in practises are recommended.

G.S. McCUTCHEON
8/10/87.

RECOMMENDATIONS

1. Amendment of the near-surface texture of sand tailings deposits by addition of silt would produce benefits for the growth of at least the grassy component of surface vegetation of agricultural cultivars.

2. The technique of 'dry seeding' should be investigated as a means of obtaining the earliest possible germination and maximum development of the grass component when establishing or improving pasture. This recommendation is made in view of the early stage of development recorded (considerably pre-tillering) for Tama rye-grass in October.

3. Unless large-scale remixing of silt with the upper level of sand tailings deposit is carried out, or unless sand tailings are known to be no more than about a metre deep over a natural soil profile, attempts at commercial production of timber should be restricted to the margins of silt dams and closely adjacent sand deposits.

4. Though no formal study was made on the effects of grazing, indications are that the 'understorey' species recorded (casuarina, peppermint and wattles) were retarded by exposure to it, and eucalypts were retarded in certain cases. Such species would benefit by protection from grazing until the age of five years.

5. In the context of proposed land uses for the area indigenous species would mostly be preferable to the exotic, albeit faster growing species. In particular jarrah should be re-established on the land. Given a moist enough site and freedom from competition for light this species is known to be capable of entering the "dynamic growth" phase at an early age, unlike its habit under canopy. This was demonstrated by the specimens recorded on a fine textured and moist site as well as by one tree on a higher site with topsoil infill at planting.

   It is recommended that a trial be initiated using either or both of long-rooted seedlings in special containers and planting into bore holes filled with silt. Placement of the trial at a location overlying the known seepage from the lakes having an artificially high water level would both give the species the best chance of forming a stand, and in the longer term the probability of ameliorating the problem caused by the seepage.

I N D E X

PASTURE & TREE ESTABLISHMENT ON SAND MINING RESIDUES AT CAPEL - AN APPRAISAL AFTER SIX YEARS

INTRODUCTION

The observations reported were made on land vested in the Lands and Forests Commission which had carried a pine plantation before extraction of heavy mineral sands by Associated Minerals Consolidated Ltd.

Replacement of waste materials, segregated during processing into coarse (sand tailings) and fine (slimes, or silt) fractions, had been done in various ways and produced varying combinations in terms of sequence and depth of fill of the two fractions, although the basic procedure was to place the silt as a slurry into basins excavated in previously deposited sand tailings. The techniques of replacing tailings, surface preparation and sowing of graminous and leguminous plant cover species have been described by Taylor*.

The earliest established trees studied were planted by the company in 1979 on a shallow silt dam on which pasture establishment was never subsequently successfully pursued and on a few sand tailings sites. Some under-storey species were added to this silt dam in 1980.

On most of the area studied plant cover establishment commenced in 1980 with sowing of a cereal/legume crop. Following this a large group of trees consisting of different numbers of eight species, selected to match the sites with sand and with silt tailings, was planted by the then Forests Department, the company purchasing the seedlings. The layout of this trial, identified as M2/80, was informal and the tree spacing somewhat variable, subject only to maintenance of easy access for agricultural machinery. For example, the plots established during this study showed stocking rates ranging from 86 to 778 stems per hectare (mean of 391 s.p.h.)

In 1981 the area was sown with pasture species and the Forests Department planted a further thirteen groups of the suite of eight tree species previously used. This planting was identified as M2/81.

Tree planting was continued in 1982 in the vicinity of a partly natural drainage line where a fair proportion of natural soil and vegetation existed, along with silt and sand tailings areas. Three indigenous and three exotic eucalypt species were added to the suite previously used.

In 1982 and 1983 reseeding was carried out on an area south of the above-mentioned drainage line, using oats and field peas over subterranean clover, rye-grass and serradella.

* Taylor, E.G. (1978) in Proceedings: Rehabilitation of mined lands in Western Australia. Perth, 11th October, 1978 (W.A.I.T.: Bentley).

Tree planting was carried out in this vicinity in 1983, again on a mixture of sites, including some very wet ground adjacent to a natural swamp, and the species mix was modified accordingly. Part was on sand tailings which had at that time been only recently seeded with agricultural species. In later years small plantings of unrecorded species have occurred around margins of silt dams which have still been deemed undesirable as pasture sites. Tree espacement has been small, producing stocking rates between 660 and 1552 stems per hectare (mean of 1182 s.p.h.)

Grazing of the pasture including most of the tree planting carried out until then was commenced in 1982 and continued in each year since. However most of the trees planted in 1982 and all of those planted since have not been subjected to grazing except by kangaroos.

A formally spaced tree species trial included in the assessment was laid down in 1980 on sand tailings with sparse pasture dating from two or three years previously. The planting sites were improved by replacement of tailings with natural topsoil but survival was still poor and the following year different species were used to fill blank spaces. This constitutes the trial identified as M5/80. It has been subject to browsing by cattle during grazing which may have been accidental in 1981 but part of the company's grazing programme since 1982.

Lastly, a statistically designed tree species trial (M1/81) laid down in 1981 on a silt dam (with various site treatments and with cattle excluded) has been drawn on for information in the form of overall mean growth data for the species resulting from the latest measurement in November 1985.

METHOD

The survey was carried out in the third week of September and the second week in October, 1986.

Plots were recorded on a systematic grid with 200 metres between lines and 100 metres between plots on each line, but making sure that each lay entirely within one site type. Additional plots for trees were located by bearing and distance from points on the grid. These plots could not always be located on a single site type particularly those centred on the narrow sand banks between silt dams.

The `soil profiles' encountered in this study were later subjectively classified into four types which were identified by letter code names as described below:-

Coarse textured and freely draining (CF).
Coarse textured but water-gaining (CW).
Fine textured but freely draining (FF).
Fine textured and water-gaining (FW)

Classification as fine textured depended on presence of an upper silt horizon at least 30 centimetres thick. Classification as a water gaining site depended sometimes on assessment of the relative elevation of the site or of indigenous indicator plant species, and sometimes on discovery of a high water table within the profile. Classification of a fine textured site as freely draining depended on presence of a relatively thin horizon of silt overlying a deep, coarse-textured horizon with no indication of high water table.

Pasture and weed condition was estimated as per cent area cover for each species within a quadrat one metre square. Species not previously known were identified by use of the relevant keys.

Tree data were recorded within a polygonal plot defined by the "available growing space" of the closest trees to a tree selected as centre, being that tree closest to the systematically selected point. The boundaries of the plot were placed perpendicular to an imaginary line joining each outer tree of the plot to its neighbour in the centrifugal direction, and equidistant between the pair. Bearings and distances from the central tree to the angles of the polygon were used to compute plot area in the field, using a programmable calculator. This allowed checking on site.

An example of the field record sheet forms Appendix 1 of this report.

Thirty four sites were recorded for pasture not overshadowed by trees, four for pasture included within tree plots and sixteen sites for tree data alone.

RESULTS

Recordings of per cent cover of ground species are summarized in Appendix 2 and tree data recorded, or derivations from data, are summarized in Appendix 3. Explanations of the meanings of column headings of Appendix 3 are presented as Appendix 3a.
Throughout this report, where means and standard deviations were calculated for percentages, the latter were first subjected to arcsin transformation and the statistics were reverse transformed.

DISCUSSION

1. Ground cover.

The ground cover category, comprising pasture legume and graminoid species and volunteer weed species, varied greatly in per cent cover of the ground and in species composition. Numbers of plots falling within different cover per cent classes are summarized in Table 1.

TABLE 1

Numbers of quadrats in cover per cent classes.

Cover % class	Number of Quadrats	Cover % class	Number of Quadrats
0-9	4	50-59	4
10-19	3	60-69	1
20-29	5	70-79	1
30-39	3	80-89	3
40-49	1	90-100	11

One plot was recorded with no vegetation and seven with complete cover. Translated into relative terms this would indicate that three per cent of the quadrats sampled carried no vegetation and eighteen per cent carried complete vegetation cover on the ground; sixty one per cent of quadrats had below two thirds of surface vegetated and thirty four per cent had less than one third vegetated. Viewed in another way, the land had, on average, forty two per cent* of its surface unvegetated (see Table 2). The cover might have increased somewhat later in the season, but because over half of the sites were in the free-draining category which would lead to early drying off, the extent of such increase might be small.
The above figure of forty two per cent appears to represent a satisfactory level of protection from wind erosion. However from the point of view of build up of humus to a natural soil condition it is obvious that the process will be very slow with such a small proportion of the surface vegetated, and that not densely. Several influences on and aspects of the establishment of ground cover are discussed below.

1.1 Effect of seasonal differences.

The poor cover of annuals is likely to be partly an effect of low rainfall. Comparing cumulative rainfall at Ludlow after the beginning of April 1986, with seventeen-year means for that parameter (raw data supplied by Busselton district staff and Commonwealth Met. Bureau) a considerable deficit can be observed.

* Differs from data quoted in Summary, calculated without arcsin conversion.

The progressive values of that deficit at the ends of the months April through September were -58, -63, -20, -91, -70 and -86 millimetres respectively. Germination would have been inhibited and growth retarded, and these effects were particularly exhibited by serradella and by Tama rye grass respectively. The low moisture retention capability of the sand tailings should be expected to exacerbate the effects of low rainfall years. A break-down by species forms Appendix 2.

1.2 Effect of site differences.

Differences in mean total ground cover between site types were small and with wide variation, as displayed in Table 2. These differences proved to be not statistically significant.

Table 2.

Total ground cover differences by sites.

		Ground Cover, percent		
Site Category	n	Mean	Conf. int.	Range
All sites	38	58.4	16.6 - 95.2	0 - 100
CF sites	18	56.6	19.1 - 93.4	14 - 100
CW sites	10	56.3	13.2 - 94.6	0 - 100
FF sites	4	65.6	20.7 - 97.8	16 - 100
FW sites	6	62.0	6.8 - 99.9	4 - 100
With trees	4	79.7	42.0 - 99.5	36 - 100
Without trees	34	57.3	14.3 - 94.3	0 - 100

When weed species cover values were eliminated however, differences significant at the 99.95 per cent probability level were demonstrated between the mean values for fine textured, freely draining (FF) sites and the coarse textured (CF and CW) sites. The mean for fine textured, water gaining sites, though higher than for the coarse textured sites, was not significantly different.
Further dissection of data into legume and cereal categories showed no significant differences related to site type for the former but an increased number of significant differences for the latter, also significance at the 99.99 per cent level of probability. These differences are summarized in Table 3.

Table 3

Ground cover by species categories and by sites.

SITE TYPE	n	MEAN COVER PERCENT Cereals & Legumes	Cereals	Legumes
FF	4	43[a]	19[a]	24[a]
FW	6	38[a]	10[b]	28[a]
CF	18	30[b]	4[c]	26[a]
CW	10	29[b]	5[c]	24[a]

Different super scripts indicate significant differences at not less than 99.95 per cent probability.

The interpretation of the data of Table 3 is that the graminoid ('cereal') species sown were more productive on the finer textured substrate than on the coarse, and that there is no evidence in the data collected that the legume species were favoured by one substrate category over the other. How ever, it is indicated in Appendix 3 that clovers appeared to be more abundant on the finer textured substrate. Serradella, the most commonly occurring legume, was as expected more abundant on coarsely textured sites.

1.3 Effect of trees.

There appeared to be a difference in mean total ground cover between groups of quadrats which were recorded within tree plots and those free of any influence of trees (see Table 2). However the difference did not prove statistically significant, possibly because the comparison was not intended initially therefore the number of quadrats recorded within tree plots was very low.

1.4 Effectiveness of species.

A subjective assessment of individual species performances is given as Appendix 3.

A summary of the mean cover achieved by the main species and by groups of species of lesser importance is provided by Table 4.

Table 4 illustrates that the most dominant species was serradella. However it is suitable for sandy sites only, while subterranean clover cultivars are available for various soil textures. New Zealand blue lupin, recorded on one end of the study area, did not establish well or provide much cover. Ryegrass established very well and provided fairly good cover in spite of the immature stage of development.

It can be noted that the oats and field peas originally sown have not persisted; oats were recorded on only two of the plots and are included with 'other grasses' in Table 4.

Table 4.

Relative dominance of ground vegetation species.

Species	Presence on sites (%)	Mean Cover* & Range (%)	Dominance Index+
Clover	34	27.3;1-70	93
Serradella	71	13.8;1-78	98
Lupin, N.Z. Blue	16	5.7;1-20	9
Other legumes	8	4.3;1-10	3
Ryegrass	74	10.4;1-68	77
Other grasses	21	3.4;1-5	7
Veldt grass	45	18.7;1-100	84
Flatweed	45	3.9;1-19	17
Capeweed	34	4.9;1-30	17
Other weeds	58	7.8;1-62	45

* On those sites where present; total number of sites = 38
\+ Dominance Index = Presence % x Mean Cover % ÷ 10.

Perennial veldt grass was notable both for presence and abundance, and the more so because of the largely volunteer nature of its occurrence. However the species is regarded as ecologically undesirable in the context of proposed land use for most of the mined area, and claims that it could be eliminated by grazing have not been borne out in practice.

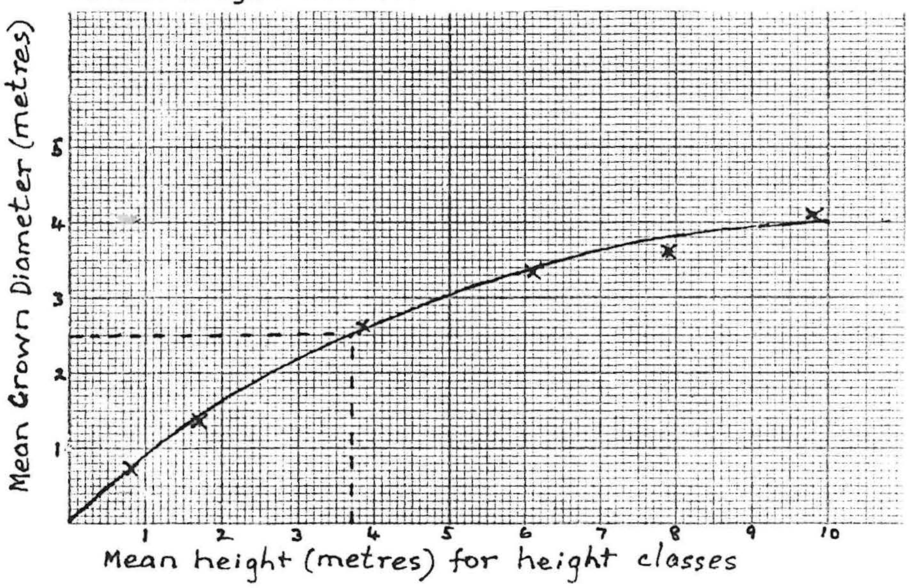
The proportion of edible legumes in relation to total forage has been estimated. This excludes W.A. Blue Lupin, Capeweed and the other weeds. The mean value of 42% (s.d = 18%) obtained is some what less than the minimum of 50% considered desirable (J. Kruger, pers. comm.) from the points of view of production of maximum bulk of forage and of maximum nutrient value. Nineteen of the thirty seven vegetated quadrats recorded had legume content higher than the minimum desirable, mostly by a considerable amount, while thirteen had less than twenty-five per cent.

2. Tree Establishment

A concise summary of the performance of the species used on the area studied forms Appendix 3 as already stated. Some of that and other data from field sheets has been expressed in different form as Appendix 4, to facilitate comparison of the species.

In the discussion which follows, success of trees planted in different years and on different site types, and comparisons between tree species, have been judged on the basis of height growth expressed as Mean Annual Increment (M.A.I.). Stem diameter growth would be of doubtful value because of the bushy or at least multi-stemmed habit of many trees. Crown diameter was also judged a less useful criterion. Mean crown diameters within height classes were approximately proportional to height only up to about the value of 2.5 metres for the latter, as shown in Figure 1.*.

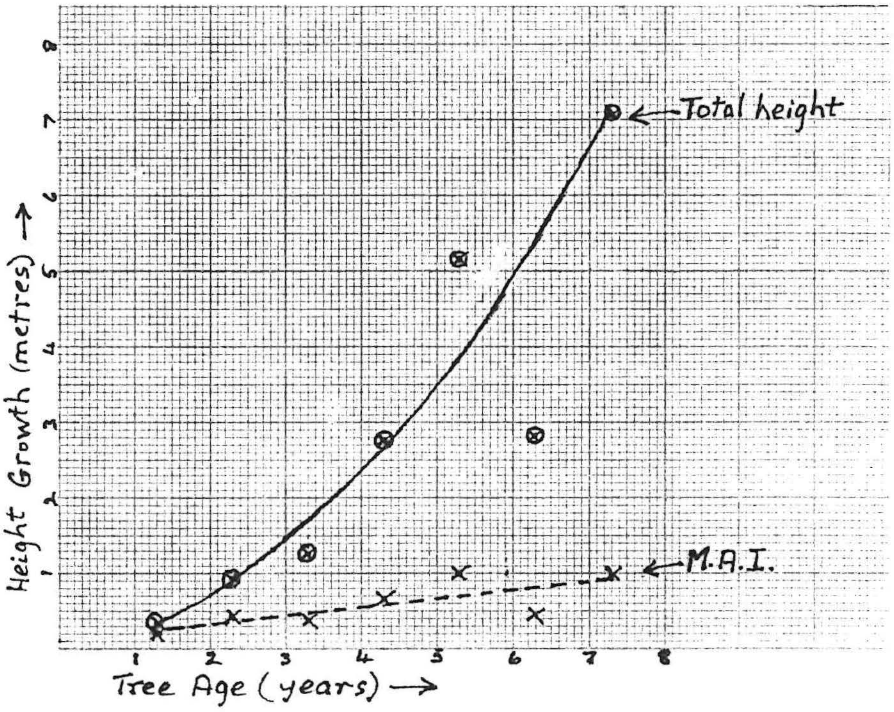
Figure 1. Regression of mean crown diameters on mean heights, within height classes.



* From the point of view of reduction of wind erosion the tree groups would have been judged already effective, though over a limited area, by the time they had attained a height of about 3.7 metres; then the mean crown diameter was 2.5 metres. This was about half of the nominal planting spacing, that is, the trees occluded half of the vertical plane presented to airflow, a condition considered necessary for significant reduction of wind velocity.

Although M.A.I. changes with age as shown in Figure 2, it was the most appropriate simple measure for the purpose of comparing growth rates of trees of different ages, and proved effective in most of the analyses of data.

Figure 2. Regression of total height growth and M.A.I. on age.



The information which could be extracted on how seasons, sites and species influenced tree growth is discussed in following sections.

2.1 Effect of seasonal differences.

Average annual rainfall (October through September) for the period 1979 to 1986 had a mean of 768mm, while the average for the period 1967 to 1979 was 855mm. The difference is very highly significant, the probability of its occurring by chance being less than one in a thousand (t for 18 d.f., .001 probability level = 10.3, compared with 3.9, tabulated). It is possible that better tree growth might have been recorded had the study been done on trees established in a sequence of years more normal with regard to rainfall. Similarly, survival of seedlings planted might have been better in higher rainfall years.

Within the years of planting of the trees studied, no statistically significant difference in total rainfall was detected. When the rainfall for the summer period of October to April, which would be likely to be critical for trees growing on a freely draining substrate, was considered, again a statistically significant difference between years was not detected. Refinement of data achieved by considering the nett balance of precipitation and potential evapo-transpiration (derived from average monthly pan evaporation at Capel x 0.6) once more provided no evidence of a significant difference between years. It is possible that seasonal variation did exist at a level not detected by the measure described above, but development of further refinements was not pursued.

Analysis of variance of the tree growth data by planting years did indicate a very highly significant difference among years (F for 5/127 d.f. and .001 significance level = 13.39 for the ten eucalypt species). Differences may be related to the possibility described above and to other factors which are discussed with reference to interactions in the following section of this report.
The effect of seasons on survival of seedlings could not be studied because data on numbers planted at each site recorded was not available.

2.2 Effect of site differences.

2.2.1 Effect of site differences on survival.

It is likely that site type would have had an effect on survival. For example, in 1980 and 1981 deaths occurred among tuart trees planted on a silt dam in 1979. Investigation led to the conclusion that isolation of root systems within the polygons resulting from cracking during de-watering of the `slimes' was the likely cause.

The poor survival demonstrated by trial No. M5/80 on sand tailings has already been referred to in the introduction. Further plantings on the same site type nearby also failed completely in 1982 and 1983, although it is possible that seedlings were pulled out by cattle in those years.

The data of the study indicate that significantly different (chi-square test) numbers of trees were recorded on different site types, as shown in Table 5. When mean numbers of trees per plot for each site type were compared there were no significant differences, as would be expected when the method of defining plots is recalled. The differences in numbers of trees on each of the site types therefore must have been due to the fact that different numbers of plots were obtained on different site types, although not significantly so. The numbers of finely textured sites were higher than would be expected from the areal proportions of silt and sand tailings determinable for the study area, but again not significantly so.

Table 5 Numbers of trees related to numbers and proportional areas of different site types.

	Site Types				Chi-Square
Parameter	FF	FW	CF	CW	
Total trees	52	28	31	41	9.32*
Trees per plot	7.4	7.0	7.8	8.2	0.1
Number of Plots	7	4	4	5	1.2
Proportional area.	38ha		44ha		0.59

* Significant at 99.95 per cent probability; other chi-square values not significant.

The above data do not allow any statistically supported conclusion to be drawn about the possibility of higher survival rates on certain site types. Further, any attempt to study differences for individual tree species would not be valid because of the deliberate attempt to match species to site in the original planting scheme.

2.2.2 Effect of site differences on growth rate.

Different growth rates of trees were observed on different site types. Higher average M.A.I. values were obtained on the coarse textured, water gaining (CW) sites and the fine textured, freely draining (FF) sites than on the coarse textured, freely draining (CF) sites and the fine textured, water gaining (FW) sites. However wide differences in variance values prevented testing of the significance of these differences when all species were considered.

This led to restriction of the study to pooled data from the ten eucalypt species which gave indication of a very highly significant difference among the site categories (F for 3/129 d.f., 0.001 significance level = 10.33). Duncan's multiple range test indicated significant differences as listed in the final column of Table 6.

Table 6.

Effect of site and year of planting on tree height M.A.I.(m).

		Planting Year						
Site	n	1979 2	1980 3	1981 7	1983 2	1984 5	1985 1	Mean *
FW	4	-	-	0.63	0.32	0.35	0.24	0.41^{a}
CF	4	-	0.15	0.82	-	0.50	-	0.41^{a}
FF	7	1.08	0.85	1.01	-	0.37	-	0.81^{b}
CW	5	0.76	-	1.23	0.76	0.37	-	0.84^{b}
Mean *		0.97^{c}	0.44^{d}	0.98^{c}	0.46^{d}	0.41^{d}	0.24	0.65

* Different superscripts indicate means which are significantly different at 99.99 percent probability (the limit of sensitivity of the computer package).

n = number of plots.

A very highly significant interaction between site type and year of planting was shown to exist. From Table 6 it can be seen that the higher growth rates on CW and FF sites were exhibited by trees older than three years but not by those younger.
The higher growth rates for older trees may relate to the usual trend for M.A.I. of young trees to be increasing with age, once the plants have successfully established themselves. Irregularities in this trend were most likely related to observed segregation of data by species in different planting years (and see the differences between species demonstrated in the following section), but any interaction between species, planting year and site was not tested.

2.3 Effect of Species.

2.3.1 Effect of species on survival.
Although survival data would very likely be variable by species, no statistical test of survival differences between species could be conducted because of the absence of early data for the sites selected as plots in the study, also the segregation of species by site types when planting. However, comparison of the "Recorded proportions" in Appendix 4 can provide a rough guide.

2.3.2 Effect of species on growth rate.
The treatment of data for analysis of differences between individual species was restricted to the simple technique of comparisons between pairs by means of Hotelling's 't' test because the problem of missing values would have become extreme in an analysis of variance including species as a value label in addition to site and year of planting. The results are presented in Table 7.

Table 7.

Tree species growth rates and significant differences.

SPECIES	n	HEIGHT M.A.I. (m)
Eucalyptus camaldulensis	20	1.26[a]
E. gomphocephala	26	0.93[a,b.]
E. Leucoxylon	9	0.75[b]
E. cladocalyx	1	0.74
Acacia saligna	1	0.72
Eucalyptus globulus	5	0.70[a,b,c.]
E. calophylla	9	0.65[b,d.]
Acacia decurrens	5	0.63[a,b,c.]
Agonis flexuosa	10	0.41[c]
Casuarina obesa	1	0.39
Eucalyptus robusta	7	0.37[b,c]
E. resinifera	28	0.35[c]
E. rudis	11	0.32[c]
Melaleuca quinquenervia	2	0.27[b,c,d,e]
E. marginata	15	0.25[c,d,e]
E. patens	16	0.24

* Different superscript letters indicate means which are significantly different at the 99.95 per cent probability level.

The pre-eminent species of those recorded was shown to be Eucalyptus camaldulensis. The species exhibited faster growth than E. leucoxylon and by inference, faster growth than all other species. However all of the top eight species exhibited acceptable growth rates.

The slower growing species can be subjectively assessed by consideration of Appendix 4, particularly by contrasting the site producing best growth with that on which most of the recorded trees occurred, and by noting the frequency of browsing on the species. Thus Agonis flexuosa recorded were probably retarded basically by poor drainage and Eucalyptus resinifera by a shortage of water, while Casuarina obesa and E. marginata suffered from very frequent browsing.

An unfortunate consequence of slow growth by trees which are palatable to grazing stock would be that the time to attain a size relatively immune to damage by browsing would be repeatedly extended and their ultimate survival possibly imperilled. A vigorous species can quickly recover from browsing as is shown by the growth of E. gomphocephala and Acacia saligna in spite of browsing frequencies of 50 and 100 per cent respectively. Nevertheless the average browsed frequency for the eight faster growing species was only 31 per cent, contrasted with 43 per cent for the eight slower growing species recorded in this study.

While browsing of trees by cattle may be seen as still contributing to some accumulation of humus in the soil, the majority of the energy and protein is eventually lost from the system. On the other hand, browsing and stem attack by insects, noted for some species in Appendix 4, should not necessarily be regarded as a detriment. If maximum growth rate of saleable timber were the objective such attack would be counter productive. However if the objective is rapid re-establishment of a self supporting ecosystem then colonization by any insects is to be seen as beneficial.

APPENDIX 1.
Field record sheet

SITE REHABILITATION ASSESSMENT

LOCALITY: ______________________

PLOT NO. ________

VEGETATION TYPE: Tree ☐ Shrub ☐ Pasture ☐

PLOT DIMENSION: ____________

MOISTURE STATUS: Free-draining ☐ Water-gaining ☐

P-YEAR: ________

NATURAL SOIL PROFILE: ______________________

SUBSTRATE:		Depth (cm)
Coarse	☐	______
Fine	☐	______
Coarse	☐	______
Nat.	☐	______

SPECIES	VITALITY STATUS	HEIGHT	NO. OF STEMS	STEM DIA.(mm)	CROWN DIA.(m)	COVER %	FLORAL STAGE	CROWN HEALTH	BOLE/BRANCH DAMAGE			FOLIAR DAMAGE		COMMENT
									WIND	ANIMAL	INSECT	ANIMAL	INSECT	
	Described as 'Dominance' classification in the report					Not calculated in the field								

APPENDIX 2

Mean percentage cover, with confidence limits, of ground species; numbers of sites in parentheses.

PLANT	COARSE TEXTURED (SAND) SITES		FINE TEXTURED (SILT) SITES		ALL SITES
	Freely draining	Water gaining	Freely draining	Water gaining	
Clover	70 (1)	26.1;14.5-39.8(4)	14.4;2.5-33.7(4)	42.8;27.6-58.6(3)	29.1;10.3-52.7(12)
Serradella sp.	17.3;0.7-49.1(16)	17.4;4.8-35.5(7)	3.0 (1)	6.0;0.2-18.9 (5)	14.4;0.9-39.8 (29)
Lupin,N.Z. blue	6.3;1.0-15.6(4)	4.5;3.8-5.2(2)	- - - - - - - - -	- - - - - - - - -	5.6;1.4-12.4(6)
Lupin,W.A. blue	63.0; (1)	2.0; (1)	- - - - - - - - -	24.0; (1)	25.0;1.8-62.5(3)
Lotus minor	- - - - - - - - -	- - - - - - - - - -	4.0 (1)	10.0 (1)	6.7;3.1-11.5 (2)
? *Medicago* sp	1.0; (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	1.0; (1)
Ryegrass	6.2;2.6-11.2(13)	13.8;2.5-32.0(6)	18.8;0.3-55.5(4)	12.8;3.9-25.7(5)	10.4;1.6-25.3(28)
? Brome grass	5.0; (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	5.0; (1)
Ripgut brome gr.	2.6; (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	2.6; (1)
Paspalum sp	5.0; (2)	- - - - - - - - - -	- - - - - - - - -	1.0; (1)	3.3;1.2-6.4 (3)
'Wild' oat	3.0; (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	3.0; (1)
Perennial					
Veldt grass	14.2;5.8-25.5(10)	28.5;0.1-83.3(5)	19.8;13.2-27.3(2)	- - - - - - - - -	18.7;1.5-48.5 (17)
Love grass	5.9;0.3-18.0(3)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	5.9;0.3-18.0(3)
Couch grass	- - - - - - - - -	- - - - - - - - - -	- - - - - - - - -	3.0 (1)	3.0 (1)
Barley grass	- - - - - - - - -	- - - - - - - - - -	- - - - - - - - -	1.0 (1)	1.0 (1)
Native grass	- - - - - - - - -	- - - - - - - - - -	- - - - - - - - -	1.0 (1)	1.0 (1)
Briza major	5.0 (1)	- - - - - - - - - -	3.0 (1)	- - - - - - - - -	3.9;2.6-5.5(2)
Capeweed	3.1;0.7-7.3(5)	7.9;5.3-10.9(2)	3.5(1.1-7.2)(4)	11.1;0-39.4(2)	4.9;0.7-12.413)
Flatweed	4.1;1.0-9.1 (9)	4.9;1.3-10.8(5)	- - - - - - - - -	2.0;0.5-4.5(3)	3.0;1.0-8.6 (17)
Erodium sp	15.6;1.3-41.2(2)	- - - - - - - - - -	1.0 (1)	3.0 (1)	7.2;0.2-23.3(4)
? *Toplis* sp	1.5;0.7-2.8(3)	12.0 (1)	3.0 (1)	1.0 (1)	2.8;0.5-6.9(6)
Sheep sorrel	3.5;0.6-8.4(4)	1.0 (1)	- - - - - - - - -		2.8;0.5-7.1(5)
Guildford grass	2.0 (1)	- - - - - - - - - -	1.0 (1)	- - - - - - - - -	1.5;0.8-2.2(2)
Pelargonium sp	5.0 (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	5.0 (1)
Stinkweed	6.0 (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	6.0 (1)
Charlock	4.0;0.3-11.6(2)	2.0 (1)	- - - - - - - - -	- - - - - - - - -	3.3;0.5-8.2(3)
Mallow	2.0 (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	2.0 (1)

Appendix 3.

Comparison of pasture species performances in terms of frequency of occurrence and of cover percentage.

Roman numerals indicate relative status, in deciles of the observed ranges of occurrence and of abundance.

Clover	Presence - V Mostly on water-gaining sites.
	Abundance - X Best on fine-textured sites, especially if fertiliser application heavier than normal.
Serradella	Presence - X
	Abundance - VII Best on coarse textured sites but can grow on fine-textured sites.
Lupin, N.Z. Blue	Presence - III Probably the species has not been used until recently. Only on coarse textured sites, mainly freely draining.
	Abundance - II
Other legumes	Presence - I
	Abundance - II Exception is W.A Blue lupin which rates X; its best development is on a coarse textured, freely draining site.
Ryegrass	Presence - X The most commonly occurring cover component, with no apparent site preference in relation to establishment.
	Abundance - IV Usually better cover where clover also prominent, an effect possibly of seeding rate or fertilizer rate.
	N.B. Both Perennial Ryegrass and Lolium multiflorum, cv. Tama were combined. The latter was most frequent but at a very early stage of development which would affect estimates of cover.
Other pasture grasses.	Presence - I Very infrequent. Rarely on fine textured sites.
	Abundance - II Significant cover only by Lovegrass on one quadrat.

Perennial Veldt grass	Presence - VI Most consistently on northern quadrats which were on or adjacent to the area deliberately sown with the species.
	Abundance - VII Can achieve similar cover on either coarse or fine textured sites.
Flatweed	Presence - IX More commonly on coarse textured sites,
	Abundance - II Also more abundant cover on those sites.
Capeweed	Presence - V Site type does not appear important to establishment.
	Abundance - II Cover value possibly better on fine textured sites which are water gaining.
Other weeds	Presence - I Most consistently occur on coarse textured, freely draining sites.
	Abundance - I, II Cover percentages rarely more than 3%.

An occurrence of the Declared Weed Plant, Paterson's Curse was notified to the company and dealt with by an A.P.B. operator who also apparently found other populations.

APPENDIX 4 RELATIVE SUCCESS OF TREE SPECIES

SPECIES	Dominance	Cover %	Height M.A.I. (m)	Basal Area M.A.I. (m2)	No. of stems	Crown Health	Damage: Bole/Branch: Wind	Damage: Bole/Branch: Animal	Damage: Bole/Branch: Insect	Damage: Foliar: Animal	Damage: Foliar: Insect	Floral stage	Sites: No.	Sites: Type	Comments
Acacia decurrens	2	21	0.63	<.001	1	Good	occ. sl. lean	some browsing					3	FF	
A. saligna *	3	35	0.72	"	bush	Good		early browsing			few chewed	Full	1	FF	
Agonis flexuosa	2	19	0.41	-	bush	Good		extensive early browsing	scale + mould			occ. buds	5	FF	
Casuarina obesa *	3	39	0.39	-	2	Good	-	Slight early browsing					1	CF	
Eucalyptus calophylla	2	31	0.65	.001	2+	Good					Galls, few chewed.		4	CW	
E. camaldulensis	4	55	1.26	.004	1	Good	occ. severe	occ. slight early	rare sawfly		Chewed, Jassid, miner.	Buds	7	CW	Form can be poor
E. ? cladocalyx	5	78	0.74	-	1	V.poor			many incisions		Chewed Jassids Blister		1	CW	Severley defoliat
E. globulus	3	38	0.70	-	1	Good	Lean				Aphid, Blister, sl. chewed		1	CF	
E. gomphocephala	3	28	0.93	.011	2	Mainly good		50% early browsing			some heavily chewed, Blister, Galls		8	CW	Often reddish lea.
E. leucoxylon	4	51	0.75	.002	2	Good	Rare lean	Moderate to severe early browsing			Chewed, Jassid, occ. blister	Buds to capsules	4	FW	Some poor form
E. marginata	2	N/A	0.25	.001	Bush	Fair/good		Repeated Browing			Chewed, grazed, Tip damage.		2	CW	
E. ? patens *	N/A	N/A	0.20	-	Bush	Poor					Grazed		1	FW	
E. ? resinifera	N/A	22	0.35	-	bush	Poor to good	Lean common	occasional browsing	occ. incisions		Blister, Chewed.		4	FF	
E. robusta	N/A	61	0.37	-	Bush	Fair	occ. sweep	"			"		1	CF	
E. ? rudis	2	2	0.32	-	Bush	Poor		Possible early			Blister, Gall, Lerp, chewed.		2	FW	
Melaleuca quinquenervia	2	10	0.27	.001	3	Fair							1	CW	

* = Single tree recorded

APPENDIX 4A

Explanation of tree statistics derived in report.

1. "Recorded proportion"
   The number of individuals of a species recorded in the study, as a proportion of the total number of trees recorded, was compared to the known proportions of the species in the suite originally planted. It is a very approximate measure of survival ability, based on the assumption that each species had an equal chance of being sampled.

2. "Relative Growth"
   This was calculated by relating mean annual increment for any species to a scale of tenths of the maximum increment recorded during the study.

3. "Relative Cover"
   This is the average value of the proportion of canopy cover which individual trees of a species contributed to the respective plots in which they occurred, expressed as a percentage. It is an alternative to the cover percent first calculated for Appendix 3.

4. "Dominance"
   Trees were subjectively categorized in a series comprising retarded, suppressed, sub-dominant, co-dominant and dominant categories. For the purpose of Appendix 3 these were ranked from 1 to 5 respectively and rank means for each species taken for plots and thence for the species over all plots.

5. "Cover percent"
   This was derived by expressing mean crown area for a species on a plot as a percentage of the sum of such means for all species on the plot, and averaging over all plots containing the species.

APPENDIX 5

COMPARISON OF TREE SPECIES PERFORMANCES - SURVIVAL, GROWTH AND FORM

A concise summary of the performance of the species used on the area studied forms Appendix 3 as already stated. Some of that and other data from field sheets has been expressed in different form below, to facilitate comparison of the species. This has been supplemented by information from the other trials described in the introduction to this report. Comparative growth rates are again expressed as deciles of the maxima recorded on this study. Necessary explanations of some of the terms used in the descriptions following are provided in Appendix 3A.

Where supplementary information on growth and survival derived from other trials is given, three points should be kept in mind when relating that to the data from the recent study. Firstly, survival should be expected to be higher on trial M1/81 because grazing by cattle was prevented and grazing by kangaroos inhibited. Apparent mean annual height growth rates could also be higher for the same reason. Secondly, the year of onset of grazing would differentially affect relative growth rates on plots not so protected; the company planting was not subjected to grazing by cattle until three years old. Finally, the trees in M1/81 received only one application of fertilizer after planting, whereas the other trees have been given fertilizer at least annually through pasture top-dressing.

A possible deleterious effect of ground cover species on trees has not been checked for because of the generally sparse nature of the ground cover.

Acacia acuminata	M5/80
Recorded proportion: -	58%
Relative growth, height: -	II

Acacia decurrens		M1/81	A.M.C.
Recorded proportion:	50%	80%	?
Browsed frequency:	50%		
Most common site:	Fine textured, freely draining.		
Best growth site:	As above.		
Relative growth, height:	IV	VIII	X
Relative growth, basal area:	I	I	-
Dominance classification:	Suppressed.		
Relative cover:	6%		
Multiple stems:	No.	-	Yes

Acacia saligna		M1/81	A.M.C.
Recorded proportion:	+ 15%	71%	?
Browsed frequency:	100%		
Most common site:	Fine textured, freely draining *		
Best growth site:	As above		
Relative growth, height:	VI	IV	X
Relative growth, basal area:	I	-	-
Dominance classification:	Sub-dominant		
Relative cover:	20%		
Multiple stems:	Bushy	Bushy	Yes

Agonis flexuosa		M1/81	A.M.C.
Recorded proportion:	117%	90%	-
Browsed frequency:	40%		
Most common site:	Coarse textured, water gaining.		
Best growth site:	Fine textured, freely draining.		
Relative growth, height:	III	IV	-
Relative growth, basal area:	I	-	-
Dominance classification:	Suppressed		
Relative cover:	6%		
Multiple stems:	Bushy	Bushy	Bushy

Casuarina obesa		M1/81	A.M.C.
Recorded proportion:	<1%	95%	-
Browsed frequency:	100%		
Most common site:	Coarse textured, freely draining *		
Best growth site:	As above.		
Relative growth, height:	IV	VIII	VII
Relative growth, basal area:	I	I	-
Dominance classification:	Sub-dominant		
Relative cover:	8%		
Multiple stems:	2	-	-

Callitris preissii	M5/80
Recorded proportion: -	Nil (was 8% after 3 years)

Eucalyptus calophylla	M1/81	M5/80
Recorded proportion: 154% (planting bias likely)		
Browsed frequency: 25%		
Most common site: Coarse textured, water gaining		
Best growth site: As above		
Relative growth, height: VI	IV	I
Relative growth, basal area: I	-	-
Dominance classification: Suppressed		
Relative cover: 13%		
Multiple stems: 2+	Bushes	-

Eucaluptus camaldulensis	M1/81
Recorded proportion: 28%	75%
Browsed frequency: + 25%	
Most common site: Fine textured, water-gaining	
Best growth site: As above.	
Relative growth, height: Best growth	IX
Relative growth, basal area: IV	I
Dominance classification: Dominant	
Relative cover: 20%	
Multiple stems: 2	-

Eucalyptus ? cladocalyx

Recorded proportion: N/A
Browsed frequency: NIL; severe insect damage.
Most common site: Coarse textured, water gaining +
Best growth site: As above.
Relative growth, height: VI
Relative growth, basal area: I
Dominance classification: Dominant
Relative cover: 29%
Multiple stems: No.

Eucalyptus globulus	A.M.C.
Recorded proportion: N/A	?
Browsed frequency: NIL	
Most common site: Coarse textured, freely draining. +	
Best growth site: As above.	
Relative growth, height: VI	XI - IXX
Relative growth, basal area: I	-
Dominance classification: Sub-dominant	
Relative cover: 15%	
Multiple stems: No	No

Eucalyptus gomphocephala	M1/81	A.M.C.
Recorded proportion: 98%	76%	?
Browsed frequency: 50% (early)		
Most common site: Coarse textured, water gaining.		
Best growth site: Fine textured, freely draining.		
Relative growth, height: VII	VI	X - IV
Relative growth, basal area: Best growth	I	-
Dominance classification: Sub-dominant		
Relative cover: 10%		
Multiple stems: 2	No	Yes

Eucalyptus leucoxylon	M1/81
Recorded proportion: 370%	90%
Browsed frequency: 29%	
Most common site: Coarse textured, water gaining.	
Best growth site: As above.	
Relative growth, height: VIII	V
Relative growth, basal area: III	Nil
Dominance classification: Co-dominant	
Relative cover: 16%	
Multiple stems: 2	

Eucalyptus marginata

Recorded proportion: 20%, sand site, 80% silt site.
Browsed frequency: 100%; repeated.
Most common site: Coarse textured, freely draining.
Best growth site: As above.
Relative growth, height: II
Relative growth, basal area: I
Dominance classification: Suppressed
Relative cover: N/A
Multiple stems: Mainly bushes.

Eucalyptus melliodora M5/80

Recorded proportion: 6%
Relative growth, height. I

Eucalyptus ? patens

Recorded proportion: N/A
Browsed frequency: NIL
Most common site: Fine textured, freely draining *
Best growth site: As above.
Relative growth, height: II
Relative growth, basal area: I
Dominance classification: N/A
Relative cover: N/A
Multiple stems: Bushy

Eucalyptus ? resinifera

Recorded proportion: N/A
Browsed frequency: 25%
Most common site: Fine textured, freely draining.
Best growth site: Fine textured, water gaining.
Relative growth, height: IV
Relative growth, basal area: I
Dominance classification: N/A
Relative cover: 14%
Multiple stems: Bushy.

Eucalyptus ? robusta

Recorded proportion: N/A
Browsed frequency: 29%
Most common site: Coarse textured, freely draining +
Best growth site: As above.
Relative growth, height: VI
Relative growth, basal area: I
Dominance classification: N/A
Relative cover: N/A
Multiple stems: Bushy.

Eucalyptus rudis

Recorded proportion: N/A
Browsed frequency: 50%
Most common site: Variable texture, water gaining
Best growth site: Fine textured, water gaining.
Relative growth, height: II
Relative growth, basal area: I
Dominance classification: Suppressed.
Relative cover: 1%
Multiple stems: Bushy.

<u>*Melaleuca quinquenervia*</u>

Recorded proportion: N/A
Browsed frequency: NIL
Most common site: Coarse textured, water gaining +
Best growth site: As above.
Relative growth, height: II
Relative growth, basal area: I
Dominance classification: Suppressed
Relative cover: 5%
Multiple stems: 3

* = single tree recorded.

+ = single plot recorded.

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PASTURE & TREE ESTABLISHMENT ON SAND MINING RESIDUES AT CAPEL - AN APPRAISAL AFTER SIX YEARS

SUMMARY

Revegetation of the mining residue surface by pasture and crop legumes and grasses, and success of establishment and growth of tree species were studied in relation to variations of rainfall-evaporation balance over time, to different site types and to species.

A possible effect of climatic variation associated with the time of, and consequently affecting, vegetation establishment and growth was not demonstrated by the study, although both monthly rainfall in the growing period of pasture and mean annual rainfall over the period were below long term averages.

The four site types recognised did not produce significantly different growth rates of ground cover species as a group, though there was possibly better growth of grasses on the finer textured substrate. Tree growth was better on the coarsely textured, water gaining sites and the finely textured, freely draining sites than on the coarsely textured, freely draining sites or the finely textured, water gaining sites..

Overall proportions of recorded quadrats covered by different vegetation groups were legumes 18%, pasture grasses 7%, veldt grass 4% and other weeds 7%.

One of the sixteen tree species gave significantly higher growth rates than the lowest nine of the remainder, and growth rates of a further seven appeared to be acceptably high.

Although both pasture and tree growth were effective in preventing erosion by wind, their potential for building up humus levels to an approximation of a natural soil was not impressive. Changes in practises are recommended.

G.S. McCUTCHEON
2/3/88.

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PASTURE & TREE ESTABLISHMENT ON SAND MINING RESIDUES AT CAPEL - AN APPRAISAL AFTER SIX YEARS

INTRODUCTION

The observations reported were made on land vested in the Lands and Forests Commission which had carried a pine plantation before extraction of heavy mineral sands by Western Titanium N.L., now taken over by Associated Minerals Consolidated Ltd.

Replacement of waste materials, segregated during processing into coarse (sand tailings) and fine (slimes, or silt) fractions, had been done in various ways and produced varying combinations in terms of sequence and depth of fill of the two fractions, although the basic procedure was to place the silt as a slurry into basins excavated in previously deposited sand tailings. The techniques of replacing tailings, surface preparation and sowing of graminous and leguminous plant cover species have been described by Taylor*.

The earliest established trees studied were planted by the company in 1979 on a shallow silt dam on which pasture establishment was never subsequently successfully pursued and on a few sand tailings sites. Some under-storey species were added to this silt dam in 1980.

On most of the area studied plant cover establishment commenced in 1980 with sowing of a cereal/legume crop. Following this a large group of trees consisting of different numbers of eight species, selected to match the sites with sand and with silt tailings, was planted by the then Forests Department, the company purchasing the seedlings. The layout of this trial, identified as M2/80, was informal and the tree spacing somewhat variable, subject only to maintenance of easy access for agricultural machinery. For example, the plots established during this study showed stocking rates ranging from 86 to 778 stems per hectare (mean of 391 s.p.h.)

In 1981 the area was sown with pasture species and the Forests Department planted a further thirteen groups of the suite of eight tree species previously used. This planting was identified as M2/81.

Tree planting was continued in 1982 in the vicinity of a partly natural drainage line where a fair proportion of natural soil and vegetation existed, along with silt and sand tailings areas. Three indigenous and three exotic eucalypt species were added to the suite previously used.

In 1982 and 1983 reseeding was carried out on an area south of the above-mentioned drainage line, using oats and field peas over subterranean clover, rye-grass and serradella.

* Taylor, E.G. (1978) in Proceedings: Rehabilitation of mined lands in Western Australia, Perth, 11th October, 1978 (W.A.I.T.: Bentley).

Tree planting was carried out in this vicinity in 1983, again on a mixture of sites, including some very wet ground adjacent to a natural swamp, and the species mix was modified accordingly. Part was on sand tailings which had at that time been only recently seeded with agricultural species. In later years small plantings of unrecorded species have occurred around margins of silt dams which have still been deemed undesirable as pasture sites. Tree espacement has been small, producing stocking rates between 660 and 1552 stems per hectare (mean of 1182 s.p.h.)

Grazing of the pasture including most of the tree planting carried out until then was commenced in 1982 and continued in each year since. However most of the trees planted in 1982 and all of those planted since have not been subjected to grazing except by kangaroos.

A formally spaced tree species trial included in the assessment was laid down in 1980 on sand tailings with sparse pasture dating from two or three years previously. The planting sites were improved by replacement of tailings with natural topsoil but survival was still poor and the following year different species were used to fill blank spaces. This constitutes the trial identified as M5/80. It has been subject to browsing by cattle during grazing which may have been accidental in 1981 but by design since 1982.

Lastly, a statistically designed tree species trial (M1/81) laid down in 1981 on a silt dam (with various site treatments and with cattle excluded) has been drawn on for information in the form of overall mean growth data for the species resulting from the latest measurement in November 1985.

METHOD

The survey was carried out in the third week of September and the second week in October, 1986.

Pasture plots were recorded on a systematic grid with 200 metres between lines and 100 metres between plots on each line, but making sure that each lay entirely within one site type. Additional plots for trees were located by bearing and distance from points on the grid. These plots could not always be located on a single site type particularly those centred on the narrow sand banks between silt dams.

The 'soil profiles' encountered in this study were later subjectively classified into four types which were identified by letter code names as described below.

Coarse textured and freely draining (CF).
Coarse textured but water-gaining (CW).
Fine textured but freely draining (FF).
Fine textured and water-gaining (FW)

Classification as fine textured depended on presence of an upper silt horizon at least 30 centimetres thick. Classification as a water gaining site depended sometimes on assessment of the relative elevation of the site or of indigenous indicator plant species, and sometimes on discovery of a high water table within the profile. Classification of a fine textured site as freely draining depended on presence of a relatively thin horizon of silt overlying a deep, coarse-textured horizon with no indication of high water table.

Pasture and weed condition was estimated as per cent area cover for each species within a quadrat one metre square. Species not previously known were identified by use of the relevant keys.

Tree data were recorded within a polygonal plot defined by the "available growing space" of the closest trees to a tree selected as centre, being that tree closest to the systematically selected point. The boundaries of the plot were placed perpendicular to an imaginary line joining each outer tree of the plot to its neighbour in the centrifugal direction, and equidistant between the pair. Bearings and distances from the central tree to the angles of the polygon were used to compute plot area in the field, using a programmable calculator. This allowed checking on site.

An example of the field record sheet forms Appendix 1 of this report.

Thirty four sites were recorded for pasture not overshadowed by trees, four for pasture included within tree plots and sixteen sites for tree data alone.

RESULTS

Recordings of per cent cover of ground species are summarized in Appendix 2 and tree data recorded, or derivations from data, are summarized in Appendix 4. Explanations of the meanings of column headings of Appendix 4 are presented as Appendix 4a.
Throughout this report, where means and standard deviations were calculated for percentages, the latter were first subjected to arcsin transformation and the statistics were reverse transformed.

DISCUSSION

1. <u>Ground cover</u>.

The ground cover category, comprising pasture legume and graminoid species and volunteer weed species, varied greatly in per cent cover of the ground and in species composition. Numbers of plots falling within different cover per cent classes are summarized in Table 1.

TABLE 1

Numbers of quadrats in cover per cent classes.

Cover % class	Number of Quadrats	Cover % class	Number of Quadrats
0-9	4	50-59	4
10-19	3	60-69	1
20-29	6	70-79	1
30-39	3	80-89	3
40-49	2	90-100	11

One plot was recorded with no vegetation and seven with complete cover. Translated into relative terms this would indicate that three per cent of the quadrats carried no vegetation and eighteen per cent carried complete vegetation cover on the ground, fifty eight per cent of quadrats had below two thirds of surface vegetated and thirty seven per cent had less than one third vegetated. *Viewed in another way, the land had, on average, forty one per cent of its surface unvegetated (see Table 2). The cover might have increased somewhat later in the season, but because over half of the sites were in the free-draining category which would lead to early drying off, the extent of such increase might be small.
The above figure of forty one per cent appears to represent a satisfactory level of protection form wind erosion. However from the point of view of build up of humus to a natural soil condition it is obvious that the process will be very slow with such a small proportion of the surface vegetated, and that not densely.
Several influences on and aspects of the establishment of ground cover are discussed below.

1.1 Effect of seasonal differences.

The poor cover of annuals is likely to be partly an effect of low rainfall. Comparing cumulative rainfall at Ludlow after the beginning of April 1986, with seventeen-year means for that parameter (raw data supplied by Busselton district staff and Commonwealth Met. Bureau) a considerable deficit can be observed.

* Differs from data quoted in Summary, calculated without arcsin conversion.

The progressive values of that deficit at the ends of the months April through September were -58, -63, -20, -91, -70 and -86 millimetres respectively. Germination would have been inhibited and growth retarded, and these effects were particularly exhibited by serradella and by Tama rye grass respectively. The low moisture retention capability of the sand tailings should be expected to exacerbate the effects of low rainfall years. A breakdown by species forms Appendix 2.

1.2 Effect of site differences.

Differences in mean total ground cover between site types were small, as displayed in Table 2. These differences proved to be not statistically significant, although cover on the finer textured sites would appear to be greater than on the coarser textured sites.

Table 2.

Total Ground Cover, percent

Category	n	Mean	95% Conf. int.*	Range
All sites	38	58.7	43.4 - 73.2	0 - 100
CF sites	18	57.3	35.9 - 77.4	14 - 100
CW sites	10	56.5	23.2 - 86.8	0 - 100
FF sites	4	65.6	3.3 - 98.2	16 - 100
FW sites	6	62.0	5.3 - 99.9	4 - 100
With trees	4	79.7	20.5 - 97.3	36 - 100
Without trees	34	56.1	39.6 - 71.9	0 - 100

* Calculated as C.I. = $\pm\ t.s/\sqrt{n}$.

When data were dissected into plant cover groups (see next section) the mean cover percentages, as displayed in Table 3 also tend to indicate that cover may be greater on the finer textured sites, for the 'Cereal' and 'Legume' groups only. It is also indicated in Appendix 3 that clovers were judged to be more abundant on the finer textured substrate.

However a two-way analysis of variance showed no significant differences in arcsin percent cover between sites (F=0.108 for d.f.=3,136).

Table 3

Ground cover by species categories and by sites.

SITE TYPE	n	MEAN COVER PERCENT Cereal	Legumes	Veldt	Other Weeds
FF	4	19	16	5	2
FW	6	10	23	0	9
CF	18	4	17	5	9
CW	10	5	19	8	4

Note that a total of means of dissected percentage data does not equate with the mean of totals of percentage cover.

1.3 Effect of trees.

There appeared to be a difference in mean total ground cover between groups of quadrats which were recorded within tree plots and those free of any influence of trees (see Table 2). However the difference did not prove statistically significant, possibly because the comparison was not intended initially therefore the number of quadrats recorded within tree plots was very low.

1.4 Effectiveness of species.

A subjective assessment of individual species performance is given as Appendix 3.
Cover percentages achieved by individual species were not statistically analysed because of the very numerous cases of absence of species from plots. Grouping of species appeared to be likely to be useful and the following groups were set up, viz. 'Cereals', 'Legumes', 'Veldt grass' and 'Other Weeds'. A one-way analysis of variance on the basis of species group cover totals for plots showed a significant difference between groups, with 99.9 percent probability (F=4.836 with d.f.=3,147). Multiple range tests indicated that the mean for the 'Legume' group was significantly higher than those for the other three groups, the equivalent normal percent cover values being 'Legumes' - 18.2, 'Weeds' - 7.2, 'Cereals' - 6.6 and 'Veldt' - 4.2.
A summary of the mean cover achieved by the main species and by groups of species of lesser importance is provided by Table 4.

Table 4 illustrates that the most dominant species was serradella. However it is suitable for sandy sites only, while subterranean clover cultivars are available for various soil textures. New Zealand blue lupin, recorded on one end of the study area, did not establish well or provide much cover. Ryegrass established very well and provided fairly good cover in spite of the immature stage of development.

It can be noted that the oats and field peas originally sown have not persisted; oats were recorded on only two of the plots and are included with 'other grasses' in Table 4.

Table 4.

Relative dominance of ground vegetation species.

Species	Presence on sites (%)	Mean Cover* & Range (%)	Dominance Index+
Clover	34	27.3;1-70	93
Serradella	71	13.8;1-78	98
Lupin, N.Z. Blue	16	5.7;1-20	9
Other legumes	8	4.3;1-10	3
Ryegrass	74	10.4;1-68	77
Other grasses	21	3.4;1-5	7
Veldt grass	45	18.7;1-100	84
Flatweed	45	3.9;1-19	17
Capeweed	34	4.9;1-30	17
Other weeds	58	7.8;1-62	45

* On those sites where present; total number of sites = 38
+ Dominance Index = Presence % x Mean Cover % ÷ 10.

Perennial veldt grass was notable both for presence and abundance, and the more so because of the largely volunteer nature of its occurrence. However the species is regarded as ecologically undesirable in the context of proposed land use for most of the mined area, and claims that it could be eliminated by grazing have not been borne out in practice.

The proportion of edible legumes in relation to total forage has been estimated. This excludes W.A. Blue Lupin, Capeweed and the other weeds. The mean value of 42% (s.d = 18%) obtained is some what less than the minimum of 50% considered desirable (J. Kruger, pers. comm.) from the points of view of production of maximum bulk of forage and of maximum nutrient value. Only nineteen of the thirty seven vegetated quadrats recorded had legume content higher than the minimum desirable, mostly by a considerable amount, while thirteen had less than twenty-five per cent.

2. Tree Establishment

A concise summary of the performance of the species used on the area studied forms Appendix 4 as already stated. Some of that and other data from field sheets has been expressed in different form as Appendix 5, to facilitate comparison of the species.

In the discussion which follows, success of trees planted in different years and on different site types, and comparisons between tree species, have been judged on the basis of height growth expressed as Mean Annual Increment (M.A.I.). Stem diameter growth would be of doubtful value because of the bushy or at least multi-stemmed habit of many trees. Crown diameter was also judged a less useful criterion. Mean crown diameters within height classes were approximately proportional to height only up to about the value of 2.5 metres for the latter, and increase in crown diameter had almost ceased by 10 metres mean height as shown in Figure 1.*

Although M.A.I. changes with age as shown in Figure 2, it was the most appropriate simple measure for the purpose of comparing growth rates of trees of different ages, and proved effective in most of the analyses of data.

* From the point of view of reduction of wind erosion the tree groups would have been judged already effective, though over a limited area, by the time they had attained a height of about 3.7 metres, then the mean crown diameter was 2.5 metres. This was about half of the nominal planting spacing, that is, the trees occluded half of the vertical plane presented to airflow, a condition considered necessary for significant reduction of wind velocity.

Figure 1. Regression of mean crown diameters on mean heights within height classes.

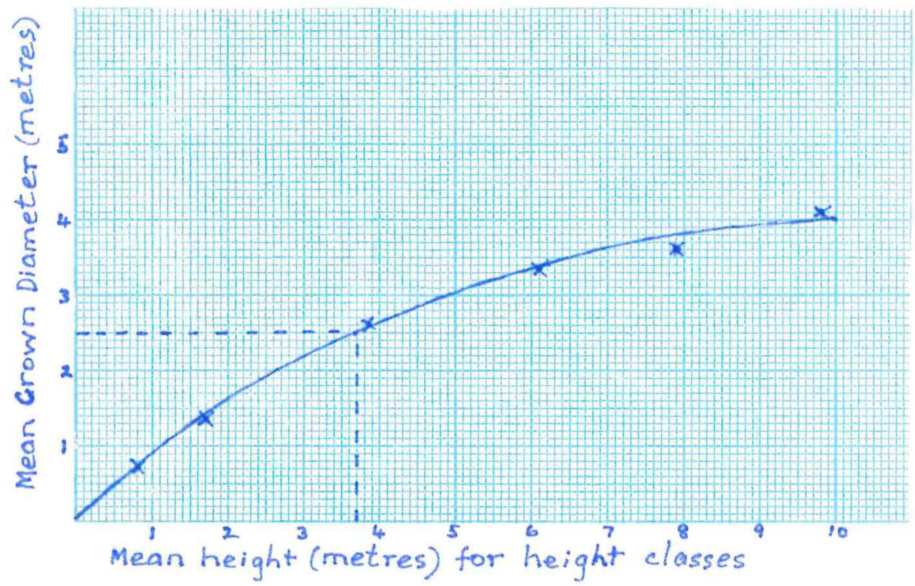
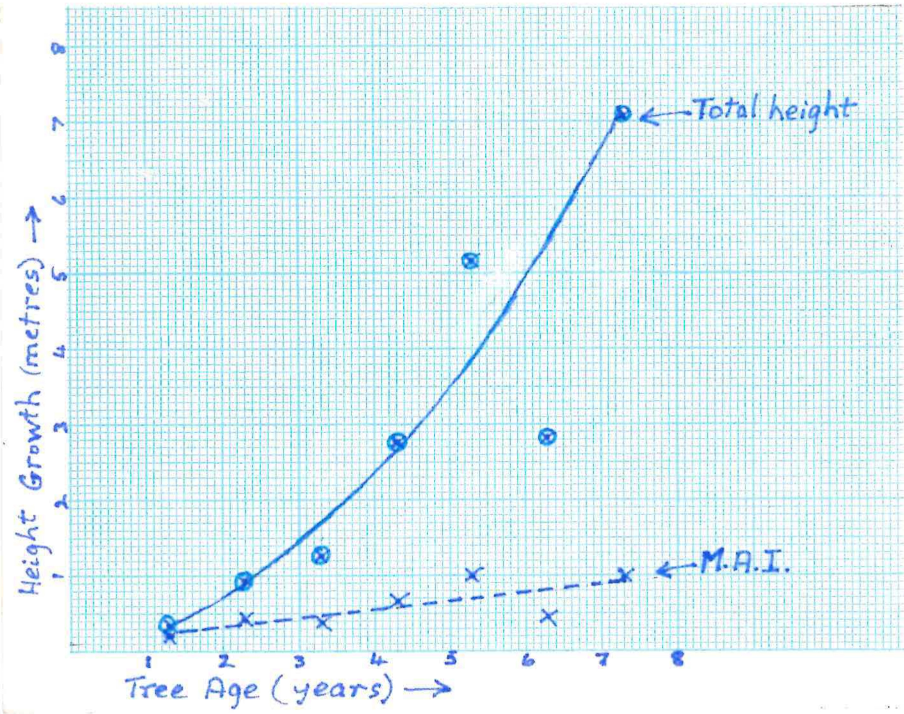


Figure 2. Regression of total height growth and M.A.I. on age.



The information which could be extracted on how seasons, sites and species influenced tree growth is discussed in following sections.

2.1 Effect of seasonal differences.

Average annual rainfall (October through September) for the period 1979 to 1986 had a mean of 768mm, while the average for the period 1967 to 1979 was 855mm. The difference is very highly significant, the probability of its occurring by chance being less than one in a thousand (t for 18 d.f., .001 significance level = 10.3). It is possible that better tree growth might have been recorded had the study been done on trees established in a sequence of years more normal with regard to rainfall. Similarly, survival of seedlings planted might have been better in higher rainfall years.

Within the years of planting of the trees studied, no statistically significant difference in total rainfall was detected. When the rainfall for the summer period of October to April, which would be likely to be critical for trees growing on a freely draining substrate, was considered, again a statistically significant difference between years was not detected. Refinement of data achieved by considering the nett balance of precipitation and potential evapo-transpiration (derived from average monthly pan evaporation at Capel x 0.6) once more provided no evidence of a significant difference between years. It is possible that seasonal variation did exist at a level not detected by the measure described above, but development of further refinements was not pursued.

Analysis of variance of the tree growth data by planting years did indicate a very highly significant difference among years (F for 5/127 d.f. and .001 significance level = 13.39 for the ten eucalypt species). Differences may be related to the possibility described above and to other factors which are discussed with reference to interactions in the following section of this report.
The effect of seasons on survival of seedlings could not be studied because data on numbers planted at each site recorded was not available.

2.2 Effect of site differences.

2.2.1 Effect of site differences on survival.

It is likely that site type would have had an effect on survival. For example, in 1980 and 1981 deaths occurred among tuart trees planted on a silt dam in 1979. Investigation led to the conclusion that isolation of root systems within the polygons resulting from cracking during de-watering of the 'slimes' was the likely cause.

The poor survival demonstrated by trial No. M5/80 on sand tailings has already been referred to in the introduction. Further plantings on the same site type nearby also failed completely in 1982 and 1983, although it is possible that seedlings were pulled out by cattle in those years.

The data of the study indicate that significantly different numbers of trees were recorded on different site types, as shown in Table 5. This was more likely because the numbers of plots on different site types differed, rather than because the number of trees per plot was greatly different. The numbers of plots with finely textured substrates were higher than would be expected from the relative areas of site types determined for the study area, though not significantly so.

Table 5 Numbers of trees related to numbers and proportional areas of different site types.

Parameter	Site Types FF	FW	CF	CW	Chi-Square
Total trees	52	28	31	40	9.24*
Trees per plot	7.4	7.0	7.8	8.0	0.08
Number of Plots	7	4	4	5	1.2
Proportional area	38ha.		44ha.		0.44

* Significant at 99.95 per cent probability, other chi-square values not significant

The above data do not allow any statistically supported conclusion to be drawn about the possibility of higher survival rates on certain site types. Further, any attempt to study differences for individual tree species would not be valid because of the deliberate attempt to match species to site in the original planting scheme.

2.2.2 Effect of site differences on growth rate.

Different growth rates of trees were observed on different site types. Higher average M.A.I. values were obtained on the coarse textured, water gaining (CW) sites and the fine textured, freely draining (FF) sites than on the coarse textured, freely draining (CF) sites and the fine textured, water gaining (FW) sites.

Analysis of variance of data from the sixteen species gave indication of a very highly significant difference among the site categories (F for 3/118 d.f., 0.001 significance level = 7.31). Duncan's multiple range test indicated significant differences as listed in the final column of Table 6.

Table 6.

Effect of site and year of planting on tree height M.A.I. (m).

		Planting Year						
Site		1979	1980	1981	1983	1984	1985	Mean *
	n	2	3	7	2	5	1	
CW	5	0.76	-	1.23	0.76	0.37	-	0.84^a
FF	7	1.08	0.85	1.01	-	0.37	-	0.79^a
CF	4	-	0.15	0.82	-	0.50	-	0.41^b
FW	4	-	-	0.63	0.32	0.35	0.24	0.41^b
Mean *		0.97^c	0.44^d	0.98^c	0.46^d	0.41^d	0.24	0.65

* Different superscripts indicate means which are significantly different with 99.99 percent probability (the limit of sensitivity of the computer package).

n = number of plots.

A very highly significant interaction between site type and year of planting was shown to exist. (F for 6, 118 d.f., 0.001 significance level = 4.69). From Table 6 it may be seen that the higher growth rates on CW and FF sites were exhibited by trees older than three years at the time of measurement but not by those younger. The higher growth rates for older trees may relate to the usual trend for M.A.I. of young trees to be increasing with age, once the plants have successfully established themselves.

Irregularities in this trend were most likely related to observed segregation of data by species in different planting years (and see the differences between species demonstrated in the following section). For example, the low mean M.A.I. recorded for the 1980 planting can be attributed mainly to the large number of *E. marginata* trees on a poor site, and the low mean M.A.I. for the 'FF' site type in particular to the fact that three of the seven trees recorded were *Agonis flexuosa*, again on a site unsuited to the species. Any interaction between species, planting year and site was not tested.

2.3 Effect of Species.

2.3.1 Effect of species on survival.

Although survival data would very likely be variable by species, no statistical test of survival differences between species could be conducted because of the absence of early data for the sites selected as plots in the study, also the segregation of species by site types when planting. However, comparison of the "Recorded proportions" in Appendix 5 can provide a rough guide.

2.3.2 Effect of species on growth rate.

The treatment of data for analysis of differences between individual species was restricted to the simple technique of comparisons between pairs by means of Hotelling's 't' test because the problem of missing values would have become extreme in an analysis of variance including species as a value label in addition to site and year of planting. The results are presented in Table 7.

Table 7.

Tree species growth rates and significant differences.

SPECIES	n	HEIGHT M.A.I. (m)
Eucalyptus camaldulensis	20	1.26[a]
E. gomphocephala	26	0.93[a,b]
E. leucoxylon	9	0.75[b]
E. cladocalyx	1	0.74
Acacia saligna	1	0.72
Eucalyptus globulus	5	0.70[a,b,c]
E. calophylla	9	0.65[b,d]
Acacia decurrens	5	0.63[a,b,c]
Agonis flexuosa	10	0.41[c]
Casurarina obesa	1	0.39
Eucalyptus robusta	7	0.37[b,c]
E. resinifera	28	0.35[c]
E. rudis	11	0.32[c]
Melaleuca quinquenervia	2	0.27[b,c,d,e]
E. marginata	15	0.25[c,d,e]
E. patens	16	0.24

* Different superscript letters indicate means which are significantly different at the 99.95 per cent probability level.

The pre-eminent species of those recorded was shown to be Eucalyptus camaldulensis. The species exhibited faster growth than E. leucoxylon and by inference, faster growth than all other species. However all of the top eight species exhibited acceptable growth rates.

The slower growing species can be subjectively assessed by consideration of Appendix 5, particularly by contrasting the site producing best growth with that on which most of the recorded trees occurred, and by noting the frequency of browsing on the species. Thus Agonis flexuosa recorded were probably retarded basically by poor drainage and Eucalyptus resinifera by a shortage of water, while Casuarina obesa and E. marginata suffered from very frequent browsing.
An unfortunate consequence of slow growth by trees which are palatable to grazing stock would be that the time to attain a size relatively immune to damage by browsing would be repeatedly extended and their ultimate survival possibly imperilled. A vigorous species can quickly recover from browsing as is shown by the growth of E. gomphocephala and Acacia saligna in spite of browsing frequencies of 50 and 100 per cent respectively. Nevertheless the average browsed frequency for the eight faster growing species was only 31 per cent, contrasted with 43 per cent for the eight slower growing species recorded in this study.

While browsing of trees by cattle may be seen as still contributing to some accumulation of humus in the soil, the majority of the energy and protein is eventually lost from the system. On the other hand, browsing and stem attack by insects, noted for some species in Appendix 4, should not necessarily be regarded as a detriment. If maximum growth rate of saleable timber were the objective such attack would be counter productive. However if the objective is rapid re-establishment of a self supporting ecosystem then colonization by insects is to be seen as beneficial.

RECOMMENDATIONS.

1. Modification of Techniques
Following the strategy of substrate improvements basically by growth of agricultural crops and input of manure from grazing animals, possible improvements suggested are as below.

1.1 Agricultural species.
1.1.1 Substrate texture improvement.
Amendment of the near-surface texture of sand tailings deposits by addition of silt would produce benefits for at least the grassy component of surface vegetation of agricultural cultivars. This method of increasing moisture retention would probably be the cheapest available.

1.1.2 Germination improvement.
The technique of 'dry seeding' should be investigated as a means of obtaining the earliest possible germination and maximum development of the grass component when establishing or improving pasture. This recommendation is made in view of the early stage of development recorded (considerably pre-tillering) for Tama rye-grass in October.

1.1.3 Change of cultivar.
Moisture appearing to be the factor limiting growth, sprinkler irrigation of crops supplied from the adjacent water bodies would seem a practical alternative, and to obtain the best results the use of a cultivar suited to that technique would be desirable. Lucerne is a crop which thrives under irrigation and is ideally suited by a sandy substrate. It can provide a year-round addition of nitrogen to a developing soil, and of fodder for strip grazing or for export. In this context should be noted the assessment presented in a report made in 1982 (F.D. internal, present author) on the basis of information received from the then operating company. This was that by 1988 the company should have enough storage on its land to the south west to sustain the summer draw down for operating purposes without recourse to water on State Forest.

1.2 Tree species.

1.2.1 Seedling establishment
Although no statistical evidence on seedling survival could be obtained during this study, observations both on the subject area and elsewhere indicate difficulty is experienced in establishing tree species on deep and freely draining substrates. Techniques recommended are either or both of a) long rooted seedlings produced in special containers and b) planting into boreholes filled with silt.

1.2.2 Tree protection.
Though no statistical study was made of the effects of browsing by stock, observations led to the conclusion that the 'understorey' species recorded (casuarina, peppermint and wattles) were retarded by exposure to it, and eucalypts were retarded in certain cases. Such species would benefit by protection from browsing until the age of five years, when at least the leading shoots would be out of reach.

1.2.3 Site selection.
Unless large scale remixing of silt with the upper level of sand tailings deposits is carried out, or unless sand tailings are known to be no more than about a metre deep over a natural soil profile, attempts at commercial production of timber should be restricted to the margins of silt dams and closely adjacent sand deposits. This of course would adversely affect the economics of production.

2. Modification of strategy.
In view of the apparent low effectiveness and slowness to produce results of the agricultural approach, there is a case that at least part of the subject area of this report should be converted to the land uses proposed in the above-cited report for the adjacent land and water to the north west, namely wildlife refuge and recreation. Two recommendations on methods then ensue.

2.1 Re-vegetation with indigenous shrubs.
The success of indigenous species in recolonizing when gravel screenings presumably containing both vegetative propagules and seed were spread upon the tailings deposits has previously been noted (1982 report cited). Also, the company has refined techniques for establishing indigenous shrub species on other sites which it operates. Cessation of fertilization and the practice of long rotations between regeneration of shrubland by burning would result in elimination of most of the agricultural species. An exception might be veldt grass, and some more positive and costly technique would be needed to eliminate that species.

2.2 Re-vegetation with trees.
2.2.1 Species selection.
Especially with the end use of wildlife refuge in mind (not merely establishment of some tree cover), tree species indigenous to the area should be employed. Two are recommended specifically, though this does not imply exclusion of any other.

2.2.1.1 Jarrah.
Given a moist enough site and freedom from competition this species is known to be capable of entering its "dynamic growth" phase at an early age, unlike its habit under canopy. This was demonstrated by the specimens recorded on a fine textured and moist site as well as by one tree on a higher site with topsoil infill at planting.
It is recommended that a trial be initiated using the techniques set down in recommendation 1.2.1 above. Placement of the trial at a location over-lying the known seepage from the lakes having an artificially high water level would both give the species the best change of forming a stand, and in the longer term the probability of ameliorating a problem caused by the seepage.

2.2.1.2 Tuart.
The species did not originally occur on the land in question because of unsuitable soil types but appears capable of forming a woodland when planted on or adjacent to silt dams. For this reason it is recommended.

G.S.W. McCutcheon.

G.S. McCUTCHEON,
15/2/88.

APPENDIX 1.
Field record sheet

SITE REHABILITATION ASSESSMENT

LOCALITY: ______________________

PLOT NO. ________

VEGETATION TYPE: Tree ☐ Shrub ☐ Pasture ☐

PLOT DIMENSION: ____________

MOISTURE STATUS: Free-draining ☐ Water-gaining ☐

SUBSTRATE:

		Depth (cm)
Coarse	☐	______
Fine	☐	______
Coarse	☐	______
Nat.	☐	______

P-YEAR: ________

NATURAL SOIL PROFILE: ______________________________

SPECIES	VITALITY STATUS	HEIGHT	NO. OF STEMS	STEM DIA.(mm)	CROWN DIA.(m)	COVER %	FLORAL STAGE	CROWN HEALTH	BOLE/BRANCH DAMAGE			FOLIAR DAMAGE		COMMENT
									WIND	ANIMAL	INSECT	ANIMAL	INSECT	
	Described as 'Dominance' classification in the report					Not calculated in the field								

APPENDIX 2

Mean percentage cover, with confidence limits, of ground species; numbers of sites in parentheses.

PLANT	COARSE TEXTURED (SAND) SITES Freely draining	Water gaining	FINE TEXTURED (SILT) SITES Freely draining	Water gaining	ALL SITES
Clover	70 (1)	26.1;14.5-39.8(4)	14.4;2.5-33.7(4)	42.8;27.6-58.6(3)	29.1;10.3-52.7(12)
Serradella	17.3;0.7-49.1(16)	17.4;4.8-35.5(7)	3.0 (1)	6.0;0.2-18.9 (5)	14.4;0.9-39.8 (29)
Lupin,N.Z. blue	6.3;1.0-15.6(4)	4.5;3.8-5.2(2)	- - - - - - - - -	- - - - - - - - -	5.6;1.4-12.4(6)
Lupin,W.A. blue	63.0; (1)	2.0; (1)	- - - - - - - - -	24.0; (1)	25.0;1.8-62.5(3)
Lotus minor	- - - - - - - - -	- - - - - - - - - -	4.0 (1)	10.0 (1)	6.7;3.1-11.5 (2)
? _Medicago_ sp	1.0; (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	1.0; (1)
Ryegrass	6.2;2.6-11.2(13)	13.8;2.5-32.0(6)	18.8;0.3-55.5(4)	12.8;3.9-25.7(5)	10.4;1.6-25.3(28)
? Brome grass	5.0 (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	5.0; (1)
Ripgut brome gr.	2.6; (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	2.6; (1)
Paspalum sp	5.0; (2)	- - - - - - - - - -	- - - - - - - - -	1.0; (1)	3.3;1.2-6.4 (3)
'Wild' oat	3.0; (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	3.0; (1)
Perennial					
Veldt grass	14.2;5.8-25.5(10)	28.5;0.1-83.3(5)	19.8;13.2-27.3(2)	- - - - - - - - -	18.7;1.5-48.5(17)
Love grass	5.9;0.3-18.0(3)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	5.9;0.3-18.0(3)
Couch grass	- - - - - - - - -	- - - - - - - - - -	- - - - - - - - -	3.0 (1)	3.0 (1)
Barley grass	- - - - - - - - -	- - - - - - - - - -	- - - - - - - - -	1.0 (1)	1.0 (1)
Native grass	- - - - - - - - -	- - - - - - - - - -	- - - - - - - - -	1.0 (1)	1.0 (1)
Briza major	5.0 (1)	- - - - - - - - - -	3.0 (1)	- - - - - - - - -	3.9;2.6-5.5(2)
Capeweed	3.1;0.7-7.3(5)	7.9;5.3-10.9(2)	3.5;1.1-7.2(4)	11.1;0-39.4(2)	4.7;0.7-12.4(13)
Flatweed	4.1;1.0-9.1 (9)	4.9;1.3-10.8(5)	- - - - - - - - -	2.0;0.5-4.5(3)	3.0;1.8-8.6 (17)
Erodium sp	15.6;1.3-41.2(2)	- - - - - - - - - -	1.0 (1)	3.0 (1)	7.2;0.2-23.3(4)
? _Toplis_ sp	1.5;0.7-2.8(3)	12.0 (1)	3.0 (1)	1.0 (1)	2.8;0.5-6.9(6)
Sheep sorrel	3.5;0.6-8.4(4)	1.0 (1)	- - - - - - - - -	- - - - - - - - -	2.8;0.5-7.1(5)
Guildford grass	2.0 (1)	- - - - - - - - - -	1.0 (1)	- - - - - - - - -	1.5;0.8-2.2(2)
Pelargonium sp	5.0 (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	5.0 (1)
Stinkweed	6.0 (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	6.0 (1)
Charlock	4.0;0.3-11.6(2)	2.0 (1)	- - - - - - - - -	- - - - - - - - -	3.3;0.5-8.2(3)
Mallow	2.0 (1)	- - - - - - - - - -	- - - - - - - - -	- - - - - - - - -	2.0 (1)

Appendix 3.

Comparison of pasture species performances in terms of frequency of occurrence and of cover percentage.

Roman numerals indicate relative status, in deciles of the observed ranges of occurrence and of abundance.

Clover	Presence - V Mostly on water-gaining sites.
	Abundance - X Best on fine-textured sites, especially if fertiliser application heavier than normal.
Serradella	Presence - X
	Abundance - VII Best on coarse textured sites but can grow on fine-textured sites.
Lupin, N.Z. Blue	Presence - III Probably the species has not been used until recently. Only on coarse textured sites, mainly freely draining.
	Abundance - II
Other legumes	Presence - I
	Abundance - II Exception is W.A Blue lupin which rates X; its best development is on a coarse textured, freely draining site.
Ryegrass	Presence - X The most commonly occurring cover component, with no apparent site preference in relation to establishment.
	Abundance - IV Usually better cover where clover also prominent, an effect possibly of seeding rate or fertilizer rate.
	N.B. Both Perennial Ryegrass and Lolium multiflorum, cv. Tama were combined. The latter was most frequent but at a very early stage of development which would affect estimates of cover.
Other pasture grasses.	Presence - I Very infrequent. Rarely on fine textured sites.
	Abundance - II Significant cover only by Lovegrass on one quadrat.

Perennial Veldt grass	Presence - VI Most consistently on northern quadrats which were on or adjacent to the area deliberately sown with the species.
	Abundance - VII Can achieve similar cover on either coarse or fine textured sites.
Flatweed	Presence - IX More commonly on coarse textured sites,
	Abundance - II Also more abundant cover on those sites.
Capeweed	Presence - V Site type does not appear important to establishment.
	Abundance - II Cover value possibly better on fine textured sites which are water gaining.
Other weeds	Presence - I Most consistently occur on coarse textured, freely draining sites.
	Abundance - I, II Cover percentages rarely more than 3%.

An occurrence of the Declared Weed Plant, Paterson's Curse was notified to the company and dealt with by an A.P.B. operator who also apparently found other populations.

APPENDIX 4 RELATIVE SUCCESS OF TREE SPECIES

SPECIES	Dominance	Cover %	Height M.A.I. (m)	Basal Area M.A.I. (m2)	No. of stems	Crown Health	Damage: Bole/Branch: Wind	Damage: Bole/Branch: Animal	Damage: Bole/Branch: Insect	Damage: Foliar: Animal	Damage: Foliar: Insect	Floral stage	Sites: No.	Sites: Type	Comments
Acacia decurrens	2	21	0.63	<.001	1	Good	occ. sl. lean	some browsing					3	FF	
A. saligna *	3	35	0.72	"	bush	Good		early browsing			few chewed	Full	1	FF	
Agonis flexuosa	2	19	0.41	-	bush	Good		extensive early browsing	scale + mould			occ. buds	5	FF	
Casuarina obesa *	3	39	0.39	-	2	Good		Slight early browsing					1	CF	
Eucalyptus calophylla	2	31	0.65	.001	2+	Good					Galls, few chewed.		4	CW	
E. camaldulensis	4	55	1.26	.004	1	Good	occ. severe	occ. slight early	rare sawfly		Chewed, Jassid, miner.	Buds	7	CW	Form can be poor
E. ? cladocalyx	5	78	0.74	-	1	V.poor			many incisions		Chewed Jassids Blister		1	CW	Severley defoliated
E. globulus	3	38	0.70	-	1	Good	Lean				Aphid, Blister, sl. chewed		1	CF	
E. gomphocephala	3	28	0.93	.011	2	Mainly good		50% early browsing			some heavily chewed, Blister, Galls		8	CW	Often reddish leaves
E. leucoxylon	4	51	0.75	.002	2	Good	Rare lean	Moderate to severe early browsing			Chewed, Jassid, occ. blister	Buds to capsules	4	FW	Some poor form
E. marginata	2	N/A	0.25	.001	Bush	Fair/good		Repeated Browing			Chewed,grazed, Tip damage.		2	CW	
E. ? patens *	N/A	N/A	0.20	-	Bush	Poor					Grazed		1	FW	
E. ? resinifera	N/A	22	0.35	-	bush	Poor to good	Lean common	occasional browsing	occ. incisions		Blister, Chewed.		4	FF	
E. robusta	N/A	61	0.37	-	Bush	Fair	occ. sweep	"			"		1	CF	
E. ? rudis	2	2	0.32	-	Bush	Poor		Possible early			Blister, Gall, Lerp, chewed.		2	FW	
Melaleuca quinquenervia	2	10	0.27	.001	3	Fair							1	CW	

* = Single tree recorded

APPENDIX 4A

Explanation of tree statistics derived in report.

1. "Recorded proportion"
   The number of individuals of a species recorded in the study, as a proportion of the total number of trees recorded, was compared to the known proportions of the species in the suite originally planted. It is a very approximate measure of survival ability, based on the assumption that each species had an equal chance of being sampled.

2. "Relative Growth"
   This was calculated by relating mean annual increment for any species to a scale of tenths of the maximum increment recorded during the study.

3. "Relative Cover"
   This is the average value of the proportion of canopy cover which individual trees of a species contributed to the respective plots in which they occurred, expressed as a percentage. It is an alternative to the cover percent first calculated for Appendix 3.

4. "Dominance"
   Trees were subjectively categorized in a series comprising retarded, suppressed, sub-dominant, co-dominant and dominant categories. For the purpose of Appendix 3 these were ranked from 1 to 5 respectively and rank means for each species taken for plots and thence for the species over all plots.

5. "Cover percent"
   This was derived by expressing mean crown area for a species on a plot as a percentage of the sum of such means for all species on the plot, and averaging over all plots containing the species.

APPENDIX 5

COMPARISON OF TREE SPECIES PERFORMANCES - SURVIVAL, GROWTH AND FORM

A concise summary of the performance of the species used on the area studied forms Appendix 3 as already stated. Some of that and other data from field sheets has been expressed in different form below, to facilitate comparison of the species. This has been supplemented by information from the other trials described in the introduction to this report. Comparative growth rates are again expressed as deciles of the maxima recorded on this study. Necessary explanations of some of the terms used in the descriptions following are provided in Appendix 3A.

Where supplementary information on growth and survival derived from other trials is given, three points should be kept in mind when relating that to the data from the recent study. Firstly, survival should be expected to be higher on trial M1/81 because grazing by cattle was prevented and grazing by kangaroos inhibited. Apparent mean annual height growth rates could also be higher for the same reason. Secondly, the year of onset of grazing would differentially affect relative growth rates on plots not so protected; the company planting was not subjected to grazing by cattle until three years old. Finally, the trees in M1/81 received only one application of fertilizer after planting, whereas the other trees have been given fertilizer at least annually through pasture top-dressing.

A possible deleterious effect of ground cover species on trees has not been checked for because of the generally sparse nature of the ground cover.

<u>Acacia acuminata</u>		<u>M5/80</u>
Recorded proportion:	-	58%
Relative growth, height:	-	II

<u>Acacia decurrens</u>		<u>M1/81</u>	<u>A.M.C.</u>
Recorded proportion:	50%	80%	?
Browsed frequency:	50%		
Most common site:	Fine textured, freely draining.		
Best growth site:	As above.		
Relative growth, height:	IV	VIII	X
Relative growth, basal area:	I	I	-
Dominance classification:	Suppressed.		
Relative cover:	6%		
Multiple stems:	No.	-	Yes

Acacia saligna	M1/81	A.M.C.
Recorded proportion: + 15%	71%	?
Browsed frequency: 100%		
Most common site: Fine textured, freely draining *		
Best growth site: As above		
Relative growth, height: VI	IV	X
Relative growth, basal area: I	-	-
Dominance classification: Sub-dominant		
Relative cover: 20%		
Multiple stems: Bushy	Bushy	Yes

Agonis flexuosa	M1/81	A.M.C.
Recorded proportion: 117%	90%	-
Browsed frequency: 40%		
Most common site: Coarse textured, water gaining.		
Best growth site: Fine textured, freely draining.		
Relative growth, height: III	IV	-
Relative growth, basal area: I	-	-
Dominance classification: Suppressed		
Relative cover: 6%		
Multiple stems: Bushy	Bushy	Bushy

Casuarina obesa	M1/81	A.M.C.
Recorded proportion: <1%	95%	-
Browsed frequency: 100%		
Most common site: Coarse textured, freely draining *		
Best growth site: As above.		
Relative growth, height: IV	VIII	VII
Relative growth, basal area: I	I	-
Dominance classification: Sub-dominant		
Relative cover: 8%		
Multiple stems: 2	-	-

Callitris preissii	M5/80
Recorded proportion: -	Nil (was 8% after 3 years)

Eucalyptus calophylla	M1/81	M5/80
Recorded proportion: 154% (planting bias likely)		
Browsed frequency: 25%		
Most common site: Coarse textured, water gaining		
Best growth site: As above		
Relative growth, height: VI	IV	I
Relative growth, basal area: I	-	-
Dominance classification: Suppressed		
Relative cover: 13%		
Multiple stems: 2+	Bushes	-

<u>*Eucaluptus camaldulensis*</u>		<u>M1/81</u>
Recorded proportion:	28%	75%
Browsed frequency:	+ 25%	
Most common site:	Fine textured, water-gaining	
Best growth site:	As above.	
Relative growth, height:	Best growth	IX
Relative growth, basal area:	IV	I
Dominance classification:	Dominant	
Relative cover:	20%	
Multiple stems:	2	-

<u>*Eucalyptus ? cladocalyx*</u>

Recorded proportion: N/A
Browsed frequency: NIL; severe insect damage.
Most common site: Coarse textured, water gaining +
Best growth site: As above.
Relative growth, height: VI
Relative growth, basal area: I
Dominance classification: Dominant
Relative cover: 29%
Multiple stems: No.

<u>*Eucalyptus globulus*</u>		<u>A.M.C.</u>
Recorded proportion:	N/A	?
Browsed frequency:	NIL	
Most common site:	Coarse textured, freely draining. +	
Best growth site:	As above.	
Relative growth, height:	VI	XI - IXX
Relative growth, basal area:	I	-
Dominance classification:	Sub-dominant	
Relative cover:	15%	
Multiple stems:	No	No

<u>*Eucalyptus gomphocephala*</u>		<u>M1/81</u>	<u>A.M.C.</u>
Recorded proportion:	98%	76%	?
Browsed frequency:	50% (early)		
Most common site:	Coarse textured, water gaining.		
Best growth site:	Fine textured, freely draining.		
Relative growth, height:	VII	VI	X - IV
Relative growth, basal area:	Best growth	I	-
Dominance classification:	Sub-dominant		
Relative cover:	10%		
Multiple stems:	2	No	Yes

<u>*Eucalyptus leucoxylon*</u>		<u>M1/81</u>
Recorded proportion:	370%	90%
Browsed frequency:	29%	
Most common site:	Coarse textured, water gaining.	
Best growth site:	As above.	
Relative growth, height:	VIII	V
Relative growth, basal area:	III	Nil
Dominance classification:	Co-dominant	
Relative cover:	16%	
Multiple stems:	2	

<u>Eucalyptus marginata</u>

Recorded proportion: 20%, sand site, 80% silt site.
Browsed frequency: 100%μ repeated.
Most common site: Coarse textured, freely draining.
Best growth site: As above.
Relative growth, height: II
Relative growth, basal area: I
Dominance classification: Suppressed
Relative cover: N/A
Multiple stems: Mainly bushes.

<u>Eucalyptus melliodora</u> <u>M5/80</u>

Recorded proportion: 6%
Relative growth, height. I

<u>Eucalyptus ? patens</u>

Recorded proportion: N/A
Browsed frequency: NIL
Most common site: Fine textured, freely draining *
Best growth site: As above.
Relative growth, height: II
Relative growth, basal area: I
Dominance classification: N/A
Relative cover: N/A
Multiple stems: Bushy

<u>Eucalyptus ? resinifera</u>

Recorded proportion: N/A
Browsed frequency: 25%
Most common site: Fine textured, freely draining.
Best growth site: Fine textured, water gaining.
Relative growth, height: IV
Relative growth, basal area: I
Dominance classification: N/A
Relative cover: 14%
Multiple stems: Bushy.

<u>Eucalyptus ? robusta</u>

Recorded proportion: N/A
Browsed frequency: 29%
Most common site: Coarse textured, freely draining +
Best growth site: As above.
Relative growth, height: VI
Relative growth, basal area: I
Dominance classification: N/A
Relative cover: N/A
Multiple stems: Bushy.

Eucalyptus rudis

Recorded proportion: N/A
Browsed frequency: 50%
Most common site: Variable texture, water gaining
Best growth site: Fine textured, water gaining.
Relative growth, height: II
Relative growth, basal area: I
Dominance classification: Suppressed.
Relative cover: 1%
Multiple stems: Bushy.

Melaleuca quinquenervia

Recorded proportion: N/A
Browsed frequency: NIL
Most common site: Coarse textured, water gaining +
Best growth site: As above.
Relative growth, height: II
Relative growth, basal area: I
Dominance classification: Suppressed
Relative cover: 5%
Multiple stems: 3

* = single tree recorded.

+ = single plot recorded.