Ludlow Titanium Minerals Mine, 34 Kilometres South of Bunbury

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Cable Sands (WA) Pty Ltd

Report and recommendations of the Environmental Protection Authority

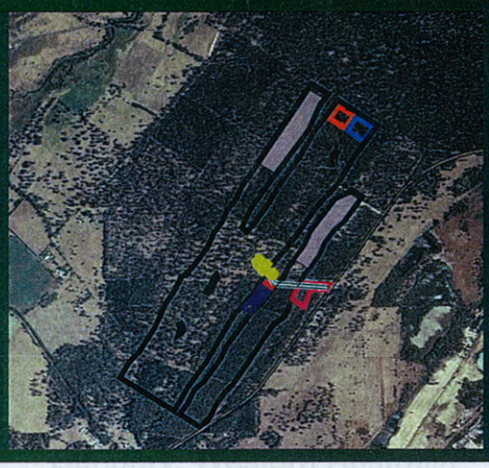
Environmental Protection Authority
Perth, Western Australia
Bulletin 1098
May 2003

18/3/2002



LUDLOW TITANIUM MINERALS MINE

ENVIRONMENTAL REVIEW & MANAGEMENT PROGRAMME


VOLUME 1

JANUARY 2002

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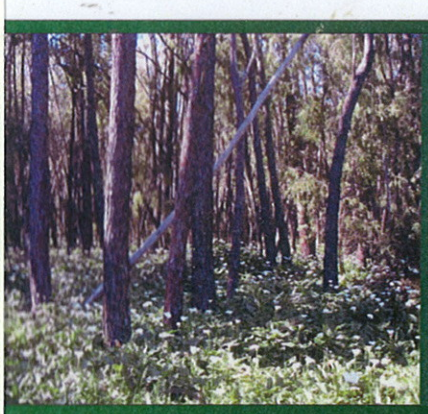
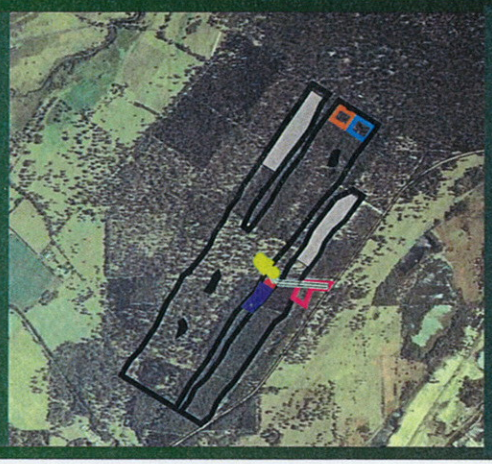


LUDLOW TITANIUM MINERALS MINE

ENVIRONMENTAL REVIEW & MANAGEMENT PROGRAMME


VOLUME 2 - APPENDICES

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Schedule 2

Proponent's Environmental Management Commitments

3 November 2003

Ludlow Titanium Minerals Mine
34 kilometres South of Bunbury
Shire of Capel

(Assessment No. 1385)

Cable Sands (W.A.) Pty. Ltd.

Proponent's Environmental Management Commitments

Schedule 2

Ludlow Titanium Minerals Mine, 34 kilometres South of Bunbury, Shire of Capel (Assessment No. 1385)

(3 November 2003)

Note: The term "commitment" as used in this schedule includes the entire row of the table and its six separate parts as follows:

- environmental factor;
- the objective of the commitment;
- a commitment number;
- the "action" to be undertaken by the proponent;
- the timing requirements of the commitment; and
- the body/agency to provide technical advice to the Department of Environmental Protection.

Environmental Factor	Objective	No.	Action	Timing	Advice
Environmental Management	To ensure environmental management is in accordance with EPA objectives and continually improves.	1	Prepare an Environmental Management and Monitoring Programme (EMMP) for the proposal. The EMMP will detail, among others, management for the following factors: 1. Vegetation and Flora; 2. Fauna; 3. Ground and surface water; 4. Greenhouse Gas; 5. Noise; 6. Dust and particulates; and 7. Radiation.	Prior to mining	DCLM, DoIR, Radiological Council

Environmental Factor	Objective	No.	Action	Timing	Advice
		2	Implement the EMMP.	During mine development and throughout mine life.	DCLM, DoIR, Radiological Council
		3	Publicly report environmental performance on an annual basis through the preparation of an Annual Environmental Report to be distributed through the Ludlow Working Party and other interested parties.	Operation and decommissioning.	
Vegetation Conservation	Maintain the abundance and diversity of species, and geographic distribution and productivity of vegetation communities.	4	Keep vegetation clearing to a practical minimum through mine planning initiatives.	Throughout project.	DCLM
		5	Implement an ongoing weed eradication program within the ML in cooperation with DCLM.	Before and during mining and for the first 2 years of the rehabilitation phase.	DCLM
	Assist in the conservation and management of Tuart Forests outside of the project area.	6	Provide to the Department of Conservation and Land Management funding of $830,000 for Tuart conservation initiatives. (Note: Procedure 4 at foot of statement sets out how these funds will be managed.)	Within 12 months following the commencement of mining.	DCLM
		7	Provide 56 hectares of land (Sussex Loc. 62 and Lot 2, plan 3280) to the Conservation Commission. Implement rehabilitation of this land in part to the value of $150,000 using methods agreed by DCLM.	Provision of land and rehabilitation of corridor within 2 years following the commencement of mining.	DCLM, LWP

Environmental Factor	Objective	No.	Action	Timing	Advice
		8	Provide 35 hectares of land known as the "Stratham Land" to the Conservation Commission.	Provision of land within 12 months following the commencement of mining.	DCLM
Fauna Conservation	Maintain the abundance, diversity and geographical distribution of native terrestrial and subterranean fauna. Protect Specially Protected (Threatened Fauna), consistent with the provisions of the *Wildlife Conservation Act 1950.* Improve understanding of subterranean fauna.	9.	Prepare a Fauna Management Plan (FMP) to address, among other issues, management of the following; 1. review of existing fauna; 2. clearing protocol; 3. employee awareness; 4. management of existing fauna; 5. habitat reconstruction; and 6. monitoring.	Prior to mining, or clearing of more than 25 hectares.	DCLM
		10	Implement within the appropriate areas a rabbit, fox and feral cat eradication program.	Before and during mining and for the first 2 years of the rehabilitation phase.	DCLM
		11	Conduct a sampling program of groundwater piezometers within the ML for the occurrence of subterranean fauna.	Prior to mining.	DCLM
Rehabilitation		12	Provide funding of $750,000, payable to DCLM in 3 equal annual instalments, for the rehabilitation of the unmined areas of the mining lease. (Note: Procedure 5 at foot of statement sets out how these funds will be managed.)	First payment within 3 months following the commencement of mining followed by two further payments one year and two years later.	DCLM

Environmental Factor	Objective	No.	Action	Timing	Advice
Water Quality Protection	Protect the quality of underlying groundwater so that surrounding users including native vegetation are not unduly effected. Ensure surface water quality is protected so that surrounding watercourses including the Ludlow River and Wonnerup Estuary are not unduly effected.	13	Prepare a Water Resources Management Plan (WRMP) to address, among other issues, management of the following: 1. review of the physical environment; 2. minimising water abstraction by recycling / reuse; 3. erosion control measures; 4. control of discharge water / turbidity; 5. controlling quality of the water circuit; 6. chemical and hydrocarbon storage; 7. contingency measures for spills; and 8. monitoring.	Prior to mining.	WRC
		14	Implement WRMP to the satisfaction of relevant authorities.	During mine development and throughout mine life.	WRC
Groundwater quantity	Ensure that the beneficial uses of groundwater can be maintained.	15	Prepare an Operating Strategy for Groundwater Abstraction which maintains beneficial uses.	Prior to mining.	WRC
		16	Implement Operating Strategy on advice of the relevant authority.	During mine development and throughout mine life.	WRC

Environmental Factor	Objective	No.	Action	Timing	Advice
Aboriginal Heritage	Ensure that the proposal complies with the requirements of the *Aboriginal Heritage Act 1972*; and Ensure that changes to the biological and physical environment resulting from the project do not adversely affect cultural associations with the area.	17	Prepare a Contingency Plan for the event of unearthing an Aboriginal artefact or archaeological material.	Prior to mining.	DIA
		18	Implement Contingency Plan as required.	If circumstances arise during mine development and throughout mine life.	DIA
European Heritage	Comply with statutory requirements in relation to areas of cultural or historical significance. Assist in the preservation and improvement of European sites of significance.	19	Consult with the Shire of Capel and local historians to define the location of heritage sites within the vicinity of the mining lease.	Prior to mining.	Shire of Capel, local historians
		20	Re-instate the location of heritage sites on completion of mining to the satisfaction of the relevant authority.	Post-mining.	Shire of Capel
		21	Donate mine production bore and power supply infrastructure to DCLM for upgrade of Ludlow Township services.	Post-mining.	DCLM

Environmental Factor	Objective	No.	Action	Timing	Advice
Noise	Protect the amenity of nearby residents from noise impacts resulting from activities associated with the proposal by ensuring that noise levels meet statutory requirements and acceptable standards. Ensure that noise and vibration levels meet acceptable standards and that an adequate level of service, safety and public amenity is maintained. (Road transport).	22	Submit and implement a Noise Management Plan (NMP) to include and address, among other issues, the following: 1. location of noise-sensitive premises; 2. baseline noise levels; 3. predicted noise contours; 4. noise control strategies; and 5. monitoring, for a two-week comment period to the Shire and the DEP.	Prior to mining.	Shire of Capel
		23	Make NMP publicly available with the comments of the Shire and DEP.	During mine development and throughout mine life.	Shire of Capel
Visual Amenity	Visual amenity of the areas adjacent to the project should not be unduly affected by the proposal.	24	Establish shelter belts along the road verge of Tuart Drive and Ludlow North Road utilising plant species approved by the Shire of Capel within the limits of adverse impacts by FPC, DCLM and the public.	Prior to mining.	Shire of Capel
Conservation Reserves	Secure the protection of the Tuart Forest National Park for the long-term.	25	The Managing Director of Cable Sands (WA) Pty Ltd will sign a letter stating that the Company will never pursue mining in the Tuart Forest National Park.	Within 2 months of the statement of environmental approval being issued.	-

Environmental Factor	Objective	No.	Action	Timing	Advice
Community Consultation/ Involvement	To ensure that interested community groups are kept informed of the project and that the proponent benefits from the experience and skills of these groups.	26	The proponent will continue to meet at least twice a year with the Ludlow Working Party (assuming members are interested). The LWP will continue as a forum for sharing information on the project to the wider community and receiving feedback. Specifically the LWP will be involved in: 1. Environmental Management and Monitoring Programme; 2. Mining and Rehabilitation Plan; 3. Water Resources Management Plan; 4. Fauna Management Plan; and 5. Fate of 56 hectare Wonnerup linkage.	Ongoing until completion of mining.	-

Abbreviations:

DCLM = Department of Conservation & Land Management
DEP = Department of Environmental Protection
DIA = Department of Indigenous Affairs
DoIR = Department of Industry & Resources
EPA = Environmental Protection Authority
FPC = Forest Products Commission
LWP = Ludlow Working Party
ML = Mining Lease
WRC = Water & Rivers Commission

LUDLOW TITANIUM MINERALS MINE M70/86 MINING AND REHABILITATION MANAGEMENT PLAN

Prepared by

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and

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June 2004

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2 POST MINING LAND-USE CONCEPT PLAN

The post-mining land use for the mining area will be consistent with that of the unmined parts of the LSF and the adjacent National Park, being for conservation of biological, physical, cultural and landscape values.

Rehabilitation will account for subtle variation in the existing environment in preference to treating the mining area as a single block. Consequently, the mining area has been divided into two landform/vegetation units, as listed below.

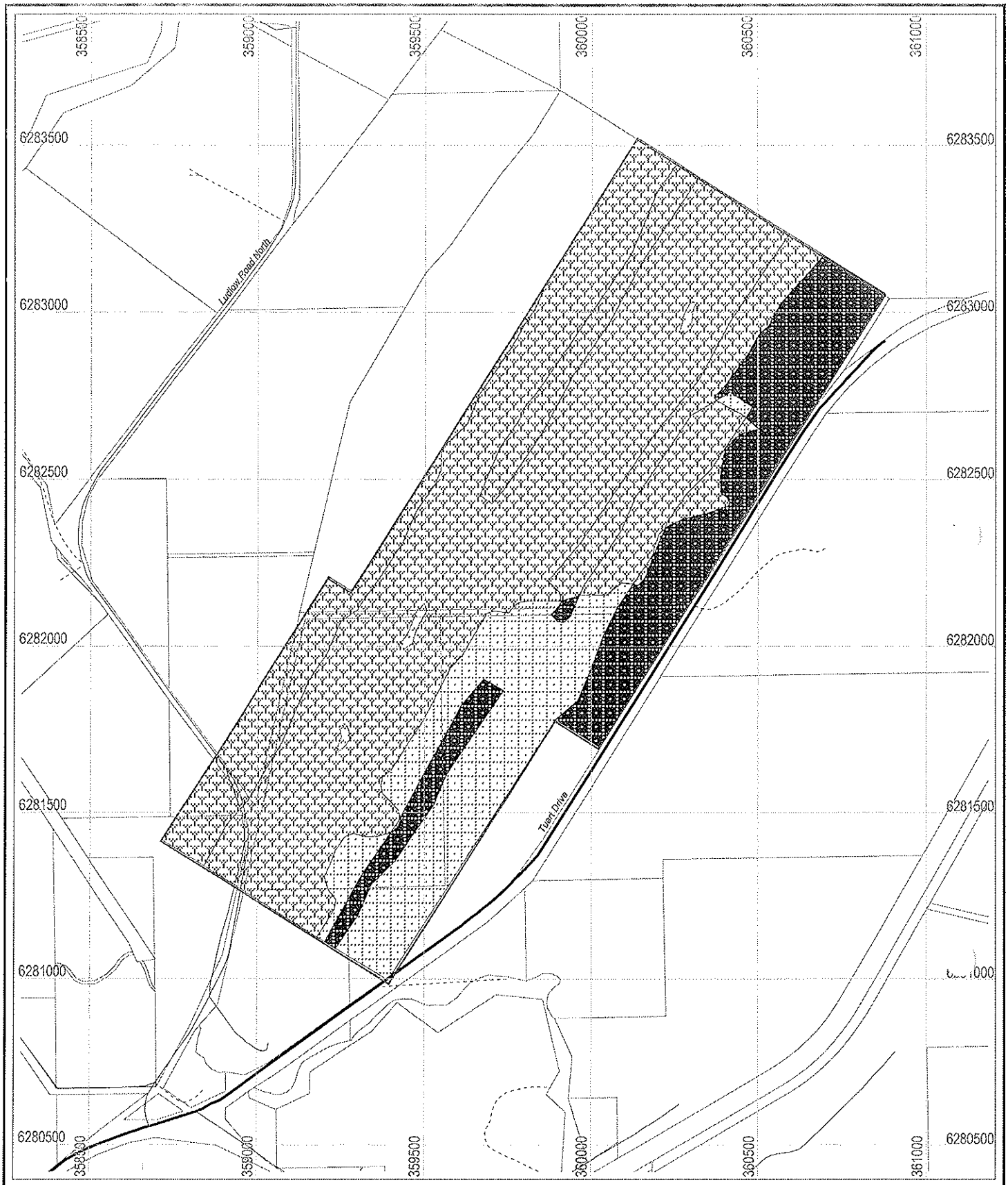
A Tuart Woodland on mined soils

- This landform unit occupies the largest area of the mining lease, including central and western portions of the mineralised zone.
- The area includes part of eight vegetation complexes as described by Bennett (2000), with seven complexes being either 'degraded' (1, 4 and 13) or 'completely degraded' (3, 5, 6 and 7), and one complex (14) assessed as being in 'good' condition.
- Revegetation will focus on reestablishing clumps consisting of pure stands of *Eucalyptus gomphocephala*, within a general ground cover of mixed low shrub species.
- Soil profile reconstruction is described in Section 5.

B Mixed Tuart/Jarrah/Marri Woodland on mined soils

- This landform unit is located primarily in the southeastern corner of the mining lease.
- The area includes part of five vegetation complexes as described by Bennett (2000), with four complexes being either 'degraded' (12) or 'completely degraded' (9 and 11), and two complexes (2 and 10) assessed as being in 'good' condition.
- Revegetation will focus on reestablishing a mixture of *Eucalyptus gomphocephala, E. marginata* and *Corymbia calophylla* in the upperstorey, an open tall shrub stratum comprising *Banksia, Acacia* and *Agonis,* and a ground cover of mixed low shrub species.
- Soil profile reconstruction is described in Section 5.

It is anticipated that all mine infrastructure will be removed from the mining lease at the completion of mining activities. This will include the main access road for the mine and plant pad (see Figure 5). Cable Sands will return tracks to their current location and standard, unless CALM indicates that current tracks are not required post-mining.



LEGEND:

- Tenement M 70/86
- Mining Tuart Forest
- Mining Tuart/Jarrah/Marri Forest
- Other Tuart Forest
- Other Tuart/Jarrah/Marri Forest
- Habitat_islands.shp

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CABLE SANDS (WA) Pty Ltd

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LUDLOW

Conceptual Post-mining land use plan for Ludlow mining lease

DWG No: LUAREH290304 FIGURE: 1

5 SOIL PROFILE RECONSTRUCTION PLAN

5.1 Scope of the Soil Profile Reconstruction Plan

The Soil Profile Reconstruction Plan has been integrated into the MRMP to facilitate its integration with mining operations. The scope of the Soil Profile Reconstruction Plan is defined by Condition 7-1 of Ministerial Statement No. 639, which states:

> 'The proponent shall conduct mining and rehabilitation in accordance with a Soil Profile Reconstruction Plan to ensure that soil profile reconstruction methods are optimised in regard to re-creating soil profiles suitable for the establishment of a Tuart forest ecosystem.
>
> Advisory agency (See procedure 3):
>
> - Department of Conservation and Land Management
>
> This Plan shall include the following:
>
> 1. work procedures to be followed in remaking soils in the mined-out sections of the orebody;
> 2. a record-keeping mechanism for recording the details of how work is actually carried out;
> 3. a progressive monitoring programme for sampling of reconstructed soils (particularly, the distribution of fines and Plant Available Water Capacity) as discrete sections of the mine pit are completed; and
> 4. a review mechanism which modifies work procedures based on the results of monitored outcomes.'

5.2 Pre-mining research into the edaphic requirements of tuart

Successful re-establishment of tuart requires knowledge of their growth characteristics so that rehabilitation strategies can be developed to maximise performance on the post-mining landform. Oracle Soil and Land Pty Ltd (OSL) conducted a study during 2001 to investigate the root distribution and water use patterns of tuart trees within the LSF and on previously reconstructed soil profiles following mineral sand mining at Yoganup Extended, 'Dunkley/Norton property' and 'Maidment property' (see Figure 7). The outcomes of this investigation are provided in OSL's report (2002), while major findings from the study are summarised below:

To further validate the root distribution and water use patterns of tuart trees within the mining lease additional studies of pre-mining soil profiles will be undertaken prior to mining. These studies will be co-ordinated so that they are implemented in conjuction with other clearing operations.

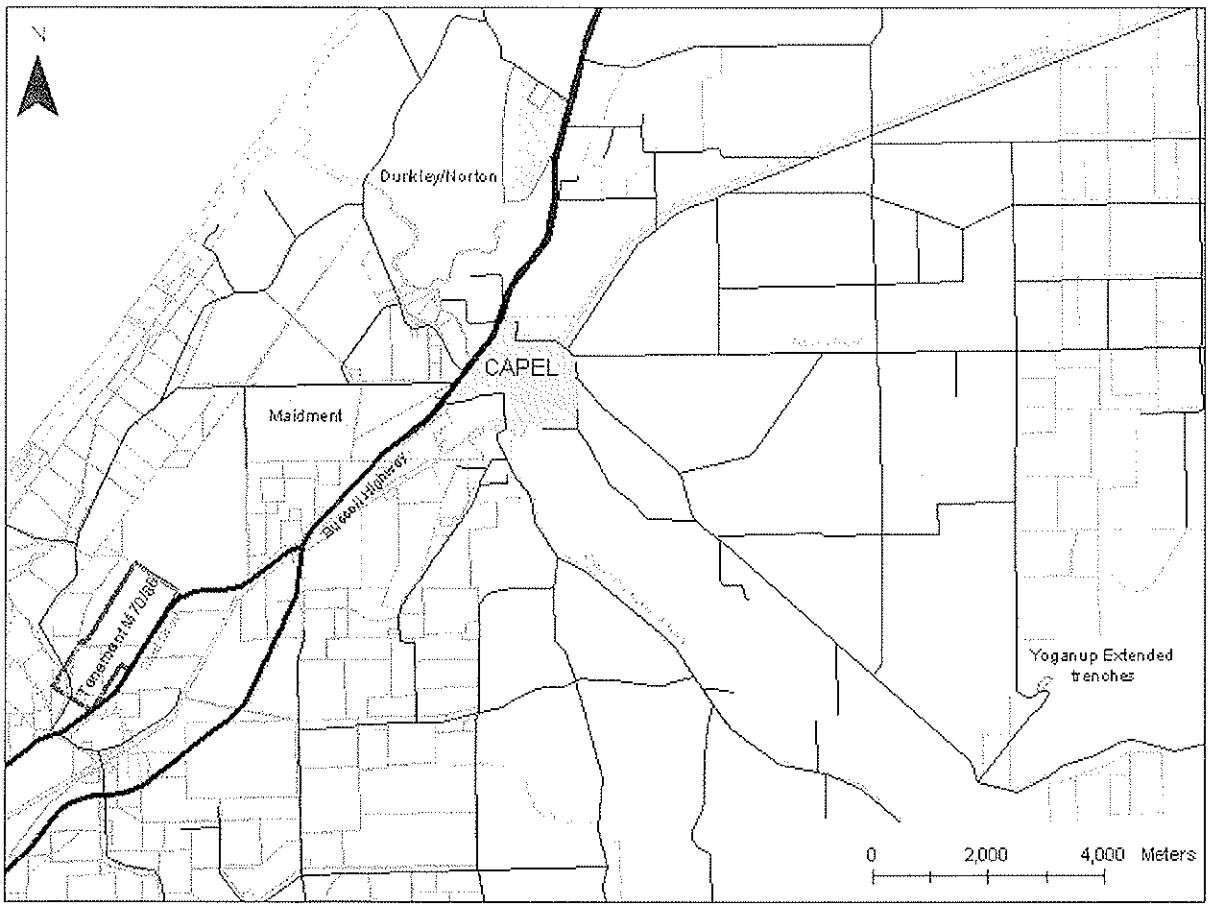

Figure 7 **Location of soil profile and tuart root distribution studies**

The root system of tuarts was observed via trenches excavated at the base of mature trees. The root system was similar to other eucalypts grown on deep sandy soils (*E. marginata*, *E. regnans*), comprising a large root bowl, radiating large surface laterals, abundant slope runner roots and an extensive sinker root system (Figure 8). The large root bowl is the dominant feature of the root system, consisting of abundant heart roots emanating from the rootstock and a dense network of fine and very fine roots. Extending from the root bowl and originating at the rootstock are numerous slope runner roots, which continue throughout the depth of the soil profile and are highly branched by horizontal and sinker roots. The surface lateral root system, which generally occurs in the surface 20cm of the soil profile, consists of large primary laterals radiating from the base of the tree. Smaller secondary laterals branch along the entire length of the primary laterals and a dense fine and very fine feeder root system is associated with both types of laterals. Sinker roots, which branch from both the primary and secondary laterals, traverse the entire soil profile.

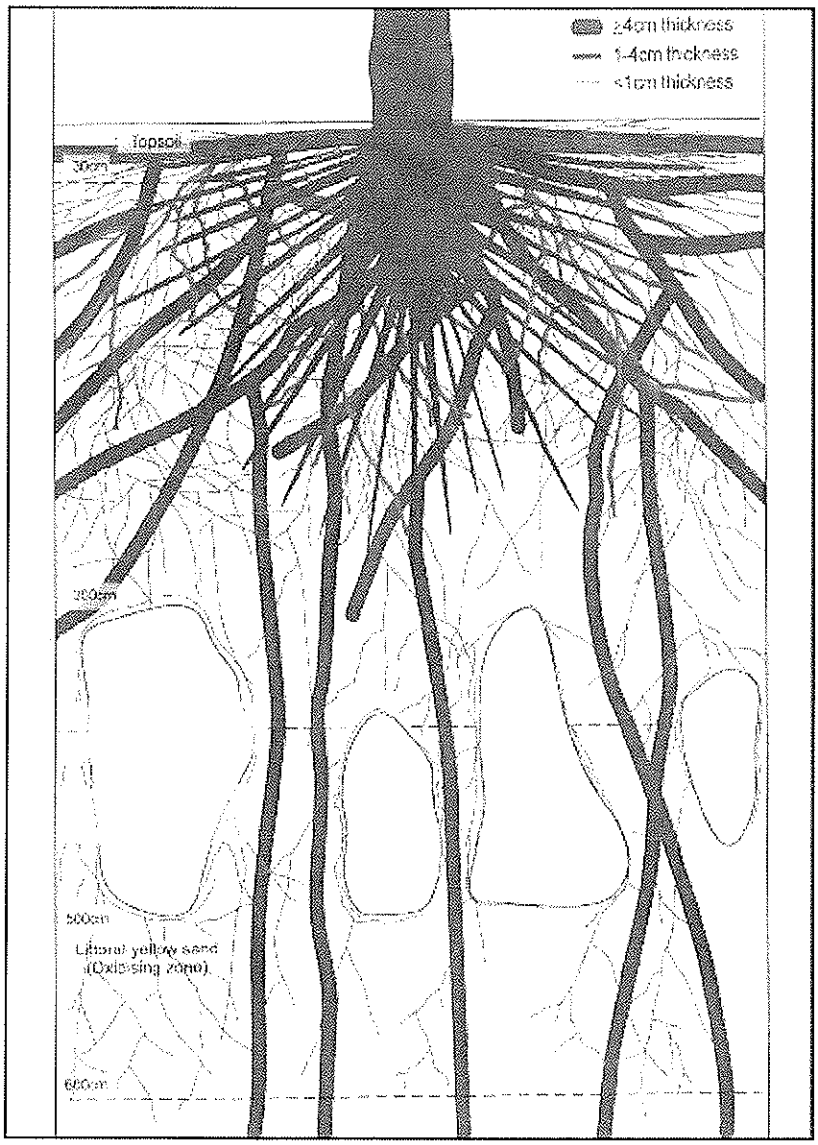

Figure 8 Typical root morphology of tuart at Ludlow (From: OSL, 2003)

Although the characteristic features of the root system were observed for all studied tuarts, variations existed in response to the depth to groundwater. On the eastern side of the LSF, where a permanent relatively shallow water table and capillary fringe occurred, horizontal roots branching from the slope runner and sinker roots dominated the root system. Large roots occurred only in the surface oxidising aeolian sand, with fine and very fine roots common in the reducing littoral sands. In contrast, on the western side of the LSF, where deep groundwater occurred, large vertical roots with minimal horizontal branching dominated the root system.

The plasticity of the root system of tuarts was highlighted at the Dunkley/Norton Property where a shallow soil profile reconstructed post-mining occurred above a clayey substrate belonging to the Cokelup Soil Series. The presence of a thin fines layer of massive structure beneath the topsoil restricted the vertical growth of large roots, with medium to fines roots only penetrating the fines layer along drying cracks. These vertical roots passed through the thin tailings sand layer and branched extensively at the surface of the clayey substrate. Fine and

very fine roots entered the clay, growing along structural surfaces within the clay; abundant fine and very fine roots occurred along all structural faces.

Good tuart growth was observed on deep reconstructed soil profiles at the Yoganup Extended Minesite, with trees reaching 14m in height after 14 years. The observed root system at this site resembled that of tuart trees observed on the western side of the LSF, where large vertical sinker roots dominated. Incorporated fines material was heavily accessed by fine and very fine roots, which occurred abundantly on all structural surfaces of this material. It is likely that roots were utilising this material as a water source, as the Plant Available Water Content (PAWC) of the fines material was considerably greater than the surrounding tailings sand.

Roots of tuart on unmined area were observed to colonise adjacent reconstructed soil profiles. At the Maidment property tuart roots extended up to 3m into the tailings sand of the reconstructed soil profile after 5 years. Dense root clusters were also observed adhering to the surface of fines material within the tailings sand.

The observed plasticity of the root system of tuarts is a highly desirable characteristic for their use in the revegetation of disturbed lands. The root system is adaptable to a variety of soil conditions and their moderate to good growth rates (approximately 1m/yr) makes them an attractive tree species for revegetation.

5.3 Summer water use patterns of tuart

Pre-dawn and diurnal leaf water potentials were measured in both remnant mature tuart trees and tuart trees planted on reconstructed soil profiles, to determine their summer water use patterns. The pre-dawn leaf water potential of remnant mature tuart trees remained relatively low throughout the summer period, indicating that these trees had access to a permanent source of water. However, high leaf water potentials developed by midday, throughout summer, suggesting that these trees were not accessing groundwater, instead they relied solely on water stored in the soil profile.

Measurements of the moisture content of native soil profiles indicate that considerable drying of the soil profile occurs to a depth of 4 to 5m. Drying of the sandy soils results in high soil water potentials developing (>1500kPa), making water within this zone unavailable to plants. Based on these results and observations of tuart root distribution, tuarts are dependent on water within the capillary fringe to survive the summer drought. The consistently low pre-dawn leaf water potentials throughout the summer period indicate that the capillary fringe is continually replenished by groundwater. This is a daily event, occurring overnight, when trees are not transpiring.

The summer water use patterns of tuart trees successfully growing on reconstructed soil profiles were similar to those growing on native profiles. This implies that tuart trees at the Yoganup Extended Minesite were accessing the capillary fringe at 9m of depth, as soil testing indicated negligable plant available water from the soil profile. Poorly performing tuart trees at the Yoganup Extended Minesite exhibited increasing water stress throughout the summer period. This was directly related to the root distribution of these trees, which was confined to the surface 2.2m of overburden material. These trees rely on a finite source of water, stored within incorporated fines material in this overburden zone.

5.4 Behaviour of tailings sand and fines material in reconstructed soil profiles

A detailed examination of the properties of tailings sand and fines material in reconstructed soil profiles was undertaken. These materials are by-products of the heavy mineral extraction process and are used to reconstruct the soil profile following mining. The properties of these soil materials will strongly influence the characteristics of the reconstructed soil profile and will ultimately influence rehabilitation performance.

While tailings sand properties resemble those of native sandy soils, the principal difference between the two is the abundance of soil particles of between 250 µm and 380 µm in size (coarse sand). This has a significant effect on the pore size distribution, and hence the water retention characteristics of the soil. Tailings sand has a greater macroporosity than native sands, which results in a lower total water storage and PAWC (see Table 4). From a mechanical and root growth perspective, the tailings sand and native sands are equivalent. Chemically the tailings sand resembles the native sands, however slightly lower nutrient and exchangeable cation values were recorded. The lower values were likely due to the removal of fines material. When the entire reconstructed profile is considered (i.e. tailings sand and fines material), these differences are removed.

Fines material has an inherent massive structure, which restricts plant root growth. The high bulk density and soil strength of the fines matrix severely impede root penetration, and roots are confined to the outer surfaces of, and drying cracks within the material. Consequently it is inappropriate to return fines material to the profile as a uniform layer. It is recommended that fines material be reincorporated as small aggregates. This will increase the surface area accessible to plant roots; this is essential as this material represents an important water and nutrient source for plants.

To further investigate the status of available water within reconstructed soils, daily soil moisture changes were modelled over a five year period (1998 to 2002) for both unmined and proposed reconstructed soil profiles in the LSF (OSL, 2003). The major outcomes from this modelling exercise are illustrated in Figure 9 and are summarised below:

1. Soil moisture contents within the unsaturated portion of proposed reconstructed soil profiles were similar to those calculated for native sandy soil profiles;

2. Noteworthy differences in soil moisture contents did occur at the end of the summer period, where soil moisture contents in the reconstructed soil profiles were lower than in the native soil profile; however, this difference was only short-lived with rapid replenishment of all soil profiles occurring with the onset of autumn rains;

3. For the surface 1m soil zone, the number of days per year where the soil moisture content exceeded 70% PAWC differed by only 9 days between the unmined and mined soil profiles. This difference increased to 30 days per year when roots of developing trees were accessing soil moisture to 4m depth. At no stage however, did the remade soil profiles become completely depleted of plant available water (ie. 0% PAWC). Therefore, tree death due to moisture stress is considered unlikely.

4. When accessing the capillary fringe at 4.3m the differences between the unmined and mined soil profiles diminished.

This soil water modelling study concluded that tuart growth and development will occur to a similar extent as in unmined areas, and that a sustainable tuart forest, with the equivalent status and vigour, can be re-established following mining (Oracle Soil & Land 2003).

Table 4 Physical and chemical properties of aeolian and littoral deposited sand at the Ludlow State Forest, and for tailings sand and fines material at three post-mining sites where tuart has been successfully reestablished (from: OSL 2002).

Properties	Natural	Post-mining Tailings Sand			Post-mining Fines Material		
	Ludlow State Forest	Maidment	Dunkley Norton	Yoganup Extended	Maidment	Dunkley Norton	Yoganup Extended
Physical							
% Coarse + Medium Sand	71.4	74.2	80.2	80.0	47.8	66.3	0.8
% Fine Sand	23.4	21.9	16.4	15.9	27.1	16.8	13.3
% Total Sand	94.8	96.1	96.6	95.9	74.9	83.1	14.1
% Silt	0.9	0.2	0.5	0.4	5.4	1.0	10.2
% Clay	4.4	3.2	2.9	3.7	19.6	15.9	75.7
Bulk Density (g/cm^3)	1.63	1.69	1.68	1.58	1.83	1.70	1.57
Soil Strength (Mpa)	0.49	0.40	0.53	0.63	1.60	2.54	>3.00
Field Capacity (cm^3/cm^3)	0.085	0.051	0.047	0.050	0.530	0.223	0.649
Permanent Wilting Point (cm^3/cm^3)	0.022	0.009	0.013	0.017	0.380	0.122	0.579
Plant Available Water Content (cm^3/cm^3)	0.063	0.042	0.034	0.033	0.150	0.101	0.070
Total Porosity (%)	42.3	46.0	42.0	37.8	57.0	42.1	72.5
Chemical							
$pH_{(1:5)}$ water	6.8	7.4	6.3	6.2	7.0	5.6	5.9
$EC_{(1:5)}$ (mS/m)	1.6	1.8	1.6	0.8	5.8	6.0	12.8
% Organic Carbon	0.17	0.04	0.13	0.10	0.85	0.58	0.40
NO_3 - N (mg/kg)	2	2	2	2	5	3	3
NH_4 - N (mg/kg)	1	1	1	1	1	1	1
Colwel P (mg/kg)	4	2	2	1	8	5	3
Colwel K (mg/kg)	26	40	36	21	125	92	115
Extractable S (mg/kg)	4.8	1.5	2.3	5.5	7.6	7.0	104.0
Reactive Fe (mg/kg)	363	176	200	273	1418	984	244
Ca (meq/100g)	0.23	0.42	0.16	0.10	7.65	0.90	1.34
Mg (meq/100g)	0.13	0.17	0.19	0.12	1.66	1.00	2.49
Na (meq/100g)	0.07	0.07	0.07	0.02	0.24	0.30	0.65
K (meq/100g)	0.07	0.10	0.06	0.14	0.33	0.23	0.27
CEC (meq/100g)	0.50	0.76	0.48	0.38	9.88	2.43	4.75
ESP (meq/100g)	14.3	7.2	14.6	6.2	2.34	12.40	13.68

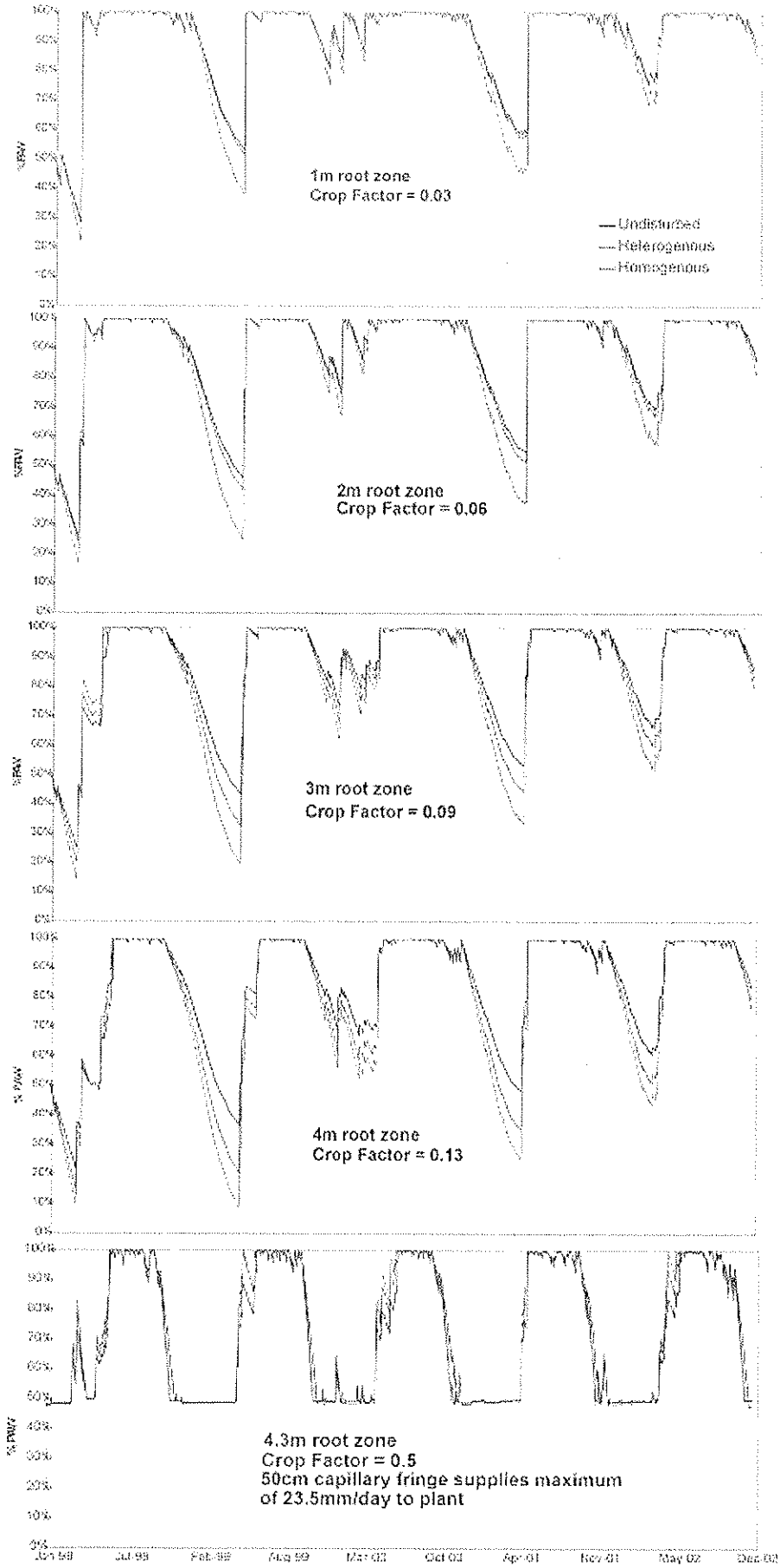

Figure 9 Soil water use by tuarts in mined and unmined soils at Ludlow (From: OSL, 2003).

5.5 Procedure for soil profile reconstruction

Principle Work Instructions:

- **WI 074 – Soil Profile Reconstruction**
- **WI 069 – Site preparation procedures**
- **WI 223 - Topsoil management**
- **WI 377 - Erosion and sediment control**
- **WI 279 - Dieback and weed hygiene**

Cable Sands primary objective for re-creating the post-mining soil profile at Ludlow will be to redistribute the small percentage of fines material within the sand tailings component as far as practical. The technique adopted to achieve this outcome consists of a sequence of the events described below and illustrated in Figure 10.

Step 1: Discharge of fines with sandy taillings

Fines laden water will be discharged directly within the tailings stream during landform reconstruction. An operating objective of the wet separation plant will be, without compromising production, to maximise fines return within the tailings stream. This technique will ensure fines particles are homogenously mixed with tailings sand particles, providing the greatest PAWC benefits in the low fines deposit.

At Maidments this technique resulted in approximately 40% of fines material returned via this method. With improved control over this process it is estimated that approximately 50% of fines material will be returned via this method at Ludlow. While difficult to predict accurately, the PAWC of this soil is expected to be approximately 4.2%.

Step 2: Excavate and fill fines dams on reconstructed ground

The remaining 50% of fines material will be collected in shallow dams which will be constructed across almost all of the remade tailings areas.

To provide additional quantities of tailings sand necessary to cover the homogenously mixed material (step 4), additional bund walls will be installed during construction to subdivide the dams into smaller sized units. To further increase the volume of sandy tailings available for mixing these walls will be pushed up higher then necessary for fines storage (approximately 2m high).

This technique will also assist the placement of the fines material deeper into the soil profile as, by pushing up bund walls, the dam floors will be excavated into the remade ground.

Fines slurry will then be progressively deposited into the dams to depths averaging 50-60cm. Deposition of fines slurry to such shallow depths will facilitate the ease of subsequent handling and blending with tailings sand.

Step 3: Blending of moist fines with sandy tailings

The fines will be partially dried, until it is at a consistency that is practical to handle with a bulldozer, but is not solid (ie. the fines will still be pliable). A bulldozer will then be used to open up large furrows in the still moist fines material. In the process, the bulldozer will drag underlying tailings sand from the base of the fines dam up into the fines material. Due to the fines material still containing a high moisture content, the mechanical agitation of the bulldozer working the sand will mix the two components.

Step 4: Incorporation of dam bunds with moist fines

While the fines are still in a moist state, sand from the bund walls will be pushed over the homogenous blend. This further mechanical agitation by the bulldozer will increase the blending of sand into the fines.

Step 5: Blending of dried upper homogenous blend with lower sandy tailings

Once sufficiently dry, the fines material will be mixed into the underlying tailings sand using a bulldozer ripping to a minimum depth of 1.7m below the finished surface. To assist and improve the blending process, Cable Sands will develop new tillage equipment. This equipment will rip the soil profile to greater depths (up to 2.5m) than conventional equipment and also enhance the mixing of soil components. For example, such an implement may incorporate a mullboard type plough on a ripper tyne.

Step 6 (not illustrated): Topsoil replacement and final ripping

Stockpiled topsoil will then be replaced to a depth of approximately 20cm and the profile re-ripped to a maximum of up to 2.5m in depth as described in Section 4.8. A single winged tyne will be used, with the primary object being to lift and aerate the soil rather than invert and mix. Final landform contours at this stage are expected to average ± 25cm of the original contours.

5.6 Soil profile outcome

Figure 11 below provides an illustration of an indicative reconstructed soil profile that will be reconstructed at Ludlow. The depths and PAWC of soil layers in the figure are indicative only as actual outcomes across the site will vary in response to variability in the landform been mined and practical limitations in the equipment and machinery used.

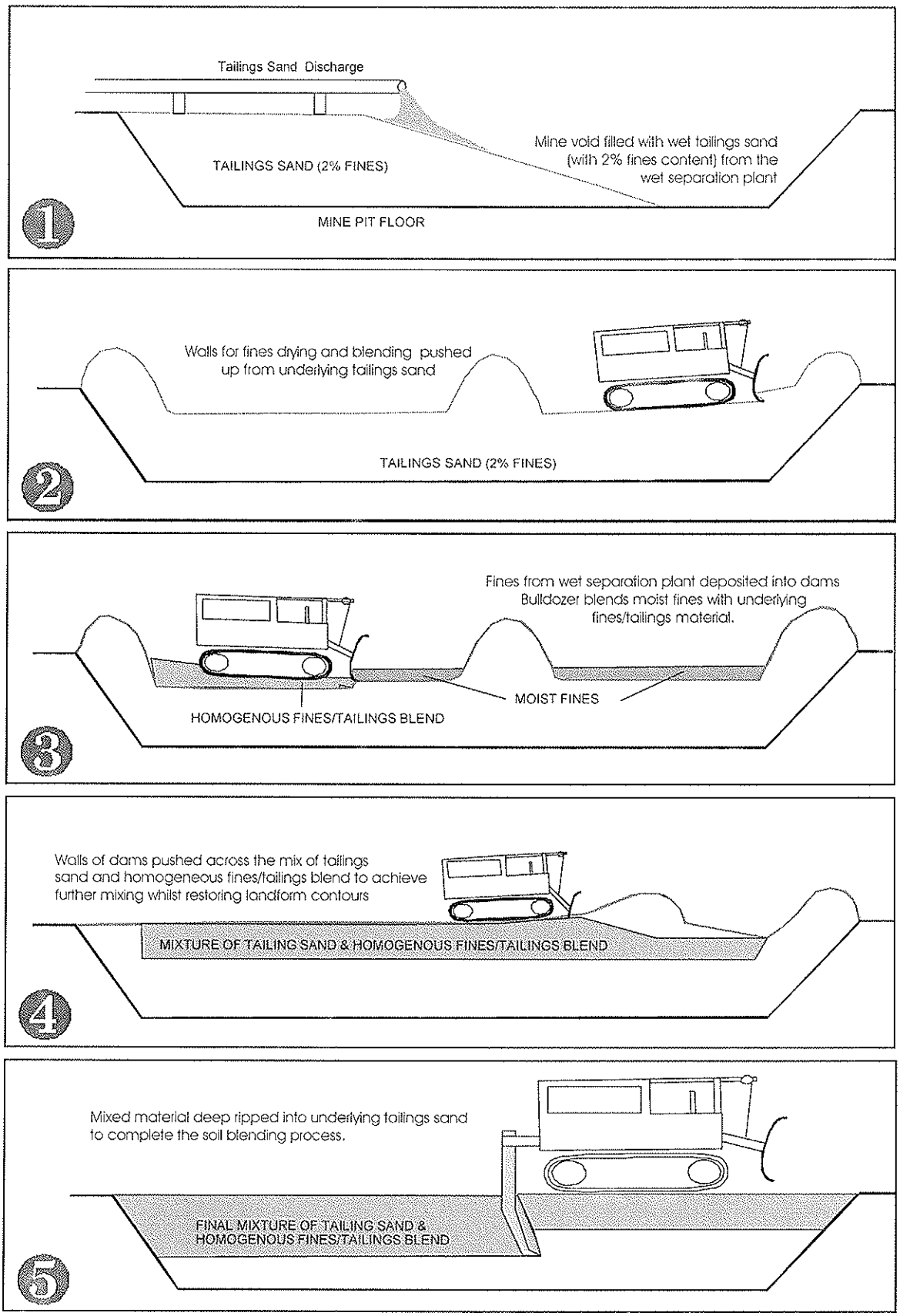

Figure 10 **Soil profile reconstruction strategy.**

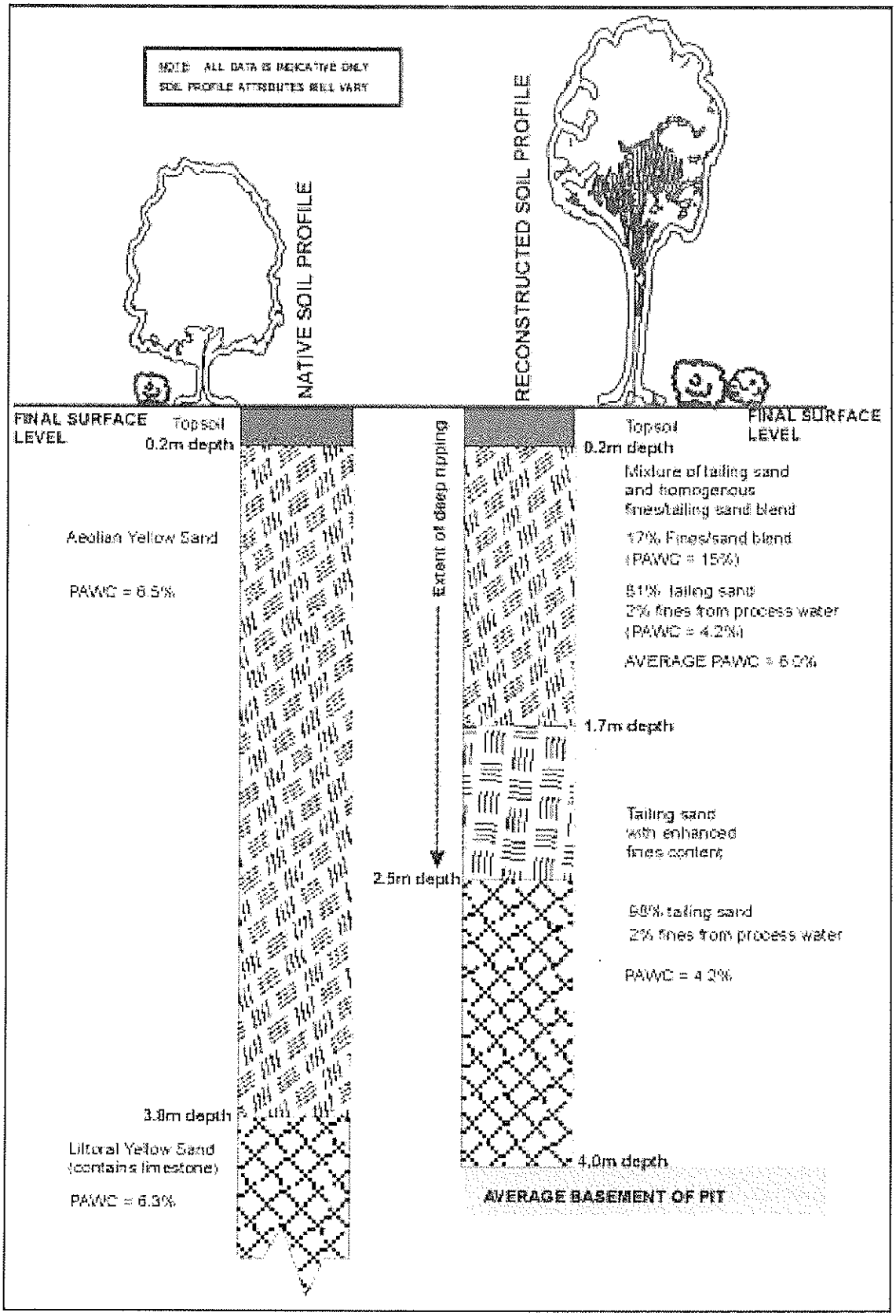

Figure 11 **Indicative Ludlow post mining reconstructed soil profile.**

5.7 Progressive monitoring of soil profile reconstruction

The chemical and physical properties of the reconstructed soils will be important for establishment and growth of revegetation. To ensure that soil profile reconstruction strategies produce a soil profile that will support sustained plant growth, post-mining reconstructed soils will be investigated regularly as set out below.

Chemical properties of the reconstructed profile are likely to be little-affected by mining and processing (Table 4), and therefore are likely to simply reflect the properties of the starting materials. However, physical properties will be changed during disturbance, processing and deposition. Therefore, physical properties of the reconstructed soils, such as bulk density, soil strength, particle size distribution, and distribution of fines, will be the focus of the monitoring program (Table 5). The proposed monitoring program includes the monitoring approach and timing for the soil re-construction process.

To enable the monitoring regime proposed below, preliminary investigations will be conducted as follows during the early stages of operation:

a) *Confirmation of key soil properties in the mined areas and of fines and sand separation during processing*

Soil investigations completed prior to mining were based on data from over 880 drill holes (approximately equivalent to 4 / ha), and from 2 excavated soil pits in the northern end of the orebodies. In order to confirm soil properties predicted from these investigations, and to provide a basis for evaluating the separation of fines and sands during processing, soils in the first area mined (Figure 5) will be characterised in more detail. Soils will be sampled during mining (from in-situ mining pit face), or prior to mining if more practical, at 24 sites across the mining area (approx 12 ha). Data collected will include particle size distribution (proportions of sand, silt, and clay) at 1 m depth intervals, and soil strength and bulk density. Plant Available Water Content (PAWC) analysis will be conducted for each site. This data will provide a baseline for comparison with levels of fines-enrichment achieved in the deposited sand tailings, and allow the effectiveness of the proposed fines-enrichment strategy to be confirmed.

b) *Distribution of fines in tailings after hydraulic deposition*

To confirm that sorting of fines and coarse fractions does not compromise the benefits from a fines-enriched tailings stream, the first completed area of deposited tailings will be investigated. Cores of the tailings profile will be taken to the base of the deposit, at increasing distances from the point of deposition. Fines content throughout the extent of the core will be measured at each location. If required, refinements to tailings deposition strategies may be used to minimise any apparent sorting.

The proportion of fines in the deposited tailings throughout the deposited area will then be calibrated against the proportion of fines in the initial tailings stream. Once a satisfactory relationship has been confirmed, then the measure of fines in the tailings stream will become the sole measure for fines content in the deposited tailings profile.

c) *Plant available water content (PAWC) in fines-enriched tailings*

Achieving improved PAWC in the tailings is a key outcome from enhancing the fines content in the tailings stream. During early stages of mineral processing, the relationship between PAWC and the fines concentration of tailings samples will be confirmed, over an

confirmed, over an appropriate range of fines concentrations by comparisn with PAWC analysis from not less than two samples from each core taken . By carefully establishing this relationship, and with consideration of information from (b) above, the PAWC in deposited tailings throughout the life of the operation will be able to be inferred from the measured fines content in the tailings stream, and will not be measured directly.

Table 5 Proposed monitoring approach, schedule and criteria, to confirm appropriate soil reconstruction in the Ludlow titanium minerals mine.

Steps in soil profile reconstruction (from section 5.5)	**Key properties of interest after each step**	MONITORING	
		Technique	**Timing**
Step 1 Tailings deposition	Fines content	Sampling of tailings stream at wet plant	Daily
Step 5 Blending of dried fines/sand blend with underlying sand tailings	Distribution and mixing of fines to minimum 1.7m below finished surface.	Visual rating system to be used on soil face exposed to at least 1.7m	After ripping and mixing
	Maximum size of fines aggregates	Visual inspection of exposed profile and and measurement as required	After ripping and mixing
	Bulk density in surface 1.7m	Bulk density cores taken in tailings sand to 1.7m depth in exposed soil profile	After ripping and mixing
	Soil strength to 1.7m depth	Penetrometer readings in exposed soil profile	After ripping and mixing
	Ripping depth	Visual inspection of exposed profile, and/or drop-penetrometer measurements in rip lines	After ripping and mixing
Step 6: Topsoil replacement and final ripping	Topsoil depth	Excavation and measure exposed profile	After topsoil replacement, and before final ripping
	Topsoil strength	Penetrometer	After final ripping

6 REVEGETATION

The revegetation objective will be to reinstate a pre-determined vegetation type for the two post mining landform/vegetation units described in Section 2; a) Tuart Woodland, and b) Mixed Tuart/Marri/Jarrah Woodland. A concept plan for the revegetation strategy is illustrated in Figure 12.

Revegetation of the post-mining landform across the larger area (tuart woodland, to the west) will deal with the establishment of overstorey within localised 'tuart clumps', comprising a combination of ashbed heaps and furrowline plots. The tuart clumps will be evenly distributed, accounting for appropriate setbacks from retained mature tuarts trees within the mine path and vegetation present on adjacent unmined ground. The minimum density of tuart clumps will be 10 per ha, comprising 5 ashbed heaps per ha (10m by 15m dimension) and 5 furrowline plots per ha (15m by 30m dimension). The density and size of tuart clumps incorporated into the rehabilitation plan is based on:

- Assessment of the current and historical rehabilitation activities of FPC and CALM at the Ludlow Tuart Forest, i.e. counting density and size of ashbed heaps previously achieved at a number of rehabilitated sites;
- An estimate of the volume of timber debris likely to become available for establishment of ashbeds following removal of remaining pines; and
- Tuart density estimates made by early settlers to the area that suggest a fully stocked forest of senescent trees (equivalent to 15 senecent tuarts per ha).

The layout of the upperstorey in the rehabilitation aims to provide a minimum initial footprint of 30 percent, with tuart clumps positioned along a curved grid to provide the foundation for establishment of a woodland structure, without creating the short term appearance of a tree plantation. High density planting of tuart within localised clumps provides the foundation for long term establishment of the woodland structure. Competition between trees within individual clumps has been shown to encourage rapid growth and contribute to the tall tree form for which the Ludlow area is renowned. Intra-clump competition between tuarts is expected to result in condition-scale classes, with a smaller number of larger healthier trees becoming progressively dominant within each tuart clump over time.

For the smaller revegetation area to the east (mixed tuart/marri/jarrah woodland), tuart clumps will average 2.5 per ha with broadscale planting of *Corymbia calophylla* and *Eucalyptus marginata* seedlings across the entire rehabilitation unit.

A low shrubland understorey structure will be reestablished between the mosaic of tuart clumps in the post mining landform, with variation in species composition between tuart woodland and mixed tuart/marri/jarrah woodland. The structure will benefit broadscale treatment of annual grasses, with the established native cover increasing competition and suppression of the annual grass component. The availability of seed and appropriateness for species to be reestablished by direct seeding will be important factors controlling composition and sowing rate of the final seed mixture. *Agonis flexuosa* (peppermint) will not be actively encouraged through direct seeding or planting due to its tendency to establish vigorously in open areas and outcompete other native species. It is likely to volunteer naturally via seed in respread topsoil and from adjacent unmined ground.

Four broad revegetation techniques will be implemented across the mining lease to achieve the above objective (see Table 6).

Table 6 Revegetation techniques to be applied within the two post mining landform/vegetation units.

Revegetation Technique	(A) Tuart Woodland		(B) Mixed Tuart/Marri/Jarrah Woodland	
	Tuart Clumps	Low Shrubland	Overstorey	Understorey
Direct seeding	✓ (ashbeds)	✓	✓	✓
Planting	✓ (furrowlines)	✓	✓	✓
Translocation		✓		✓
Advanced Tuart Trees	✓		✓	

6.1 Direct Seeding

Direct seeding is an appropriate method for increasing biodiversity and achieving rapid establishment of a vegetative cover, which will be particularly important for controlling reemergence of introduced weeds from the topsoil store at Ludlow.

The rehabilitation program will utilise seed supplied by an experienced operator, familiar with the Ludlow area. All collections will be provenance correct and harvested under a permit from CALM. Correct provenance for rehabilitation of the Ludlow minesite will be defined as any part of the Swan Coastal Plain south of and including Yalgorup National Park.

Optimising the success of direct seeded species will require appropriate pre-treatments to overcome seed dormancy. Germination during the first growing season will be maximised by pre-treating all legume species with boiling water prior to sowing. There will also be appropriate boiling and scarification treatment of other hard-seeded species; smoke treatment will also be considered where appropriate.

The timing of direct seeding will be dependent on completion of specific site preparation techniques, and as such will not occur until late April/early May at the earliest, and end of July at the latest.

Overstorey

Regeneration of tuart by direct hand seeding will be restricted to ashbed heaps. Optimum sowing time will be late May, following burning of the heaps. Subject to availability, tuart seed will be direct sown at a rate equivalent to 250g per hectare with no less than 150 g per hectare applied.

Within the mixed tuart/marri/jarrah woodland, a variety of other tall shrub and tree species, including *Corymbia calophylla, Eucalyptus marginata, Banksia attenuata* and *B. grandis*, will be reestablished at least partially through direct seeding (see Table 7).

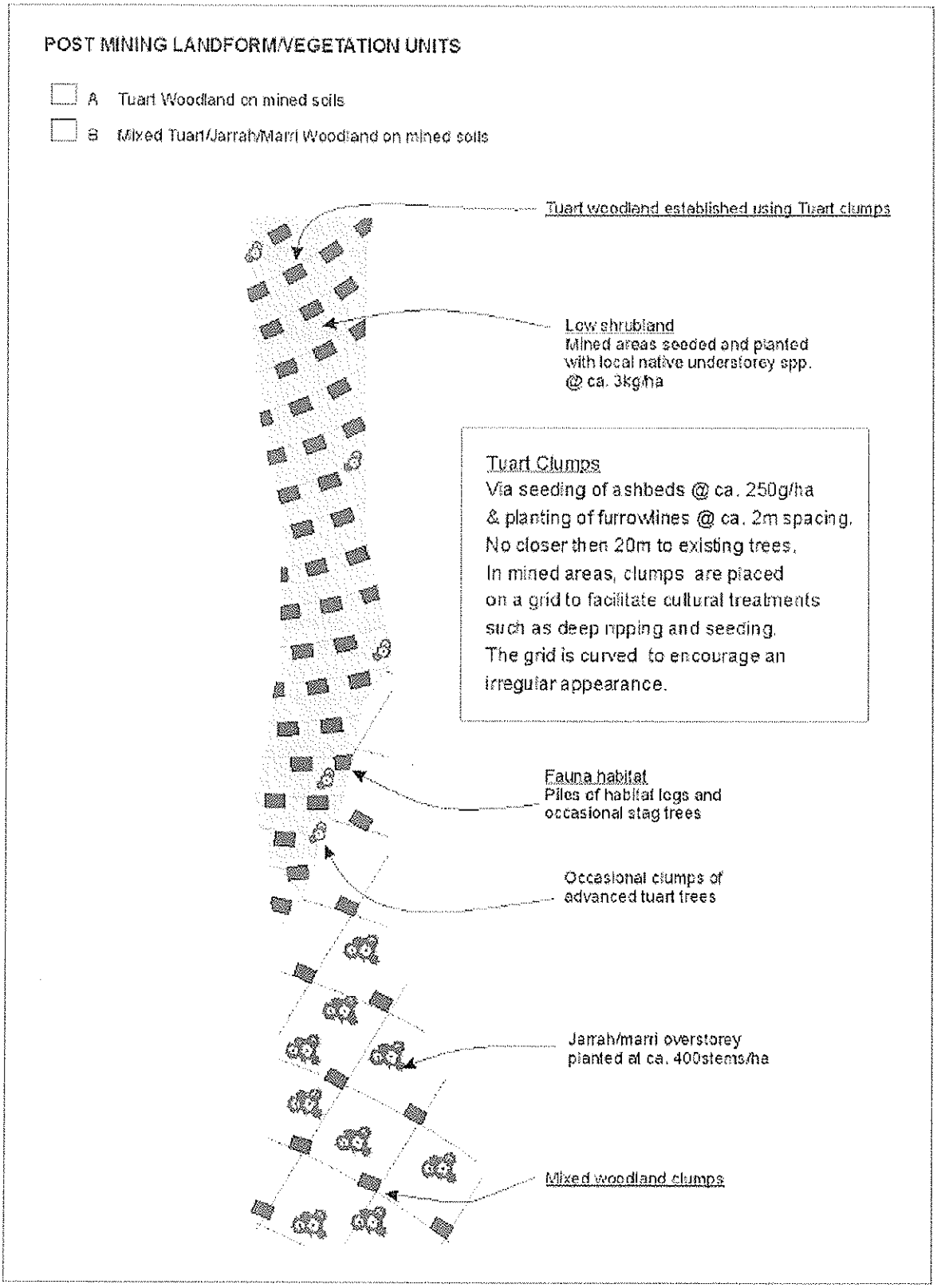

Figure 12 Concept plan for revegetation strategy.

Understorey

The species composition sown within the mixed tuart/jarrah marri woodland on the eastern side of the mining area will differ to that applied over the tuart woodland on the western side of the mining area (see Table 7).

Subject to availability, there will be direct seeding of selected understorey taxa over the post-mining landform at a total rate approximating 3 kg/ha with no less than 1.5kg/ha applied. Sowing rates for individual species in the final mix will be influenced by seed availability, seed quality and germination characteristics, and the relative importance of each taxa in the revegetation.

Cable Sands will consult with CALM and the DOE on the final understorey species list prior to implementation of the first staged rehabilitation event.

6.2 Planting

Principle Work Instruction:

- **WI 152 - Planting Native Seedlings**

A number of species occurring within the mining lease survive fire and other disturbance by resprouting from epicormic buds, lignotubers, rhizomes, corms, tubers or bulbs. Some of these resprouters also regenerate readily from seed, while for others this is rare (recalcitrant species). Regeneration from seed may be limited by low or infrequent seed set, low seed viability, the requirement for specific germination stimuli, or a short-lived seed bank. For species that only set small quantities of viable seed, seedlings will be propagated from this resource in the nursery and then planted into prepared rehabilitation areas. For species where seed collection or germination of seed is not possible, plants will be produced by vegetative propagation using cuttings or rootstock material. Commercial nurseries will be contracted to supply much of the required stock, with the balance supplied by Cable Sands' own nursery in Bunbury. All nurseries will be required to operate in accordance with the Nursery Industry Association of Australia's *NIASA Best Practice Guidelines.*

Overstorey

Nursery-grown tuart seedlings will be planted at 2m intervals along furrowlines, equating to approximately 75 tuart seedlings per furrowlined 'tuart clump' (30m long by 15m wide). In addition, where direct seeding of ashbed heaps is unsuccessful, infill planting with tuart seedlings will occur to ensure a minimum density of 15 tuarts per ashbed during the first growing season. Fertiliser tablets will be buried at the time of planting approximately 15-20cm from the base of seedlings to encourage tree growth, whilst discouraging weeds.

In addition to conventional tubestock, advanced tuart seedlings grown in the nursery for up to three years will be planted in small groups outside the tuart clumps to provide an immediate age class structure.

Within the Mixed Tuart/Jarrah/Marri Woodland complex, *Corymbia calophylla* and *Eucalyptus marginata* seedlings will be planted outside the 'tuart clumps' at a combined density approximating 400 stems per ha. Other tree species including *Banksia attenuata* and *B. grandis* will be planted to provide a lower tree stratum.

Understorey

Because of the short period between collection of seed (usually completed January/February each year) and planting time (May-August), seed and cuttings for tubestock production of understorey species will be collected in the year prior to planting to ensure a sufficient period for propagation.

Seedlings for understorey species will be planted evenly across the rehabilitation site. With a variety of other understorey species also developing from seed, the re-established vegetation is expected to have a suitably randomised distribution.

6.3 Inoculation with mycorrhizal fungi

Seed and seedlings used for rehabilitation will be innoculated with mycorrhizal fungi. The following steps will be required to:

1. Collection of mycorrhizal fungi as inoculum.

Putative mycorrhizal fungi will be collected during the fruiting season (July-September) from under tuarts in the Ludlow Forest.

2. Preparation of mycorrhizal inoculum and inoculation.

Mycorrhizal fruitbodies will be air dried and prepared for inoculation in the nursery. Inoculum will be either watered into tuart seedling beds or mixed into the potting mix. Some seed will be coated with a mix of mycorrhizal fungi.

3. Monitoring mycorrhizal development.

To ensure that the mycorrhizal species have established, mycorrhizal development will be monitored in the nursery and/or in the field after planting. The presence of mycorrhizal fungi will be established by recognition of fruitbodies, and fungal identification systems such as mycorrhizal anatomy, molecular probes.

Table 7 Plant taxa suitable for rehabilitation within different post-mining vegetation complexes (A, & B; see Section 2) at Ludlow.

Propagation methods: T=Topsoil B=Block harvesting S=Seed spread directly onto restored landforms N=Nursery seedlings via seed or cuttings
x = present in mining lease, suitable for complex A or B

Family	Species	Description	Propagation Method	Presence in ML	A	B
ANTHERICACEAE	*Thysanotus multiflorus* R.Br. (many-flowered fringed lily)	Caespitose **perennial herb to 0.5m**, Aug-Jan, sand, laterite, granite	S, B		x	x
CHENOPODIACEAE	*Ragodia baccata* Moq. (berry saltbush)	Spreading **shrub to 2m**, Feb-May Oct-Dec, white grey sand / limestone	S	x	x	
CYPERACEAE	*Lepidosperma effusum* Benth. (spreading sword sedge)	Rhizomatous tufted **perennial sedge to 2.5m**, Apr-Jun/Sep-Nov, white sand, brown loam in winter wet depressions	N, B	x		x
	Lepidosperma squamatum Labill.	Rhizomatous tufted **perennial sedge to 1m**, Mar-Nov, calcareous peaty or lateritic sand, sandy clay, swamps	N, B	x		x
DASYPOGONACEAE	*Lomandra micrantha* Ewart (small-flowered mat rush)	Rhizomatous **perennial herb to 0.7m**, Apr-Jul, sand, sandy clay	N, B	x	x	x
DILLENIACEAE	*Hibbertia cuneiformis* Sm. (cutleaf hibbertia)	Sprawling **shrub to 3m**, Jan-Mar / Jun-Nov, white/grey sand coastal swampy plains	N, B	x	x	x
	Hibbertia racemosa Gilg (stalked guinea flower)	Spreading **shrub to 0.17m**, Jul-Dec, white or yellow sand, limestone coastal	N, B	x	x	x
EUPHORBIACEAE	*Phyllanthus calycinus* Labill. (false boronia)	Erect **shrub to 1.2m**, Jun-Jan, sandy soils	S, B	x	x	x
HAEMODORACEAE	*Aigoz anthos manglesii* D.Don (Mangles kangaroo paw)	Rhizomatous **perennial herb to 1.1m**, Aug-Nov, white yellow grey sand	S, N, B	x		x
	Conostylis aculeata R.Br. (prickly conostylis)	Rhizomatous perennial **grass-like herb to 0.5m**, Aug-Nov, winter wet areas on a variety of materials	S, N, B	x		x
	Conostylis candicans Endl. (grey cottonhead)	Rhizomatous perennial grass-**like herb to 0.4m**, Jul-Nov, sand, sandy loam, limestone coastal	S, N, B		x	
IRIDACEAE	*Patersonia occidentalis* R.Br. (purple flag)	Rhizomatous tufted **perennial herb to 0.7m**, Apr/Sep-Jan, sandy winter-wet depressions	S, B	x	x	
JUNCACEAE	*Juncus pallidus* Nordensk. (field woodrush)	Rhizomatous tufted **perennial herb to 0.4m**, Aug-Sep, sand, sandy clay, loam	T, B	x	x	
MIMOSACEAE	*Acacia alata* R.Br. (winged wattle)	**Shrub to 2.1m**, Apr-Dec, variety of soils including saline flats	S		x	
	Acacia cochlearis Wendl. (rigid wattle)	Bushy pungent **shrub to 3m**, Jul-Oct, coastal sandplains	S		x	
	Acacia elensa Lindl. (wiry wattle)	Erect **shrub 1-2m**, Aug-Oct, sandy, sandy/lateritic soils	S			x
	Acacia huegelii Benth.	Straggling, semi-prostrate to erect spiny **shrub to 1m**, Oct-Feb, white/grey or yellow/brown sand, laterite	S		x	x
	Acacia paradoxa DC. (kangaroo thorn)	Prickly **shrub to 4m**, Jul-Oct, white/grey sand and swampy areas	S		x	
	Acacia pulchella R.Br. (prickly moses)	**Shrub to 3m**, May-Dec, sandy soils, clay loam over laterite, swamps	S		x	x

Family	Species	Description	Propagation Method	Presence in ML	A	B
	Acacia saligna Wendl. (orange wattle)	Dense often weeping **shrub or tree to 6m**, Jul-Nov, variety of habitats	S	x	x	x
	Acacia stenoptera Benth. (narrow winged wattle)	Scrambling prickly **shrub 0.2-0.7m**, Mar-Dec, sandy/lateritic soils	S			x
	Acacia willdenowiana Wendl. (grass wattle)	Slender erect sometimes scrambling **shrub to 0.6m**, Jun-Sep, sand loam and lateritic soils, often in winter-wet depressions	S		x	x
MYRTACEAE	*Corymbia calophylla* Hill & Johnson (marri)	**Tree to 40m**, Dec-May, sandy and lateritic soils	S, N	x		x
	Eucalyptus gomphocephala DC. (tuart)	**Tree to 40m**, Jan-Apr, sand over limestone on coastal plain	S, N	x	x	x
	Eucalyptus marginata Sm. (jarrah)	**Tree to 30m**, Jun-Jan, grey sand, clay or sandy loam, laterite	S, N	x		x
	Kunzea ericifolia (Sm.) Heynh. (spearwood)	Erect **shrub 1-4m**, Jul-Dec, peaty sand / grey sand moist	S, N			x
	Kunzea recurva Schauer	Erect **shrub 0.3-2m**, Aug-Dec, variety of soils, winter wet depressions	S, N			x
	Melaleuca acerosa Schauer	**Shrub to 1.5m**, Aug-Dec, dunes & limestone soils	S, N		x	
	Melaleuca incana R.Br. (grey honeymyrtle)	**Shrub or tree 0.4-5m**, May-Nov, sand / sandy clay, winter wet depressions	S, N		x	x
	Melaleuca preissiana Schauer. (moonah)	**Tall shrub / tree to 9m**, Nov-Feb, sandy soils, swamps	S, N			x
	Melaleuca systena Craven ms (coastal honeymyrtle)	Erect/spreading **shrub 0.5-2m**, Feb-Mar / Aug-Dec, yellow/orange sand over limestone	S, N		x	
ORCHIDACEAE	*Caladenia* spp.	**Tuberous perennial herb to 0.3m**, Jul-Dec, coastal woodlands	T, B	x	x	x
PAPILIONACEAE	*Bossiaea eriocarpa* Benth. (common brown pea)	Straggly **shrub 0.2-1m**, Jul-Nov, sandy soils	S			x
	Brachysema praemorsum Meisn.	Tangled prostrate to ascending **shrub to 0.6m**, Aug-Jan, damp depressions	S		x	x
	Bonierema dilatifolium A.DC.	**Climber**, Aug-Dec, sand	S		x	x
	Bonierema nanum (Andrews) Sims	**Shrub to 0.4m**, sandy soils, clay loams	S			x
	Daviesia decurrens Meisn. (prickly bitter pea)	Erect **shrub 0.3-1m**, Jun-Sep, lateritic soils	S			x
	Daviesia divaricata Benth. (marno)	Erect **shrub to 3m**, Jun-Nov, white, grey or yellow sand over limestone	S	x		x
	Daviesia podophylla Crisp	Erect spreading **shrub 0.3-1m**, Jul-Oct, sand	S			x
	Daviesia preissii Meisn.	Dense **shrub to 0.6m**, Dec-Feb, lateritic soils	S		x	x
	Gompholobium aristatum Benth.	Erect **shrub 0.1-0.8m**, Jul-Dec, white/yellow sand	S			x
	Gompholobium marginatum R.Br.	Prostrate spreading **shrub 0.05-0.4m**, Aug-Nov, gravelly soils	S			x
	Gompholobium tomentosum Labill. (hairy yellow pea)	Erect **shrub 0.3-1m** high, Jul-Jan, white/grey/yellow sand	S			x
	Hardenbergia comptoniana Benth. (native wisteria)	**Climber**, Jul-Oct, coastal sands, dunes, limestone	S	x	x	x
	Jacksonia horizontalis (Sweet) DC.	Erect slender prickly **shrub 0.1-0.6m**, May-Oct, gravelly soils	S			x

Family	Species	Description	Propagation Method	Presence in ML	A	B
	(holly-leaved hovea)					
	Hovea stricta Meisn.	Erect **shrub 0.2-1m**, Jun-Oct, white/grey or yellow sand	S			x
	Hovea trisperma Benth. (common hovea)	Straggling **shrub 0.1-0.7m**, May-Nov, sandy soils, laterite	S			x
	Isotropis cuneifolia (Sm.) Jacks (granny bonnets)	Prostrate spreading per. herb **or shrub 0.05-0.3m**, Jul-Nov, sand clay/loam laterite, winter-wet flats	S			
	Jacksonia furcellata DC. (grey stinkwood)	Weeping erect **shrub to 4m**, Oct-Mar, sany soils in swampy depressions	S	x	x	x
	Kennedia coccinea Vent. (coral vine)	**Climber**, Aug-Nov, sandy soils	S	x	x	
	Kennedia prostrata R.Br. (scarlet runner)	**Prostrate or twining shrub**, Apr-Nov, sandy gravelly soils	S	x	x	x
	Sphaerolobium medium R.Br.	Erect leafless **shrub to 0.6m**, Aug-Dec, sandy or clayey soils, laterite	S		x	
PITTOSPORACEAE	*Sollya heterophylla* Lindl. (Australian bluebell)	Twining shrub or **climber to 3m**, Oct-Feb, variety of soils	S		x	x
PROTEACEAE	*Adenanthos meisneri* Lehm.	Semi-prostrate lignotuberous **shrub to 1.5m**, Jul-Apr, white-grey or brown sand, gravel	N	x		x
	Banksia attenuata R.Br. (slender banksia)	Lignotuberous **tree or shrub to 10m**, Oct-Feb, white / yellow / brown sand	N,S	x		x
	Banksia grandis Willd. (bull banksia)	**Tall shrub / tree to 10m**, Sep-Jan, white / grey sand, laterite	N,S			x
	Grandra lindleyana Meisn.	**Shrub to 3m high**, May-Oct, sand or sandy loam, limestone	S,N		x	x
	Hakea prostrata R.Br. (harsh hakea)	Erect/spreading/**prostrate shrub 0.3-5m**, Aug-Oct, sandy soils	S			x
	Stirlingia latifolia Steud. (blueboy)	Erect lignotuberous **shrub to 1.5m**, Aug-Oct, white, grey, yellow-brown or black sand	B	x		x
THYMELAEACEAE	*Pimelea rosea* R.Br. (rose banjine)	Erect **shrub to 1m**, Jul-Dec, variety of soils, coastal	S	x	x	x
XANTHORRHOEACEAE	*Xanthorrhoea gracilis* Endl. (graceful grasstree)	**Tufted grass tree to 2m**, no trunk, Oct-Jan, lateritic loam, gravel, sand	B, N	x		x
ZAMIACEAE	*Macrozamia riedlei* Gardner (zamia)	**Cycad**, 0.5-3m, fertile Sep-Oct, lateritic soils, jarrah forest	S, N, B	x	x	x
			Species number:		33	51

7 MAINTENANCE

7.1 Erosion Control

Principle Work Instructions:

- **WI 224 – Native vegetation pre-clearing checklist**
- **WI 377 – Erosion and sediment control**

The Ludlow Mining Lease occurs over sandy soils of relatively low relief. Due to a combination of the high infiltration capacity of these sands and the low slopes occurring within the area, the risk of erosion by fluvial processes is considered negligible.

By contrast, the risk of wind erosion is relatively high due to exposure of the site to frequent windy conditions. Winter storms bring strong squally winds from the northwest to southwest. During summer, southwesterly sea breezes occur in the afternoon, while hot dry easterly winds of moderate strength occur at night and early in the day.

A number of strategies will be utilised to minimise the risk of wind erosion. For exposed areas, including topsoil stockpiles, stabilisation can be achieved via a number of options:

- Timing of operations. Staged clearing (refer to Figure 4) followed by progressive rehabilitation of mined areas will minimise the time that open areas remain exposed to wind erosion.
- Spraying a thin (ca.2mm) layer of fines.
- Laying of brush, although supply of this material will be limited.
- Periodic use of a water cart

The final rehabilitated landform (after topsoiling) will be stabilised using the following techniques:

- Revegetation with seed and planted seedlings;
- Ripping to roughen final surface and slow wind speed at ground level.
- Laying of brush, although supply of this material will be limited;
- Spreading of wood chips developed from timber stockpiles.

7.2 Vermin control

Principle Work Instruction:

- **WI 095 - Protection of native vegetation rehabilitation from grazing**

The fauna survey identified a number of introduced species existing within the mining lease and National Park that are known to directly compete with native fauna for habitat; these include the rabbit, black rat, fox and feral cat. To reduce environmental pressure and encourage re-colonisation of native fauna into rehabilitation areas, there will be baiting programs conducted in conjunction with, or following approval from CALM.

The close proximity of cleared agricultural land to the Ludlow State Forest and National Park has supported an increase in population numbers of some fauna species to nuisance levels.

The increased numbers of rabbits and kangaroos in particular, produces heavy grazing pressure on native vegetation and has the potential to impact significantly on rehabilitation areas within the project area. Grazing pressure will be reduced within newly rehabilitated areas by:

- Baiting for rabbits will be conducted annually in the rehabilitation area, as described in WI 095.
- Fox and feral cat control will be conducted in accordance with the Fauna Management Plan.
- Constructing a fence around the perimeter of the mining area, as described in Section 4.1.

7.3 Fire Management

Principle Work Instruction:

- **WI 225 - Management of clearing operations**

A fire control program will be implemented in collaboration with CALM to reduce the risk of wildfire both within the mining lease and from surrounding State Forest. Firebreaks will be established to a minimum width of 5m and maintained at strategic points within the mining lease.

Fire risk associated with storing vegetation debris for ashbed heap construction will be reduced by separating stockpiles into distinct units, and establishing fire breaks around the perimeter of individual stockpiles. When placed in their final position for burning the stockpiles will be positioned in open areas and at least 20m from standing tuarts. All prescribed burning of ashbed heaps is to be approved by the CALM District Manager. Burning will occur during autumn (April-May) when weather conditions permit and following guidelines outlined in WI 225.

7.4 Disease Management

Principle Work Instruction:

- **WI 279 - Dieback and weed hygiene**

Due to the pre-existing level of disturbance within the LSF, the application of WI279 will be limited to the following requirements:

1. Installation of a grid at the entrance to the minesite to ensure all vehicles entering the site drop loose particulate matter from their tyres and chassis.

2. Requirement for all earthmoving machinery to be cleaned prior to entering the minesite

3. Minesite Supervisor, or delegate, to inspect all earthmoving machinery for compliance with point 2 above.

4. In the event of inadequate cleanliness, the minesite washdown bay will be utilised to remove excess debris.

Armillaria

Armillaria luteobubalina is a widespread and common pathogen in Australia that is known to cause root rot and death in forest plant species. Susceptible plant species are in the Proteaceae, Mytaceae, Papilionaceae, Epacridaceae and Mimosaceae families (Shearer 1994). Studies by Pearce and Malajczuk (1990) indicate that *Armillaria luteobubalina* is indigenous to the forests of south western Australia and the greatest incidence and severity of disease development has been observed in forests after disturbance following logging.

Treetec Consulting Pty Ltd (2003) undertook reconnaissance surveys of the LSF in June and July 2003 to observe fruiting bodies of *Armillaria luteobubalina*. Only three occurrences of the pathogen were observed at the base of dead Tuart trees during the time of peak fruit body production. These results suggest that Armillaria in the Ludlow Tuart forest is of a low incidence and has a minimal effect on forest health and growth of both the mature and regrowth trees.

However, the behavior of *Armillaria luteobubalina* mirrors that of other eucalypt forest in southern Australia where it may lay dormant until host resistance is altered by stress or disturbance such as logging leading to a major imbalance between host and pathogen. Therefore, it is important that during clearing operations, all potential infective material such as tree butts and or roots are removed and destroyed to minimize the carry over of inoculum to revegetated sites.

Dieback disease

Due to the presence of Jarrah (Eucalyptus marginata) within the NE corner of the mining lease, consideration has to be given to the potential effects of Phytophthora cinnamomi on this species as a result of mining.

Advice from CALM (Busselton Office) suggested the risk of increased spread of the Phytophthora fungus from mining was low. The sandy, well-drained nature of soils would restrict the natural movement of the fungus through the soil. In addition, uncontrolled access throughout the area for many years is likely to have promoted the spread of the fungus if present, already.

Insect Attack

Several theories have been proposed for the stimulus of insect outbreaks within Tuart Woodland, including lowered water table, air pollution, frost, long periods without fire, and drought stress caused by overstocking within the peppermint-dominated understorey (Bradshaw 2000). While no single cause has been proven, it is apparent that tuarts are more vulnerable to insect attack when placed under stress.

Insect attack is commonly reported for seedling trees located on the edge of or between ashbed heaps at Ludlow, but is less common for more vigorous trees located in the centre of ashbed heaps (Anon 1927). In addition, only vigorous tuart regeneration has been observed to recover from insect attack (Brockway 1963). A similar trend has been recorded within Kings Park, where the growth of young tuarts became stagnant after only a few years due to competition from surrounding shrubs and trees, and they were subsequently attacked by insects (Beard 1967). For successful establishment free of insect attack, there was a

requirement for tuarts to be planted as 6-9 month old seedling trees in natural gaps within the bush canopy, where competition was reduced and tuart vigour correspondingly increased.

The vigour of tuarts in the post-mining rehabilitation will be maximised by ensuring a number of important factors co-exist:

- A local source of viable seed,
- Receptive seed beds onto which 'tuart clumps' can be established utilising ashbed heaps and furrowlines,
- Protection during the early stages of development from fire, grazing and weeds, and
- Ongoing monitoring of tree health.

7.5 Weed Control

Principle Work Instructions:

- **WI 378 - Weed management within native vegetation rehabilitation**
- **WI 279 - Dieback and weed hygiene**

Introduction of weed species to the Ludlow Tuart Forest can be related to the multiple land uses supported by the area over the past 170 years. Critical primary weed species within the Ludlow mining lease including *Zantedeschia aethiopica* (arum lily), *Asparagus asparagoides* (bridal creeper) and *Pinus* (pine trees), competitively exclude native species, exhibit rapid growth rates and are able to invade relatively closed and intact vegetation communities. Secondary priority weeds are those that invade after primary weed removal, fire or clearing and include veldt grass (*Ehrharta calycina*) and soursob (*Oxalis* spp.). These also need to be controlled to allow recovery of natural vegetation species and to ensure revegetation success.

Vehicle and machinery cleanliness is desirable at Ludlow to ensure new weeds are not introduced to the site and the existing weed store is not compounded. The application of hygiene measures for weed control will be in accordance with the Company standard (WI 279) as summarised in Section 7.4. In addition, specific control measures will be implemented to enhance the establishment of native species, as outlined below.

Canopy Structure

Many areas throughout the mining lease are presently over-shaded due to the high density of canopy species such as pine trees (plantation form) and peppermint (localised groving). Reduced light intensity has encouraged the establishment of a number of primary weed species including arum lily and bridal creeper (Meney 1999). Harvest of pine trees from the entire mining lease, and selective thinning of dense peppermint groves present outside the mineralised zone will open the canopy and increase light intensity at ground level, significantly reducing the density of primary weed species. The openness of the mineralised zone post-mining will provide similar benefits.

Heat generated through the burning of ashbed heaps will sterilise the underlying topsoil seed store and provide a competition-free environment during the initial growing season. The furrowline technique provides a similar period of weed control through mechanical removal of the topsoil layer and associated weed store.

Ongoing herbicide application via spot spraying will target persistent weeds reoccurring within rehabilitated tuart clumps.

Understorey

Promotion of a native understorey cover through direct seeding, planting and translocation will reduce the potential for introduced weed species to reestablish, by increasing species diversity and competition. Broadscale herbicide application will be implemented to control annual grasses and woody weeds outside of tuart clumps. The low stratum of native shrubs rehabilitated outside of localised tuart clump areas will facilitate weed control by allowing broadscale application of selective herbicides utilising a 4WD motorbike mounted boom spray.

8 REHABILITATION IMPLEMENTATION PERFORMANCE

The 'Rehabilitation Implementation Performance' table (Table 8) has been developed to fulfill two purposes:

1. To provide a checklist for implementation by mining and rehabilitation staff; and
2. To provide a checklist for auditing of rehabilitation performance by regulators.

To fulfill these purposes, additional fields will be entered into the table when in use, indicating:

- Spatial unit - The rehabilitation 'block' as defined by vegetation type, disturbance type and schedule in Cable Sands' geographical information system (GIS).
- Status - e.g. 'Not yet applicable', 'Complete', 'In progress', 'Non-compliant'.
- Timing - Start and finish dates for tasks.
- Corrective actions - Details of any management required to address non-compliant tasks.

Table 8 Rehabilitation Implementation Performance Table.

CRITERIA OR INTENT	COMPANY STANDARD	SITE SPECIFIC CRITERIA	RESPONSIBILITY
Pre-Clearing Checks			
Fencing	WI 095	1.5m netting with rabbit-proof skirting as per Section 4.1 MRMP	Environmental Officer
Clearing approvals	WI 224	As per WI 224	Mine Supervisor
DRF and Priority Flora search	Nil	Confirmation from CALM	Environmental Officer
Harvest of pine trees	Nil	Confirmation from FPC	Mine Supervisor
Mine path surveyed and pegged	WI 224	Section 4.2 MRMP	Mine Supervisor
Mine path areas: - picked of native seed, - cuttings taken for propagation of seedlings, - recalcitrant species block harvested	WI 224	Section 4.2 MRMP	Environmental Officer
Stockpile areas defined	WI 224	Section 4.2 MRMP	Mine Supervisor
Dozer operators instructed	WI 224	As per WI 224	Mine Supervisor
Clearing			
Brushing cleared and stockpiled	WI 094	Section 4.2 MRMP	Mine Supervisor
Pine debris, pine stumps and understorey cleared and stockpiled	WI 225	As per WI 225	Mine Supervisor
Block harvesting	WI 068	One-week loader time allocated annually to the block harvesting of plants from within the mine path to either topsoil stockpiles or directly onto prepared rehabilitation surfaces as per Section 4.3, MRMP	Mine Supervisor
Topsoil stripped and stockpiled	WI 223	Topsoil stripped to 200mm depth, and stockpiled to less than 2m in height as per Section 4.4 MRMP	Mine Supervisor
Additional investigation of pre-mining soil profiles	Nil	Section 5.2 MRMP	Environmental Officer
Tuart trees harvested	WI 225	Confirmation from FPC	Mine Supervisor
Tuart tops and tuart stumps cleared and stockpiled	WI 225	Section 4.2 MRMP	Mine Supervisor

CRITERIA OR INTENT	COMPANY STANDARD	SITE SPECIFIC CRITERIA	RESPONSIBILITY
Landform Reconstruction			
Interface between mined and unmined zones in the void scarified	Nil	Section 5.5 MRMP	Mine Supervisor
Discharge of fines laden water with direct return tailings stream into the mine void	Nil	Sections 5.5 MRMP	Mine Supervisor
Solar dried fines material deep ripped into the surface profile	Nil	Section 5.5 MRMP	Mine Supervisor
Topsoil respread	WI 223	Section 5.5 MRMP	Mine Supervisor
Re-introduction of stag trees and habitat logs	WI 067	Section 4.6 MRMP Construct 1 fauna habitat/ha	Mine Supervisor
Tuart clumps constructed	WI 069	Section 4.7 MRMP Construct 10 tuart clumps/ha for unit A & 2.5 tuart clumps/ha for unit B	Mine Supervisor
Deep ripping	WI 069	Entire post-mining rehabilitation area deep ripped as per Section 4.8 MRMP	Mine Supervisor
Brushing	WI 094	Section 4.9 MRMP	Mine Supervisor
Revegetation			
Direct Seeding	Nil	Subject to availability, tuart seed direct sown over ashbeds at an individual rate equivalent to 250g/ha Subject to availability of seed, other rehabilitation areas direct seeded with understorey shrubs. Section 6.1, Table 7 MRMP	Environmental Officer
Planting	WI 152	Where direct seeding of ashbeds is unsuccessful, infill plant with nursery propagated tuart seedlings at 2m intervals along furrowlines Nursery propagated understorey seedlings planted throughout the entire rehabilitation area Section 6.2, Table 7 MRMP	Environmental Officer
Block harvesting	WI 068	One-week loader time allocated annually to block harvesting plants from within the mine path to either topsoil stockpiles or directly onto prepared rehabilitation surfaces. Section 4.3, Table 7 MRMP	Mine Supervisor
Decommissioning			
Prepare a discussion paper for decommissioning	Nil	Prepare a discussion paper for circulation with stakeholders, at least 6 months prior to cessation of mining. Section 4.11 MRMP	Environmental Officer
Maintenance			
Vermin Control	WI 095	Section 7.2 MRMP	Environmental Officer
Fire	Nil	All fire breaks in place and maintained prior to October annually as per Section 7.3 MRMP	Mine Supervisor
Weed Control	WI 095	Section 7.5 MRMP	Environmental Officer
Monitoring			
Soils	Nil	Test pits established in the rehabilitation annually as described in Section 9.1 MRMP	Environmental Officer
Groundwater	Nil	Monthly monitoring of standing groundwater levels Section 9.2 MRMP	Environmental Officer
Vegetation	Nil	Annual monitoring of rehabilitated vegetation within the mining lease, and vegetation in the surrounding State Forest and National Park. Section 9.3 MRMP	Environmental Officer

9 MONITORING

9.1 Soils

Soil profile

The monitoring procedure for soil profile reconstruction is described earlier in Section 5.7. The techniques used will largely mirror those used in the pre-mining studies of soil characterisation (OSL, 2002) including the annual excavation of test pits to allow analysis of physical and chemical soil parameters down the reconstructed soil profile.

Topsoil nutritional status

In addition to a detailed assessment of the soil profile prior to topsoil replacement, revegetated topsoils will also be sampled regularly (1-2 year intervals) to determine long-term trends in soil nutrition.

Parameters to be analysed will include:

- % organic carbon.
- pH
- Electrical conductivity.
- Nitrate and ammonium nitrogen
- Phosphorus.
- Potassium
- Exchangeable cations.
- Trace elements (eg. Cu, Zn, Mn, Bo)

9.2 Groundwater

The water level in piezometers will continue to be monitored on a monthly basis allowing for comparison with pre-mining conditions; details fully outlined in the 'Water Resources Management Plan'.

Six monthly reporting of groundwater levels will assist in the assessment of rehabilitation success. Progress of vegetation towards the stated performance criteria may then be reviewed giving consideration to the prevailing groundwater conditions. A higher level of confidence that the revegetated landscape is sustainable over the long term will be possible where monitoring indicates that groundwater has returned to approximate pre-mining levels.

9.3 Vegetation

Assessment of Rehabilitation

The sampling strategy chosen for the Ludlow rehabilitation reflects the objectives of the site, and allows for assessment of the revegetation's progress towards achieving completion criteria. The completion criteria do not necessarily reflect the pre-mining vegetation condition, which was confirmed as being highly degraded (Bennett, 2000).

Monitoring of rehabilitation will commence in the second spring following rehabilitation and continue on an annual basis until the third assessment, at which time the monitoring interval will be reviewed.

Two monitoring procedures will be utilised to facilitate assessment of the overstorey and understorey strata respectively:

1. Overstorey: Permanent 10m x 10m plots will be established to sample tree density, tree height and stem diameter at breast height (DBH) by species. Crown health will also be scored via a visual assessment, giving particular consideration to symptoms of insect or fungus (Armillaria) attack.
2. Understorey: Permanent belt transects of 20 contiguous 1m by 1m quadrats will be established to sample plant density, % ground cover, and maximum height by species.

Rehabilitation blocks (as distinguished by vegetation type and rehabilitation age) will be sampled with adequate replication to ensure the data is representative of the vegetation present. This will be demonstrated via graphing of 'species-area curves' for the understorey vegetation.

Within each rehabilitation block, three revegetation units will be assessed separately:

A. Tuart clumps established in ashbed heaps;
B. Tuart clumps established in furrowline plots; and
C. Low shrubland established between tuart clumps.

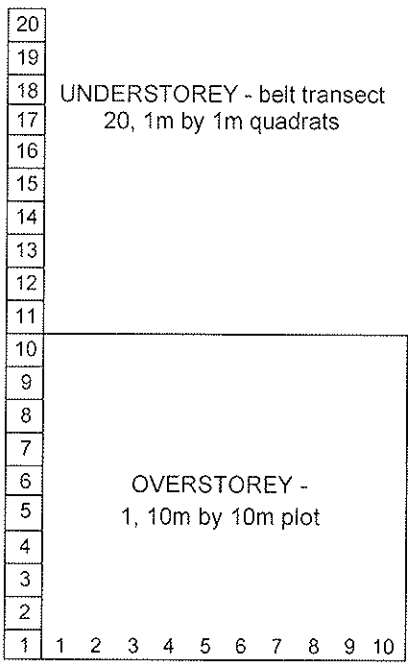

Figure 13 Layout of permanent understorey belt transect (20, 1m by 1m quadrats) and overstorey plot (10m by 10m), established as part of the post-mining rehabilitation monitoring programme.

Assessment for impacts to surrounding vegetation

Monitoring remnant vegetation health in areas of State Forest and National Park surrounding the mining lease is described in the Tuart Preservation Plan.

10 ENVIRONMENTAL COMPLETION CRITERIA

Major alterations to the Ludlow Tuart Forest associated with multiple land use disturbances make it difficult to accurately determine standards for criteria perceived as being important to rehabilitation success. Rehabilitation practices have been developed by trial and error over time, to become routinely applied as part of CALM's ongoing rehabilitation and management of the Ludlow Tuart Forest. Cable Sands will contribute to the continued development of rehabilitation techniques and management practices as part of the mining and rehabilitation process, and in doing so increase the level of current standards.

Progressive completion criteria have been developed (Table 9) for the two post mining landform/vegetation units within the Ludlow mining lease. Three stages are identified and it is anticipated that the achievement of standards for all specified criteria within each stage will result in staged relinquishment of Environmental Performance Bonds.

As stated above, many aspects of the tuart ecosystem are poorly understood and require further research and development before guarantees associated with their implementation can be made. The completion criteria developed have been matched to currently achievable technology. It is acknowledged that with technological advancement rehabilitation techniques may change during the mining operation, and where these changes facilitate an improvement in the rehabilitation outcome, associated completion criteria may be reviewed. Therefore, completion criteria will be subject to periodic review, with amendments made to the satisfaction of DEP, CALM and DMPR.

Table 9 Draft Completion Criteria for Mining Lease M70/86.

ELEMENT	CRITERIA	A Tuart Woodland	B Mixed Tuart/Jarrah/Marri Woodland
	1. EARLY (Year 1)		
Sustainable Growth and Development			
Vegetation establishment	C-1. Tuart clump development at 10 clumps/ha in suitable areas (5 ashbed heaps/ha, 5 furrowline plots/ha)	Y	N/A
	C-2. Individual tuart clumps to average 15m in length by 10m in width for ashbed heaps, and 30m in length by 15m in width for furrowline plots		
	C-3. No tuart clumps developed within 20m of the base of existing trees	Y	N/A
	C-4. Topsoil spread over a minimum of 90% of the rehabilitated mine path	Y	Y
Integrated Landscape			
Landform/Soils	C-5. No uncontrolled surface runoff or soil erosion	Y	Y
	C-6. For each stage of mining, test pits established pre and post mining to assess the following chemical and physical parameters: - nutrients, pH and EC - particle size distribution (proportions of sand, silt and clay) - soil strength - bulk density to confirm they are capable of supporting the proposed revegetation cover	Y	Y
Accessibility	C-7. The reconstructed landform to be consistent with pre-existing slopes, within a small margin	Y	Y
	C-8. Access routes retained across the mining lease, as required for ongoing fire and weed management	Y	Y
Safety	C-9. No hazards resulting from mining to be present over the mining lease	Y	Y
Integrated Management			
Armillaria control	C-10.All stumps within the mining area removed or destroyed	Y	Y
Fauna	C-11.One fauna habitat/ha reestablished across the reconstructed landscape	Y	Y
	2. MID (Year 2-4)		
Sustainable Growth and Development			
Sustainability of overstorey	C-12.At 15 months, tree density within tuart clumps to average the equivalent of 400 seedlings/ha, with not more than 10 percent of the assessment plots failing to record this density	Y	N/A
Sustainability of understorey	C-13.At 15 months no areas greater than 0.5ha without understorey	Y	Y

ELEMENT	CRITERIA	A Tuart Woodland	B Mixed Tuart/Jarrah/Marri Woodland
	C-14.At 15 months species richness of native plant species to be at least 20, with not more than 10 percent of the assessment plots failing to record this level of species richness	Y	Y
Integrated Landscape			
Landform/Soils	C-15.Surfaces stable with an adequate plant cover	Y	Y
	C-16.Reconstructed soil profile does not restrict vertical root development of trees	Y	Y
Resilience of Vegetation			
Competition	C-17.Ground coverage of primary weed species to be at least equivalent to corresponding State Forest rehabilitated by CALM and of similar age	Y	Y
	3. LATE (Year 5-10)		
Sustainable Growth and Development			
Sustainability of overstorey	C-18.At 10 years tree density within tuart clumps to average 200 stems/ha or greater, with not more than 10 percent of the assessment plots failing to record this density	Y	N/A
Sustainability of understorey	C-19.At 10 years no areas greater than 0.5ha without understorey	Y	Y
	C-20.At 10 years native plant species richness within rehabilitated areas to be at least 20	Y	Y
Land use			
Conservation	C-21.Rehabilitation is progressing towards success, as determined by positive trends for plant biodiversity values monitored annually, and is seen to provide added value to the existing Tuart Forest National Park	Y	Y
Heritage	C-22.Heritage values have been protected	Y	Y
Integrated Landscape			
Accessibility	C-23.The agreed access plan implemented successfully	Y	Y
Landform/Soils	C-24.The rehabilitation surface stable and vegetated, with no uncontrolled run-off	Y	Y
Resilience of Vegetation			
Armillaria	C-25.Dieback symptoms restricted to less than 10 percent of the total area	Y	Y
Insects	C-26.Insect attack is no more vigorous within the mine site rehabilitation, as compared to adjacent areas of tuart forest	Y	Y
Competition	C-27.Ground coverage of primary weed species to be at least equivalent to corresponding State Forest rehabilitated by CALM and of similar age	Y	Y
Integrated Management			
Access	C-28.Roads / tracks retained or constructed under the agreed access plan are adequate for fire	Y	Y

ELEMENT	CRITERIA	A Tuart Woodland	B Mixed Tuart/Jarrah/Marri Woodland
	control		
Fire	C-29.The site is capable of being burnt in a mosaic pattern	Y	Y
End land use	C-30.The site meets the agreed end land use/s	Y	Y

FAUNA SURVEY OF THE LUDLOW MINING LEASE; 2001

Final Report

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21/11/'01

EXECUTIVE SUMMARY

This fauna survey was carried out as part of a study being conducted by Cable Sands WA Pty Ltd into the feasibility of extracting mineral sands from the Ludlow Mining area. The fauna survey is required because the Mining Lease is in an area known to be rich in fauna, including some Threatened species, and the Lease also lies between two sectors of the Ludlow Tuart Forest National Park. The aims of the survey were to review existing information on fauna in the project area, and to gather site-specific data in the field, such as the identification of important habitats and measures of abundance of fauna species. Field-work was undertaken over the period 25th March to 1st April and 20th to 25th October 2001 in the project area and the immediately adjacent National Park, and included:

- trapping for amphibians, reptiles and mammals, including bats;
- spotlighting and track surveys for nocturnal mammals;
- censussing for birds;
- searching for reptiles;
- an assessment of environmentally significant ("habitat") trees.

On the basis of the literature review, the vertebrate fauna predicted to use the site consists of 4 species of amphibians, 25 species of reptiles, 85 species of birds and 23 species of mammals. Of these, 3 frog, 11 reptile, 45 bird and 13 mammal species were recorded in the area, including the adjacent National Park. No Threatened invertebrate fauna are known to occur in the area, but one Threatened reptile, six Threatened birds and six Threatened mammals are or may be present.

The results of field-work indicated a number of significant features of the site with respect to fauna, including:

- The abundance of reptile species tended to be greatest in areas where there was a lot of ground cover, either in the form of logging debris or as low, dense shrubs. An area of particular significance for reptiles was in the north-east of the Mining Lease, where the vegetation is more structurally and floristically complex than elsewhere due to the blending of Tuart forest and woodland of Marri, Jarrah and Banksia.
- Although numbers of captures of mammals were too low to support firm conclusions, there was an indication that the National Park immediately north-east of the Mining Lease is particularly rich in species.
- Bird species richness and abundance were lowest in the pine plantation and in mixed pine/Tuart, but was high in the north of the Mining Lease and in the adjacent National Park.
- There is a possibility that the Endangered Short-billed Black-Cockatoo is breeding, or attempting to breed, in Tuart trees in the north of the Mining lease and adjacent National Park.
- The abundance of Brush-tailed Possums in the Mining Lease as determined by spotlighting was higher in 2001 than was found in equivalent surveys carried out in 1986-1988.
- The abundance of Brush-tailed Possums in the Mining lease and adjacent National Park seems to vary seasonally, with a possible movement of possums into the mining lease to feed on "flowering" pine trees in spring.

- The Ring-tailed Possum is more abundant in the adjacent National Park than in the Mining lease.
- The Mining Lease contains 50 environmentally significant trees. These are likely to be important for possums, may be used by breeding waterbirds such as the Australian Shelduck and may support the Masked Owl (a Threatened taxon). Several of the significant trees contained nests of birds of prey.

Concerns about the impact of mining upon fauna in the project area relate to loss of habitat and fragmentation of habitat due to the site's location between two areas of National Park. Habitat loss can be reduced by minimising areas of disturbance and avoiding environmentally significant trees where possible, while successful rehabilitation has the potential to re-instate habitat values. The issue of fragmentation relates to the ability of a species to persist in small, isolated populations, and the value of habitat corridors in preventing isolation. Development of the mining lease will not completely remove connectivity between the two parts of the National Park, but it will reduce the width of linking habitat and therefore increase the relative importance of remaining corridors. Rehabilitation of these corridors would increase their effectiveness in providing linkage.

CONTENTS

INTRODUCTION

As part of the Environmental Impact Assessment process being undertaken by Cable Sands WA Pty Ltd for a proposed mineral sands mine near Ludlow, a comprehensive fauna survey is being undertaken. Such a comprehensive survey is being carried out because the Mining Lease area is in a region that is recognised as having considerable environmental significance, with several species of threatened fauna known to be present. The Mining Lease also lies between two parts of the Ludlow Tuart Forest National Park and is close to the Ramsar listed Vasse-Wonnerup Wetlands. Therefore, Cables Sands recognises that there is considerable public interest in the fauna values of the site and how the company proposes to manage these values. This report presents the results of the first period of field-work carried out as part of this survey.

The aims of a comprehensive fauna survey can be summarised as follows:

- Provide a detailed review of existing information on the fauna species present or expected to be present at a site, from published and unpublished records and including species scheduled as Threatened under the WA Wildlife Conservation Act and/or the Federal Environmental Protection and Biodiversity Conservation (EPBC) Act.
- Identify areas or habitats within a site that are of special conservation significance for fauna.
- Produce quantitative data on levels of abundance of fauna through standard sampling procedures. Such data can be compared with information collected elsewhere, and also provide a baseline that can be used for the assessment of future rehabilitation.

METHODS

Site Description

The Ludlow Mining Lease has an area of 216 ha, but the proposed mining area, located east-north-east of the Ludlow Townsite, has an area of 130 ha. This mining area lies immediately south-west of part of the Ludlow Tuart Forest National Park, with further areas of the National Park south of Ludlow Townsite. Although degraded through the establishment of pine plantations and probably by grazing, as well as having been subject to logging, the vegetation of the mining area has been surveyed by Bennett Environmental Consulting who recognised 13 associations. The southern portion of the mining area supports pine plantation and Tuart *Eucalyptus gomphocephala* woodland, often mixed with some pine trees, whereas the northern portion of the mining area has more complex vegetation due to the intergradation of tuart woodland with Marri *Corymbia calophylla* and Jarrah *Eucalyptus marginata* woodlands associated with heavier, low-lying soils. Most of Bennett's vegetation associations are therefore in this northern sector.

To the immediate south-west, north-west and south-east of the mining area, native vegetation is substantially degraded, being developed for the Ludlow townsite, cleared for agriculture or recently logged. To the north-east of the mining area, however, the adjacent National Park supports native vegetation that is, in the regional

context, only lightly disturbed. This vegetation consists of Tuart woodland with a variable Peppermint *Agonis flexuosa* mid-storey, with some elements of Marri and Jarrah woodlands in the east.

Field Survey Programme

Field work for this project was undertaken primarily by Dr Mike Bamford and Mr Peter Smith, of Bamford Consulting Ecologists, with assistance from Mrs Sue Holmes, a Ludlow resident, and Cable Sands staff. Field work took place from 25th March to 1st April, with trapping occurring over five nights from 27th March to 1st April 2001, and over the five nights from 20th to 25th October. Work carried out in the field included:

- Systematic trapping for amphibians, reptiles and mammals;
- Spotlighting for mammals and nocturnal birds;
- Mist-netting and the use of an ultrasonic detector for bats;
- Clearing of tracklines to detect tracks left by mammals;
- Censussing for birds;
- Assessment of environmentally significant ("habitat") trees (March only);
- Intensive searching for reptiles (mainly in October);
- The keeping of opportunistic records at all times, including opportunistic observations on birds, mammals and reptiles.

Methods employed for these components of the field project are described in the following sections, while Table 1 provides descriptions of fauna sampling sites, and when and where work was undertaken. Note that field work focussed on 5 sites: three within the proposed mining area (Sites 1, 2 and 3) and two in the adjacent National Park immediately to the north-east (Sites 4 and 5).

Systematic Trapping for Amphibians, Reptiles and Mammals

Systematic trapping for amphibians, reptiles and mammals took place at five sites, with the layout of traps (the Kingston layout) being that recommended by CALM. This layout consists of a grid of pitfall, Elliott and cage traps as illustrated in Figure 1. Five such grids were established and were operated for five nights in each sampling period as indicated above, with the Elliott and cage traps baited with universal bait, consisting of a stiff mixture of rolled oats, peanut paste and sardines. Trapping efforts were therefore 45 trapnights with cage traps and 75 trapnights with each of Elliott and pitfall traps at each site in each sampling period. For each trap type, total effort in each field trip was therefore: cage traps - 225 trapnights; Elliott traps - 375 trapnights; and pitfall traps - 375 trapnights. All traps were removed at the end of the October field trip.

The five trapping sites were made up of three within the proposed mining area and two in the adjacent National Park. These are described in Table 1. These sites covered the range of vegetation associations recognised in the Bennett Environmental Consulting survey. In addition to there being too many such associations for each to be sampled intensively, many of these associations were small in area and differed only subtly from other associations; therefore it was not considered worthwhile to attempt to sample them for fauna.

Trapping sites were checked each morning and all specimens caught were identified, some basic measurements were taken and mammals were marked with a black felt pen on the inside of the ear so that they could be recognised if caught again within a few days. Details on specimens caught are presented in Appendix 4. Trapping and all handling of specimens were carried out under Licence to Take Fauna for Scientific Purposes No. SF003410.

Spotlighting Surveys

Spotlighting surveys were undertaken to target nocturnal species that were unlikely to be detected by other means, such as the Ring-tailed Possum and nocturnal birds. In addition, spotlighting surveys were designed to repeat similar surveys carried out on the site in the late 1980s by staff of Westralian Sands. Records of these 1980s surveys were made available for comparative purposes, and M. Bamford assisted in some of the 1980s surveys as a volunteer. The 1980s surveys took place before Fox control was carried out in the Tuart forest.

As indicated on Tables 1 and 3, three spotlighting surveys were undertaken in both March and October (see Appendix 2 for details). Each of these surveys began over half an hour after sunset, by which time it was dark, and was carried out with two spotlights operated from a vehicle travelling at about 5 km/hr. Three or four people were present (driver, two spot-lighters and sometimes an observer/recorder), and the recorder also operated an Anabat II ultrasonic detector to record bats passing overhead. Note that only one species of bat, the White-striped Bat *Nyctinomus australis*, could be detected by this means, as the ultrasonic calls of other species are not well-known. Although part of the call of the White-striped Bat is detectable within normal hearing range, most specimens were heard only with the ultrasonic detector.

The surveys followed a route similar to that followed during the 1980s surveys that included parts of the mining area and the adjacent National Park (see Figure 2). During surveys, the distance travelled and notes on tree species and habitat were made whenever a sighting was recorded.

Between the March and October field trips, Cable Sands personnel carried out additional spotlighting surveys along the same route. These surveys took place on 2nd May, 13th June, 31st July and 19th September and coincided with the new moon. Data from these surveys are summarised on Table 3e.

Mist-Netting for Bats

Mist-netting for bats was undertaken only on the evening of 31st March at Site 5. Three nets were set with a total length of 40 m, and they were aligned to cross a track were vegetation and a large tree served to create a narrow "flyway", with the line of nets extending into a clearing alongside the track in case bats were foraging in that area. The nets were set by sunset (1815 hr) and were dismantled at 2000 hr. Recordings of the ultrasonic calls of bats flying past, and those caught, were made to facilitate identification of bats in the future without the need to capture them.

Clearing of Tracklines

The clearing of tracklines involved sweeping a length of bare ground smooth so that the tracks of animals that crossed this area could be readily seen. This was done in 100 m lengths by dragging several sacks half-filled with sand behind the vehicle in the evening, and then checking these prepared tracklines the following morning. Tracklines were cleared at Sites 1, 2, 4 and 5 for at least one night in each of the March and October field trips. Dates are presented in Table 1 and results in Table 4.

Censussing for Birds

Records of birds were made opportunistically both at and when travelling between sites, but two systematic approaches were also used. Whenever trapping sites were checked a bird-list was prepared, providing presence/absence information for each bird species for five survey events at each site. This information makes it possible to compare the relative abundance of a species between sites. Results of this approach to carrying out bird censussing are presented in Table 6.

The second systematic approach used to record birds involved censussing at each site. The method used was a 15 minute, approximately 2 ha area search technique, with four search-areas being covered at each site. These search areas were based around the trapping quadrats at each site and results are presented in Table 5. This technique has been recommended by Birds Australia (the Royal Australasian Ornithologists Union) as being robust and producing consistent results in varying habitats and with different observers (Loyn 1986).

Hand-searching for Reptiles

This was carried out opportunistically during both field trips, but in October two person-hours were devoted to hand-searching for reptiles at each site. This involved turning over logs and searching through leaf-litter and loose soil with a three-pronged cultivator. This is a recognised technique for locating cryptic and especially fossorial reptiles. Results presented in Table 4b.

Assessment of Environmentally Significant ("habitat") Trees

Although the vegetation of the mining area has been degraded by past activities, Cable Sands has mapped all mature Tuart trees that remain in the area, and an assessment of these mature trees was undertaken to identify those of particular environmental significance.

The environmental significance of trees was assessed and scored by recording, for each specimen, the following parameters:

- Diameter at breast height (estimated in metres);
- The approximate distance to the nearest Tuart (estimated in metres, with scores as follows: $\leq$ 10 m = 3; 11-30 m = 2; 30-50 m = 1; > 50 m = 0);
- Whether or not the canopy of the tree touches the canopy of any other tree, scored on scale from 0 (no canopy touching) to 3 (branches interlocking in a clump of trees);

- The presence of smaller trees adjacent to and leaning against significant tree, forming a ladder so that possums can readily access the canopy of the significant tree, scored on scale from 0 (no ladder tree) to 2 (extensive contact between significant tree and ladder tree);
- The presence of droppings (of Brush-tailed Possums) present on ground beneath tree, scored as 0 for no and 1 for yes.
- The number and apparent usage of hollows was scored from 1 (few hollows not obviously used) to 3 (several hollows with clear usage indicated by polished wood at the entrance of at least one hollow);
- Notes, such as the presence of nests (birds of prey).

These parameters were chosen because they are most likely to indicate that a tree is of particular value for wildlife. For example:
Large trees are more likely to provide nesting hollows and may simply provide a greater amount of habitat than small trees;
The distance to the next large tree is important as many species, particularly arboreal mammals, may make greater use of trees that are in groups than of trees that are isolated and can only be accessed by the mammal walking across the ground.
Similarly, canopies of adjacent trees touching means that the mammal may not have to venture to the ground at all, while the presence of ladder trees makes it easy for mammals to access the branches and canopy of large trees.
The presence of droppings indicates that a tree has been used in the recent past, while the presence of nests, such as those of birds of prey, also indicates recent (and probably ongoing) usage.
The number of hollows visible, and evidence that they are used, is a clear measure of the value of a tree.

These observations are presented in Appendix 3, while the scores were added to calculate an environmental value for each significant tree (see Table 7).

Opportunistic observations

At all times during field work, observations were noted where they contributed to the accumulation of information on fauna of the study area. These included casual observations of birds, evidence of mammals and some searching for reptiles under logs and loose bark.

Sources of Information

Because even an intensive field study cannot be expected to record all species present in an area, the survey results were supplemented with records from a number of sources. Specimen records of frogs, reptiles and mammals were requested from the WA Museum and records were also requested from CALM's Threatened Fauna Database for the area. The Threatened Fauna Database includes threatened invertebrates. Bird, reptile and mammal records for the nearby Capel Wetlands Centre, where observations have been made continuously since the mid 1980s, were obtained from Doyle and Carter (1998) and Bamford (1997). Additional information on birds that could be expected in the area was obtained from Blakers *et al.* (1984) and Johnstone and Storr (1999), while additional information on reptiles was obtained

from Storr *et al.* (1983, 1986, 1990 and 1999). Dell *et al.* (unpub.) provided a review of vertebrate fauna in tuart forests, including Ludlow.

These supplementary sources of information were used to create lists of species expected to occur at the site. As far as possible, expected species are those that are very likely to utilise the project area, and such lists exclude species that have been recorded in the general region as vagrants. Particularly among the birds, for example, vagrants can be recorded almost anywhere and the Capel Wetlands Centre species list includes a number of seabirds.

Taxonomic orders and names used in this report generally follow Tyler *et al.* (1984) for amphibians, Storr *et al.* (1983, 1986, 1990 and 1999) for reptiles, Strahan (1983) for mammals and Christidis and Boles (1994) for birds. Where recent taxonomic revisions have occurred, earlier names are given in parenthesis.

Species are considered to be of national conservation significance if they are listed under the Commonwealth Environmental Protection and Biodiversity Conservation Act, the WA Wildlife Conservation Act, CALM's list of Priority species, Cogger *et al.* (1993), or are classed as near threatened or threatened in Garnett and Crowley (2000). See Appendix 5 for categories used by these authors. Species are considered to be of local conservation significance if they are poorly represented in the general area or are at the limit of the species distribution in the region, but are not listed as being of national conservation significance.

RESULTS – field surveys in March/April and October 2001

Systematic Trapping for Amphibians, Reptiles and Mammals

The sampling programme with pitfall, cage and Elliott Traps resulted in the capture of 3 frogs of 1 species, 54 reptiles of 4 species and 24 mammals of 5 species in March, and 77 frogs of 3 species, 19 reptiles of 6 species and 32 mammals of 4 species in October (Table 2). Strong differences were apparent in the numbers of captures, especially with frogs and reptiles, between the March and April trips, and this was due mainly to the weather. Conditions in March were warm and dry, whereas the October field trip experienced cool, wet weather. This favoured frogs but suppressed reptile activity. It had been hoped that the October trip would coincide with fine weather that, in spring, is associated with high levels of reptile activity.

The numbers of captures of most species were too low for comparisons to be made between sites, but the skink *Lerista elegans* was very abundant at Sites 2 and 3, another skink *Morethia lineoocellata* and the Dwarf Skink *Menetia greyii* were very abundant at Site 3, while Site 3 was also notable for the abundance of the House Mouse. Sites 2 and 3 had considerable ground cover in the form of logging debris and understorey shrubs respectively, which may have influenced the abundance of these species. In contrast, the abundance of the Brush-tailed Possum in both field trips at Site 1, which was a pine plantation, is not so easily explained. It could, however, be related to the proximity of the Ludlow Townsite. Brush-tailed Possums are also reported to forage in pine plantations when the pines are "flowering", but most flowering had occurred before the October trip.

Differences in numbers of captures between sites do not suggest that the mining area supports an assemblage of amphibians, reptiles and mammals that differs in composition or abundance from that of the adjacent National Park. There are, however, patterns in abundance across the sites that indicate differences probably related to local vegetation structure. For example, Site 1 (pine plantation) was very poor in amphibians and reptiles, while the two National Park sites (Sites 4 and 5) were poor in reptiles, with Site 4 being very poor in mammals. Both these National Park sites had very open understoreys with little debris that might provide shelter for reptiles, while Site 4 was also a very open woodland. This open-ness may have made it difficult for species such as the Brush-tailed Possum to visit the ground and therefore get caught in traps, or they may really be at low densities in this area. This was also the only site where Foxes were recorded. The single record of a Brush-tailed Phascogale at Site 5 in the National Park, may be related to the more complex vegetation structure present at this site and to the juxtaposition of dense vegetation around a wetland.

Spotlighting surveys

The results of spotlighting surveys are presented on Table 3 and Appendix 2. These results include summaries of the results of surveys conducted in 1986-1988 (mining lease only), and between the March and October 20012 field trips. This allows for comparisons to be made within the mining lease between 1986-1988 and 2001, between the Mining lease and the adjacent National Park in 2001, and to look at seasonal variation in abundance in 2001.

The recording rate of some of the species in the Mining lease was very similar in 1986-1988 compared with 2001 (Table 3d). The Brush-tailed Possum, however, was much more abundant (5.8 and 12.7 per 5 km) in 2001 than in 1986-1988 (1.3 per 5 km). Data collected between the March and October field trips show similarly high recording rates of the Brush-tailed Possum in the Mining lease (Table 3d), so this is unlikely to be a seasonal effect. The 1986-1988 data were collected throughout the year, but the Brush-tailed Possums were recorded at fairly consistently low levels (see Appendix 2). The most likely explanation is that the Brush-tailed Possum has increased in abundance in the Mining lease due to Fox control.

The Brush-tailed Possum also appears to differ in abundance between the Mining lease and the National Park, at least at some times of the year, with 5.8/5 km and 12.1/5 km respectively in March, but 12.7/5 km and 11.3/5 km in October (Table 3d). In the May to September surveys, the relative abundance of Brush-tailed Possums in the Mining lease and National Park varied considerably, with a trend for them to be more abundant in the Mining lease in all surveys except that of September (Table 3e). Especially with results from single surveys, it is not certain to what extent these patterns are a true reflection of the abundance of possums, but at least the results of the sets of three surveys in March and October showed a considerable consistency from night to night (see Appendix 2). Brush-tailed Possums clearly use the Mining lease extensively, and may concentrate in this area when the pine trees are "flowering", but rely more on the National Park at some other times of the year, such as March (suggested by March survey results). These results also suggest that Brush-tailed Possums are very mobile.

The Grey Kangaroo was generally more abundant in the Mining lease than the National Park, was more abundant in 2001 than in 1986-1988 and was more abundant in late winter/spring than in autumn/early winter (Tables 3d and 3e). Differences between 1986-1988 and 2001 may reflect large changes in the population size, while other differences seemed to be related to Kangaroos concentrating on the margins of farmland near the Mining lease in late winter/spring.

All 11 records of the Ring-tailed Possum made in 2001 were in National Park. While this does not mean that the species is absent from the Mining lease, the species clearly prefers National Park, with most sightings in the vicinity of Site 5 where there is a dense mid-storey of Peppermint Trees *Agonis flexuosa*. Ring-tailed Possums were recorded infrequently in the Mining lease during the 1986-1988 surveys, but it was noted that these records were almost entirely due to specimens seen when forestry thinning operations were being carried out nearby in July 1988 (see Appendix 2).

Mist-netting for Bats

Mist-netting for bats is usually most successful on warm summer evenings but, despite this, single specimens of two species were caught in March. These were the Greater Long-eared Bat *Nyctophilus timoriensis* and Gould's Long-eared Bat *Nyctophilus gouldii*. Both were females with weights and forearm lengths of 15 gm and 9.5 gm, and 47.8 mm and 41.6 mm, respectively. Recordings of the ultrasonic calls of these two species were made as the specimens were released. The calls of a third species were also recorded as an individual flew around the net. It is suspected that this was Gould's Wattled Bat *Chalinolobus gouldii*, a common species in the South-West, but this could not be confirmed. Although no bats were caught in October, a bat that was probably *Vespedalus regulus* was seen near Site 5.

The White-striped Bat *Nyctinemus australis* was the only bat consistently detected during spotlighting surveys and was present at similar levels of abundance in the Mining lease and the National Park, but it is not known how representative this species is of other bats. It is a high-flying bat, whereas *Nyctophilus* spp., for example, tend to forage low and close to vegetation. The White-striped Bat was more common in March than in October, probably due to the poor weather conditions in October.

Tracklines

The Trackline surveys (Table 4) effectively reinforced the results from trapping and spotlighting for some species and also provided some interesting seasonal comparisons, although such studies need to be carried out regularly for firm conclusions to be made. For example, Brush-tailed Possums were recorded more on the tracklines in the Mining Lease in October than in March, and this appeared to be consistent with spotlighting and trapping results. Similarly, there were more Grey Kangaroo tracks in general in October, when more Kangaroos were seen during spotlighting, than in March.

The record of a Fox at Site 4 in both March and October is consistent with the sighting of a Fox near Site 4 during spotlighting in October. A cat was also detected on the trackline at Site 4 in October. The presence of these two predators around Site

4 may have affected the abundance of Brush-tailed Possums in the area. It could also have made the possums reluctant to venture to the ground in the very pen woodland of the site, hence the lack of possum captures in the traps.

Censussing for Birds

The results of censussing for birds are presented in Tables 5 and 6. On the basis of the area search approach (Table 5), Site 3 (Tuart with a shrubby understorey) was particularly rich in species and individuals, while Site 2 (mixed Tuart/pine plantation) was poor in individuals in both March and October, and poor in species in March. Site 1 (pine plantation) was poor in species and individuals in March but was rich in October. To some extent, this was due to birds such as the Yellow-rumped Thornbill foraging along the Tuart and Peppermint edge of the pine plantation, but there did appear to be a seasonal movement of some species into the pine plantation. For example, in October compared with March in Site 1, the Grey Fantail scored 13 compared with 4, the Golden Whistler 9 compared with 0, the Scarlet Robin 6 compared with 0 and the Western Gerygone 13 compared with 1. These species were all observed in the pine plantation in October, although the Gerygones were gathered around an isolated Tuart tree. These observations suggest that some seasonal movement into the pine plantation does take place, and the pines are of more value to birds than was suggested on the basis of the March data.

Because of the low numbers of species and individuals in Sites 1 and 2, particularly in March, Site 3 and the two National Park sites (Site 4 and 5) are the most significant areas for birds. In particular, these sites supported species dependent upon dense understorey and nectar-bearing plants, as well as some species of the eucalypt canopy, like the Weebill and Striated Pardalote, and some parrots that were poorly represented at Sites 1 and 2.

The results of bird surveys based on presence/absence when traps were being checked (Table 6) show greater consistency between most sites than was found with the area search approach. This is probably because observations over several days allow for more opportunities to record species and make the impact of nomadic species that appear infrequently but in large numbers, such as the Silvereye, less significant. The consistency in numbers of species and records in Sites 3, 4 and 5 serves to highlight the low number of species and records in Site 1 and 2.

Hand-searching for Reptiles

Hand-searching for reptiles contributed to the study by adding two reptile species, the Marbled Gecko *Phyllodactylus marmoratus* and the Southern Blind Snake *Ramphotyphlops australis*, which were not recorded during other aspects of the work (Table 4b). Although the search effort was the same at each site, numbers of specimens found during hand-searching tend to reflect the ease with which specimens can be found at a site, rather than being necessarily related to abundance. For example, the Three-toed Skink *Hemiergis peroni* was found at all sites but was particularly easy to find at Site 1 where specimens were concentrated under rotting pine logs.

Assessment of Environmentally Significant ("habitat") Trees

Fifty trees were recorded as being of particular environmental significance; details of their assessment are presented in Appendix 4 and their scores are presented in Table 7. Parameters used to assign scores to each tree are described in the Methods and in Appendix 4. The Eastings and Northings of these trees are presented in Table 7, and it is proposed that the locations of the trees be examined with respect to the ore body to determine how the largest number of the most significant trees can be retained through the mining process.

DISCUSSION – the faunal assemblage of the Ludlow Project Area

The fauna of the general region of Ludlow is better known than in many other parts of Western Australian, with long-term studies at the Capel Wetlands Centre, only a few km north-east of Ludlow Townsite, as well as projects conducted by CALM and fauna surveys carried out by Cable Sands at Gwindinup, east of Capel (Bamford and Bamford 2000). Combined with data from CALM's Threatened Fauna Database, WA Museum specimen records, Birds Australia's Database of bird records and personal observations from assorted projects in the region over the past 15 years, it is therefore possible to put the results of the March/April survey into an overall species list for the Ludlow area.

Invertebrates

No field-work was undertaken to investigate the invertebrate fauna of the project area, but invertebrates were included in the investigation of CALM's Threatened Fauna Database. No Threatened invertebrate taxa are recorded for the Ludlow area.

Amphibians

Although nine frog species are known from the Ludlow area, only four are likely to be present in the Mining lease on a regular basis (Table 8). These four, in particular the Moaning Frog and the Pobblebonk, are terrestrial as adults and occur only around wetlands when breeding. The remaining species stay close to wetlands even when not breeding, although small numbers may disperse into adjacent woodland and could therefore occur in the north-eastern corner of the Mining lease, which is about half a kilometre from the nearest wetland. Sites 3 and 5, near this area, were where the Sandplain Froglet *Crinia insignifera* and the Pobblebonk *Limnodynastes dorsalis* were caught. In contrast, the Moaning Frog *Heleioporus eyrei* was widespread, especially in October. This species is very abundant at the Capel Wetlands Centre, where marked individuals have been recorded moving from woodland sites over a kilometre to breeding sites. They have also been found to move readily across open areas yet to be rehabilitated after mining (Bamford 1997).

None of the frog species known from the Ludlow area is Threatened or is otherwise of conservation significance. The Frog Fungus *Batrachochytrium dendrobatidis* that has been associated with catastrophic declines in the abundance of some frog species has been recorded in the area but no local declines of species have been noted (Aplin and Kirkpatrick 2001).

Reptiles

The majority of reptile species known from the Ludlow area are expected on the Mining lease (Table 8), the exceptions being species closely associated with wetlands such as *A. trilineatum*, *G. gracilis* and *Glaphyrmorphus* sp.. Note that the latter species is currently undescribed and its status as a species is uncertain. Despite this, a dead specimen of the Long-necked Tortoise was found at Site 2 and, although a Fox may have carried it there, these tortoises are known to travel long distances overland. Furthermore, females may lay their eggs several hundred metres from water, so animals living in McCarley's Swamp to the east of Tuart Drive could use the Mining lease for egg-laying.

The skink *C. australis* is not expected as, although recorded in the Bunbury area (B. Bow pers. comm.), it is a conspicuous species that has not been found at the Capel Wetlands Centre after over 10 years of trapping. The status of the skink *L. distinguenda* is uncertain at the Capel Wetlands Centre due to confusion with the very similar *L. elegans*, but it appears from trapping results that only *L. elegans* is present on the Mining lease. The snake species that have been listed as expected although they have not been recorded at the Capel Wetlands Centre are included in WA Museum lists for the region. They have been listed as expected because they are all small species that can be difficult to find, especially if they occur at low densities. Similarly, the small skink *L. lineata* has been included as expected because it is known from the general region and can be hard to find. For such species, the conservative approach has been taken and it is assumed that they are present.

The only species of conservation significance that may be present is the South-West Carpet Python (Schedule 4 of the Wildlife Conservation Act, Vulnerable according to Cogger *et al.* 1993). Although present in coastal heathlands between Peppermint Grove Beach and Bunbury, it has not been reported from the Ludlow region. The small skink *L. lineata* has been recorded from the Busselton area on the basis of WA Museum records and is listed as Rare or Insufficiently Known by Cogger *et al.* (1993), but the species was removed from the Threatened list under the WA Wildlife Conservation Act some years ago.

Sampling of reptiles in March and October recorded only a small proportion of the species expected. Higher numbers of captures had been expected in the spring survey but unseasonal weather prevented this. Despite this, trapping results indicate that areas with dense ground cover, either in the form of logging debris (Site 2) or low shrubs (Site 3), support high densities of some reptile species. For at least these species, the Mining lease may support higher densities than the National Park. There are undoubtedly areas of National Park with dense, low shrubs that support comparable reptile densities, but these results make it possible to comment on the importance of different parts of the Mining lease for reptiles. On the basis of trapping results, the pine plantations and Tuart woodland of the southern part of the Mining lease would appear to support low densities of most species, whereas vegetation with dense cover at ground level, particularly in the north-east of the Mining lease, appears to support high densities of some species.

Birds

Only 45 of the 85 bird species expected were observed during the field trips (Table 9), but many of the species not recorded in the study area were seen on adjacent farmland or can only be expected as irregular visitors. The bird list would be much more extensive if waterbirds had been included and, while many waterbird species are likely to fly over the Mining lease when travelling between wetlands in the area, they have been excluded because they are not dependent on the site. The only waterbirds listed are those that might breed in the area, including ducks that use tree hollows and two heron species that often nest in tall trees some distance from water, and two species of ibis that may occasionally forage in open areas. Some landbirds known from the region have also been excluded from the list, as there is little chance that they use the Mining lease area regularly. These landbirds include the Emu (still found east of Capel) and two species associated with stream-side vegetation: the White-breasted Robin and the Red-eared Firetail. Both these species have been recorded at the Capel Wetlands Centre, but disappeared when stream-side vegetation along the Ludlow River was cleared in the early 1990s (pers. obs.).

Bird species of conservation significance that are or may be present are the:
Square-tailed Kite (Priority 4 according to CALM);
Peregrine Falcon (Specially Protected under the WA Wildlife Conservation Act);
Short-billed or Carnaby's Black-Cockatoo (Endangered in Garnett and Crowley 2000, under the Federal EPBC Act and under the WA Wildlife Conservation Act),
Long-billed or Baudin's Black-Cockatoo (Near-Threatened in Garnett and Crowley 2000, Vulnerable under the Federal EPBC Act and the WA Wildlife Conservation Act);
Barking Owl (southern population Near-Threatened in Garnett and Crowley 2000, Priority 2 according to CALM);
Masked Owl (southern population Near-Threatened in Garnett and Crowley 2000,Priority 4 according to CALM).

Both the Kite and the Falcon may be present only as occasional individuals visiting the area, as there are no reports of these species being consistently present in the Ludlow region, with the Square-tailed Kite recorded for the first time at the Capel Wetlands Centre only recently (F. Doyle, pers. comm.).

A Barking Owl was reported calling near Ludlow Townsite on 19th October 2001 but was not heard during the October field trips. This suggests that at least one specimen occasionally visits the area. The Masked Owl has occasionally been recorded from the Ludlow Tuart forest and is currently subject to a survey programme being operated by CALM. In this programme, the species has been detected in part of the National Park referred to as North Paddock, several kilometres to the north-west of the Mining lease. It was intended to gather data during the March and October field-trips to contribute to this programme, but the survey technique is based upon playing a recording of the Owl's call, and a copy of the recording could not be obtained. Despite this, it is possible that one or more pairs of Masked Owls are present in the Mining lease. It would therefore be valuable to determine if any Masked Owls are present within the Mining lease, and to identify roost and nest trees.

The two Black-Cockatoos may both be present at times. The Short-billed Black-Cockatoo was observed in both March and October, while Dell *et al.* (unpub.) report the presence of the Long-billed Black-Cockatoo in Ludlow Tuart forest. The Short-billed Black-Cockatoos were feeding in pine plantations in March, but in October they were scattered through Tuart woodland, mainly around Sites 3, 4 and 5. Several of the sightings were of pairs and on two occasions, these birds were inspecting hollow limbs. On another occasion, a single bird was sitting in a large Tuart at Site 3, raising the possibility that its mate was on a nest. Traditionally, this species migrates to breed in eucalypt woodlands of the Wheatbelt in late winter and it has not been reported breeding in Tuart forest. However, given the loss of breeding habitat in the Wheatbelt, and the presence of large tree hollows (therefore nest sites) and nearby pine plantations (source of food) at Ludlow, it is possible that the birds may be undergoing a behavioural change. Such a behavioural change may have occurred with the Regent Parrot, which originally depended upon Wheatbelt woodlands for breeding and formerly declined as a result of habitat loss, but increased in abundance on the coastal plain from Busselton to Perth, where breeding has been reported in Tuarts (Johnstone and Storr 1998, Higgins 1999).

Observations and bird censussing indicate that the pine plantation that makes up much of the southern part of the Mining lease is generally poor habitat for birds, but is used seasonally by some species and may be important for the Short-billed Black-Cockatoo. Within the Mining lease, vegetation like that around Site 3 appears to be favoured by birds, and this is probably a result of the complex vegetation structure and floristics, due to elements of eucalypt/Banksia woodland in this location. In addition, large Tuart trees containing hollows, even if the tree is isolated and surrounded by degraded vegetation, may be utilised by parrots and cockatoos, and waterbirds such as the Australian Shelduck and Australian Wood Duck, for breeding.

Mammals

Although only eight of the 23 expected mammals were recorded on the Mining lease (Table 10), this number does not include the Brush-tailed Phascogale, Ring-tailed Possum, two species of long-eared bats and the Fox recorded in the adjacent National Park. As these were within a few hundred metres of the Mining lease it can be assumed they are present; therefore over half the expected mammal species have effectively been recorded, especially as two bat species remain unconfirmed. The expected mammal species that were not recorded include one additional bat species, the Lesser Long-eared Bat, that has been trapped at the Capel Wetlands Centre (M. Bamford unpub. data).

Those mammal species recorded in the Ludlow area that have not been listed as observed or expected in the Mining lease are mostly species that rely on understorey vegetation, and have not been recorded at the Capel Wetlands Centre despite appropriate sampling techniques used. These include the Mardo, Gilbert's Dunnart and Honey Possum that were recorded during the surveys carried out for Cable Sands at Gwindinup, east of Capel, in 1999 (Bamford 2000). The Rakali has been found at the Capel Wetlands Centre but is confined to permanent water and would therefore only be expected in the Mining lease as a vagrant.

Mammal species of conservation significance that have been recorded or are expected are as follows:
Chuditch (Vulnerable under the Federal EPBC Act and the WA Wildlife Conservation Act);
Brush-tailed Phascogale (Priority 3 according to CALM);
Quenda (Conservation Dependent under the WA Wildlife Conservation Act
Western Ring-tailed Possum (Vulnerable under the Federal EPBC Act and the WA Wildlife Conservation Act);
Brush Wallaby (Priority 4 according to CALM);
F. mackenziei (Priority 4 according to CALM);

Of these, the Chuditch is known from the Gwindinup area some 20 km to the east and has recently been reported from near Wonnerup House, south of Ludlow (H. Butler pers. comm.). It therefore can be assumed that individuals of this species may pass through the Mining lease on occasions, although the lack of capture suggest that there is no resident population. All other mammal species of conservation significance were either recorded during the field-work or are considered very likely to be present. In all cases, however, they are likely to be concentrated in the north of the Mining lease where the vegetation is least disturbed.

Data collected on mammals during the field-work provided some conflicting results. For example, the Brush-tailed Possum was caught most often in the pine plantation (Site 1) and spotlighting data suggested that this species is sometimes more abundant on the mining lease than in the adjacent National Park. However, the high density of possums around the nearby Ludlow Townsite probably influenced the high capture rate in the pine plantation, while the species is known to be attracted to pine trees when they are "flowering" in early spring. Furthermore, results from baited traps can be biased, as in poor habitat animals may be less cautious about entering traps in search of food.

In addition to those mammals listed in Table 10, there are several mammal species considered to be extinct in the Ludlow area. For example, the Tammar *Macropus eugenii*, Woylie *Bettongia penicillata* and Boodie *Bettongia lesueur* may have been present. The Quokka *Setonix brachyurus* may have occurred around wetlands in the region and is known to persist in suitable habitat just south of Bunbury, but there are no recent records from the Ludlow area.

Impacts of Mining

Development of a sand mine in the Mining lease will inevitably result in some loss of habitat. This loss can be minimised by means including:

- disturbing as small an area as possible;
- avoiding recognised habitat trees of high value where possible; and
- undertaking rehabilitation by re-using (not stockpiling) topsoil and developing a rehabilitated landscape that uses native plants and incorporates high value features for fauna.

Results from the field-work indicate the importance of floristic and structural diversity in vegetation and the presence of ground-cover, including logging debris and

low shrubs. At the Capel Wetlands Centre, trial rehabilitation has demonstrated that branches and logs can create structural complexity in a site early during rehabilitation to accelerate colonisation by reptiles (M. Bamford, unpub.).

In effect, a rehabilitated minesite follows the principle of old field succession in which the faunal assemblage able to use the site will change over time as the vegetation develops. This means that even with rehabilitation enhancements such as branches, logs and even whole trees, there will be a period of time during which the site will not be able to support some species. This is a major concern with the Ludlow Mining lease, as its position between two parts of the Ludlow Tuart Forest National Park means that mining will tend to fragment existing populations of some fauna species.

The isolation of fauna populations by habitat fragmentation is a major conservation issue and has been subject to extensive debate (for example, Margules *et al.* 1982, Noss and Harris 1986, Soule and Simberloff 1986, Simberloff and Cox 1987, Saunders and Hobbs 1991, Saunders *et al.* 1993, Saunders and Ingram 1995). This debate has focussed on the ability of small, isolated populations to persist in habitat fragments, and the value of habitat corridors in preventing isolation. Small, isolated populations are vulnerable to local extinction and it is this that has led to the progressive extinction of some bird species from reserves in the WA Wheatbelt (Cale 1990). Small, isolated populations can also be affected by inbreeding, although Mills and Allendorf (1996) have suggested that little genetic exchange with outside populations is needed for a largely isolated population to maintain genetic conformity with other populations of the same species. They proposed a "one migrant per generation" rule.

Concern at the impact of fragmentation caused by mining between the two parts of the Ludlow Tuart Forest National Park is such that a review of the issue was carried out in 1989 (Dames and Moore 1989). This report concluded that species present in the area are already coping with extensive habitat fragmentation. The report further concluded that the persistence of fauna in an already extensively fragmented landscape demonstrated the ability of species to utilize corridors and cross barriers. It was felt that the proposed mine area would leave broad corridors, particularly to the west, which would allow for fauna to move between the two parts of the National Park. It was also pointed out that the existing landscape of the Mining lease contains some large areas of poor fauna habitat. This was confirmed by the present field surveys that found the pine forest to support low densities of birds, and found a lower density of Ring-tailed Possums in the Mining lease than in the adjacent National Park. The existing landscape is already imposing a degree of fragmentation between the two areas of the National Park.

The conclusions made by the 1989 report do not change the fact that development of the Mining lease will, albeit temporarily, destroy a large area of habitat, while the ability of fauna to cope with fragmentation is no reason for introducing more fragmentation. Development of the Mining lease will increase the reliance of fauna on the corridors that are retained; the corridor along Tuart Drive to the east of the Mining lease is very narrow, while that to the west is State Forest containing a lot of pine trees that have been or are to be harvested. Therefore, if anything can be done to improve the quality of the habitat in these corridors before mining occurs, this will

reduce the fragmentation effect of the mining. Except in the case of large birds and mammals, corridors do not serve as corridors in the sense of movement of individual animals. Rather, they provide a narrow strip of habitat that can support populations of a species and act as a corridor for genes. Therefore, corridors are most effective when they provide good quality habitat for the greatest possible range of species.

In considering the fragmentation potential of the proposed mining, the point should also be considered that rehabilitation after mining has the potential to create on the Mining lease habitat of better quality than exists now. It must be appreciated, however, that success in the development of habitat has to be measured over long periods of time. For many fauna species, success will be measured over decades, while for some; success will be measured over centuries.

TABLE ONE. Descriptions of fauna sampling sites, including dates, locations of corners and times of surveys.

Site 1. In Ludlow Mining Lease. Corners at: 359408E and 6281448N; 359358E and 6281375N; 359423E and 6281279N; 359479E and 6281395N.
Mature pine plantation with scattered Tuarts, most of the Tuarts being young. Little understorey and a dense litter layer of pine needles.
Trapping grid: 15 assisted pitfalls, 15 Elliott Traps and 9 cage traps. 27/03-01/04/'01 and 20-25/10/'01.
Bird censussing: 4 areas, each of 2 ha and each searched for 15 minutes, from 1550 to 1620 on 30th March 2001.
Trackline: 100 m cleared on evening 30th March, inspected on morning 31st March, and on evenings of 22nd and 23rd October, inspected on mornings of 23rd and 24th October.
Hand-searching for reptiles: 24th October, 2 person-hours.

Site 2. In Ludlow Mining Lease. Corners at: 360195E and 6282897N; 360288E and 6282824N; 360247E and 6282698N; 360146E and 6282765N.
Regrowth Tuart and Peppermint with some young pines. Little understorey and dense litter layer consisting mainly of pine needles. A lot of decomposing pine logs.
Trapping grid: 15 assisted pitfalls, 15 Elliott Traps and 9 cage traps. 27/03-01/04/'01 and 20-25/10/'01.
Bird censussing: 4 areas, each of 2 ha and each searched for 15 minutes, from 1630 to 1700 hours on 28th March 2001, and from 1528 to 1600 on 23rd October 2001.
Trackline: 100 m cleared on evening 30th March, inspected on morning 31st March, and on evenings of 22nd and 23rd October, inspected on mornings of 23rd and 24th October, but no data from 24th October because trackline had been driven over.
Hand-searching for reptiles: 24th October, 2 person-hours.

Site 3. In Ludlow Mining Lease. Corners at: 360643E and 6282687N; 360682E and 6282819N; 360026E and 6282855N; 360546E and 6282757N.
Tuart open woodland with some Peppermint forming a mid-storey and a shrubby, moderately open, low understorey of *Adenanthos* sp. Little litter but a lot of dried grasses and herbs forming a ground cover.
Trapping grid: 15 assisted pitfalls, 15 Elliott Traps and 9 cage traps. 27/03-01/04/'01 and 20-25/10/'01.
Bird censussing: 4 areas, each of 2 ha and each searched for 15 minutes, from 1515-1545 hours on 28th March 2001, and from 1530-1600 on 24th October.
Trackline: No trackline.
Hand-searching for reptiles: 23rd October, 2 person-hours.

Site 4. In National Park. Corners at: 360978E and 6284039N; 361122E and 6283977N; 361171E and 6284075N; 361047E and 6284109N.
Tuart open woodland with some Peppermint forming a mid-storey. No understorey and little leaf litter, but a lot of dried grasses and herbs form a ground cover.
Trapping grid: 15 assisted pitfalls, 15 Elliott Traps and 9 cage traps. 27/03-01/04/'01 and 20-25/10/'01.
Bird censussing: 4 areas, each of 2 ha and each searched for 15 minutes, from 1405 to 1435 hours on 30th March 2001 and 1524-1600 on 22nd October 2001.
Trackline: 100 m cleared on evening of 31st March, inspected on morning of 1st April, and on evenings of 22nd and 23rd October, inspected on mornings of 23rd and 24th October, but no data from 24th October because of rain.
Hand-searching for reptiles: 23rd October, 2 person-hours.

Site 5. In National Park. Corners at: 361371E and 6283399N; 361241E and 6283446N; 361194E and 6283338N.
Mixed woodland of Tuart with scattered Marri and Jarrah, and a mid-storey composed of Peppermint and Bull Banksia. Some shrubby understorey and a lot of dried grasses and herbs form a ground cover.
Trapping grid: 15 assisted pitfalls, 15 Elliott Traps and 9 cage traps. 27/03-01/04/'01 and 20-25/10/'01.
Bird censussing: 4 areas, each of 2 ha and each searched for 15 minutes, from 1500 to 1530 hours on 30th March 2001, and from 1528 to 1600 on 23rd October 2001.
Trackline: 100 m cleared on evening of 31st March, inspected on morning of 1st April, and on evenings of 22nd and 23rd October, inspected on mornings of 23rd and 24th October.
Hand-searching for reptiles: 22nd October, 2 person-hours.

TABLE TWO. Numbers of captures of amphibians, reptiles and mammals at Sites 1, 2 and 3 (in the mining area) and sites 4 and 5 (in the National Park), March (M) and October (O) 2001. Complete common and scientific names are given in Tables 8 and 10.

Species	Site 1		Site 2		Site 3		Site 4		Site 5	
	M	O	M	O	M	O	M	O	M	O
FROGS										
Sandplain Froglet									-	5
Moaning Frog	-	3	1	15	1	16	1	23	-	14
Pobblebonk					-	1				
REPTILES										
Scincidae (skinks)										
Fence Skink									-	1
Three-toed Skink	1	-	-	1	1			1		
Lerista elegans	1	-	8	-	4	2	1		1	
Dwarf Skink			2	-	5	4	6	1	3	
Morethia lineoocellata	1	-	2	4	15	2	2		1	
Bobtail					-	1			-	2
MAMMALS										
Dasyuridae										
Brush-tailed Phascogale									1	
Peramelidae (bandicoots)										
Quenda or Brown Bandicoot	-	1	2	1	-	1			1	
Phalangeridae (possums)										
Brush-tailed Possum	7	6	-	4	2	6	1	-	2	5
Muridae (rats and mice)										
Black Rat	2	2	-	1						
House Mouse	-	1			6	3				
Leporidae (rabbits)										
Rabbit							-	1		
Total captures: Frogs:	0	3	1	15	1	17	1	23	0	19
Reptiles:	3	0	12	5	25	9	9	2	5	3
Mammals:	9	10	2	6	8	10	1	1	4	5
All species:	12	13	15	26	34	36	11	26	9	27

TABLE THREE. Results from spotlighting surveys. Distances travelled in the Mining Lease and the National Park are indicated. Values in parenthesis are young on the back (Brush-tailed Possums) and Boobook Owls heard but not seen.

Table 3a. March 2001.

Species	28th March		30th March		31st March	
	ML 5.9 km	NP 2.1 km	ML 5.8 km	NP 2.7 km	ML 2.9 km	NP 1.8 km
Tawny Frogmouth	1	1	1	-	-	-
Grey Kangaroo	12	-	7	7	-	-
Brush-tailed Possum	6	7	9	7	2	2
Ring-tailed Possum	-	1	-	1	-	-
White-striped Bat	2	-	8	6	-	-
Rabbit	3	1	6		1	2
Feral Cat	2	-	-	-	-	-

Table 3b. October 2001.

Species	20th October		22nd October		23rd October	
	ML 5.4 km	NP 2.6 km	ML 5.4 km	NP 2.7 km	ML 5.4 km	NP 2.6 km
Southern Boobook	-	-	-	(3)	-	-
Grey Kangaroo	11	4	54	12	25	1
Brush-tailed Possum	15 (3)	4	13 (5)	7 (1)	13 (2)	6
Ring-tailed Possum	-	1	-	1	-	-
White-striped Bat	-	-	1	-	-	-
Rabbit	1	2	1	2	2	1
Fox	-	-	-	-	-	1

Table 3c. Summary of 2001 and 1986-1988 data. Data collected in 2001 are presented as the total number of records of each species, while data from 1986-1988 are presented as a mean number of records for each species per survey (out of a total of 20 surveys). Results of the individual 2001 and 1986-1988 surveys are presented in Appendix 2.

Species	Mining lease		National Park		Mining lease
	March 14.6 km	October 16.2 km	March	October 7.5 km	1986-1988 (mean 8.9 km)
Southern Boobook	-	-	-	-	0.2
Tawny Frogmouth	2	-	1	-	1.1
Brush-tailed Phascogale	-	-	-	-	0.1
Grey Kangaroo	17	90	4	17	6.0
Brush-tailed Possum	17	41	16	17	2.4
Ring-tailed Possum	-	-	2	2	0.2
White-striped Bat	10	1	6	-	NA
Rabbit	10	4	3	5	5.8
Feral Cat	2	-	-	-	0.1
Fox	-	-	-	1	0.2

Table 3d. Summary of 2001 and 1986-1988 spotlighting results, presented as recording rates standardised to the number of each species seen per 5 km.

Species	Mining lease		National Park		Mining Lease
	March	October	March	October	1998-1988
Southern Boobook	-	-	-	-	0.11
Tawny Frogmouth	0.7	-	0.8	-	0.6
Brush-tailed Phascogale	-	-	-	-	0.06
Grey Kangaroo	5.8	27.8	3.0	11.3	3.4
Brush-tailed Possum	5.8	12.7	12.1	11.3	1.3
Ring-tailed Possum	-	-	1.5	1.3	0.1
White-striped Bat	3.4	0.3	4.5	0	NA
Rabbit	3.4	1.2	2.3	3.3	3.3
Feral Cat	0.7	-	-	-	0.06
Fox	-	-	-	0.7	0.1

Table 3e. Supplementary spotlighting results provided by Cable Sands personnel. Surveys followed approximately the same route as surveys carried out in the late 1980s and in March and October 2001, with 5.5 km in the Mining Lease (ML) and 2.5 km in the National Park (NP). Results are standardised to the number of animal seen per 5 km.

Species	2nd May		13th June		31st July		19th Sept	
	ML	NP	ML	NP	ML	NP	ML	NP
Southern Boobook	0	0	0	0	0.9	0	0	0
Tawny Frogmouth	0	4	0	0	0	0	0	0
Grey Kangaroo	2.7	0	9.1	4	26.4	16	18.2	0
Brush-tailed Possum	8.2	0	10.1	6.0	17.3	6.0	10.0	22.0
Ring-tailed Possum	0	0	0	6.0	0	2.0	0	4.0
Rabbit	5.5	0	0.9	2	0	0	2.7	0
Feral Cat	0	0	0.9	0	0	0	0	0

TABLE FOUR-A. Results of trackline surveys (see Methods and Table 1 for details). In March, survey dates were: A – 31st March; B – 1st April. In October, survey dates were: A – 23rd October, B – 24th October.

March 2001.

Species	Site number and survey date					
	1	2	4		5	
	A	A	A	B	A	B
Quenda	-	-	-	-	1	-
Brush-tailed Possum	2	-	-	1	2	2
Grey Kangaroo	1	1	-	-	-	-
House Mouse	-	1	1	-	-	-
Black Rat	-	-	-	-	1	-
Fox	-	-	1	1	-	-
Rabbit	-	-	-	-	2	-
Frogmouth or Boobook Owl	-	-	-	-	-	1

October 2001

Species	Site number and survey date					
	1		2	4		5
	A	B	A	A	B	B
Quenda	-	-	2	-	-	1
Brush-tailed Possum	3	3	5	-	-	-
Grey Kangaroo	3	1	3	3	2	-
Fox	-	-	-	1	1	-
Cat	1	-	-	1	1	-
Rabbit	2	1	2	-	-	-

TABLE FOUR-B. Results of hand-searching for reptiles in October 2001, indicating the number of specimens of each species found in 2 person-hours of searching.

Species	Site 1	Site 2	Site 3	Site 4	Site 5
Marbled Gecko	-	-	1	-	1
Fence Skink	-	-	-	-	1
Three-toed Skink	8	3	2	1	3
L. elegans	-	-	-	2	-
Dwarf Skink	-	-	-	1	-
M. lineoocellata	1	-	2	3	2
Southern Blind Snake	1	1	-	-	-

TABLE FIVE. Summary of bird censussing in March (M) and October (O) 2001, presenting the total number of each species seen in four, 15 minute searches, each covering an area of *ca.* 2 ha (therefore the number seen in 8 ha). Raw data from bird censussing are presented in Appendix 3.

Species	Site 1		Site 2		Site 3		Site 4		Site 5	
	M	O	M	O	M	O	M	O	M	O
Wedge-tailed Eagle	-	-	-	-	-	-	1	-	-	-
White-bellied Sea-Eagle	-	-	-	1	-	-	-	-	-	-
Brown Goshawk	-	-	-	-	-	-	-	1	-	-
Collared Sparrowhawk	-	-	-	-	-	-	-	-	1	-
Brown Falcon	-	-	-	-	-	-	-	1	-	-
Common Bronzewing	-	-	-	-	-	-	2	-	-	2
Short-billed Black-Cockatoo	-	-	-	-	-	-	-	1	-	-
Regent Parrot	-	2	1	-	1	4	-	2	-	4
Australian Ringneck	1	4	9	2	12	19	15	19	15	5
Red-capped Parrot	-	3	2	3	3	-	8	2	3	1
Laughing Kookaburra	1	1	-	2	5	2	-	-	-	1
Splendid Fairy-wren	-	-	-	-	3	8	-	-	-	3
Spotted Pardalote	-	-	-	-	3	-	-	-	1	-
Striated Pardalote	-	1	4	11	1	11	3	8	5	10
Weebill	-	-	-	5	10	9	8	4	6	-
Western Gerygone	1	13	2	4	3	7	7	2	1	5
Inland Thornbill	3	-	5	2	3	7	11	2	10	5
Yellow-rumped Thornbill	-	13	-	-	-	-	-	-	-	2
Red Wattlebird	-	3	-	1	2	7	1	-	2	11
Brown Honeyeater	-	-	-	-	4	-	-	2	-	-
Western Spinebill	-	-	-	-	2	-	-	-	-	-
Scarlet Robin	-	6	3	2	-	6	-	-	-	1
Golden Whistler	-	9	-	1	-	-	4	-	2	1
Rufous Whistler	-	2	-	1	-	-	-	-	-	-
Grey Fantail	4	13	10	2	8	6	19	5	16	10
Black-faced Cuckoo-shrike	-	-	-	-	-	-	1	-	-	-
Grey Butcherbird	-	-	-	-	-	3	3	1	3	-
Australian Magpie	-	-	3	-	-	5	-	2	7	1
Australian Raven	3	2	-	-	4	3	-	2	-	-
Silvereye	7	3	-	1	37	-	-	-	-	3
Number of species	7	14	9	14	16	14	13	15	13	16
Number of observations	20	75	39	38	11 1	86	83	54	72	65

TABLE SIX. Additional observations on birds made when checking the traps at each site in March (M) and October (O) 2001. Birds were recorded when traps were checked on five occasions, so the maximum number of times a species could be recorded at a site was five.

Species	Site 1		Site 2		Site 3		Site 4		Site 5	
	M	O	M	O	M	O	M	O	M	O
Little Eagle	-	-	-	-	-	-	-	1	-	-
Whistling Kite	-	-	-	1	-	-	-	-	-	1
Short-billed Black-Cockatoo	1	1	2	1	-	3	-	4	-	4
Regent Parrot	-	1	-	1	2	1	1	2	1	4
Australian Ringneck	2	2	3	2	4	4	4	5	3	5
Red-capped Parrot	-	-	1	1	2	-	1	3	1	2
Common Bronzewing	-	-	-	-	-	2	-	-	-	1
Fan-tailed Cuckoo	-	-	-	-	-	-	-	-	-	1
Shining Bronze-Cuckoo	-	-	-	1	-	1	-	1	-	1
Southern Boobook	-	-	-	-	-	-	1	-	-	-
Laughing Kookaburra	-	-	1	-	1	-	1	1	-	2
Sacred Kingfisher	-	-	-	-	-	2	-	1	-	1
Splendid Fairy-wren	-	-	1	-	3	2	-	-	1	-
Spotted Pardalote	-	-	1	-	1	-	2	-	-	-
Striated Pardalote	-	-	2	3	1	5	4	4	3	4
Weebill	-	-	1	1	4	2	1	3	2	1
Western Gerygone	2	4	4	4	3	5	3	4	4	4
Inland Thornbill	-	2	4	4	-	4	3	5	2	-
Yellow-rumped Thornbill	-	3	-	-	1	-	1	-	-	1
Red Wattlebird	-	1	1	1	3	5	2	4	1	5
Western Spinebill	-	-	-	-	1	-	-	-	-	-
Scarlet Robin	1	-	-	-	-	-	2	-	-	-
Varied Sittella	-	-	-	-	-	-	1	-	-	-
Grey Shrike-thrush	-	-	-	-	-	-	1	-	-	-
Golden Whistler	2	5	1	3	-	1	-	3	4	1
Rufous Whistler	-	3	-	-	-	-	-	-	1	-
Grey Fantail	2	5	5	4	2	3	2	3	5	3
Black-faced Cuckoo-shrike	-	-	-	-	-	-	-	-	1	2
Grey Butcherbird	1	-	1	-	1	4	2	3	2	-
Australian Magpie	1	1	-	-	2	-	2	4	-	2
Australian Raven	1	1	4	-	4	-	1	5	2	4
Silvereye	-	-	1	1	2	1	-	-	2	-
Number of species	9	12	16	14	17	17	19	18	16	21
Number of records	13	25	33	28	37	46	35	54	35	51

TABLE SEVEN. Environmental scores of significant trees based upon data presented in Appendix 3. See Methods for how scores were calculated.

Easting	Northing	Environmental score	Easting	Northing	Environmental score
360 334	6282 484	3	360 448	6382 412	3
360 351	6283 026	9	360 437	6282 329	1
360 331	6283 009	8	360 318	6282 212	5
360 129	6282 929	8	360 075	6282 865	4
360 182	6282 992	5	360 052	6282 735	6
360 147	6283 009	9	359 657	6282 283	5
360 149	6283 042	7	359 676	6282 278	5
360 211	6283 117	7	359 609	6282 140	10
360 249	6283 161	9	359 615	6282 146	11
360 374	6283 302	9	359 625	6282 155	9
360 385	6283 268	7	359 347	6282 077	4
360 450	6283 403	10	359 228	6282 147	7
360 460	6283 398	9	359 270	6282 121	7
360 460	6283 404	9	359 289	6282 300	5
360 415	6283 117	10	359 431	6282 379	4
360 357	6283 072	9	359 474	6282 287	3
359 885	6282 503	8	359 481	6282 278	4
359 812	6282 459	8	359 715	6282 688	10
359 753	6282 512	8	359 790	6284 846	5
359 556	6282 157	8	359 840	6282 792	6
359 500	6282 071	8	359 847	6282 657	7
359 164	6281 915	6	359 860	6282 776	8
359 361	6282 176	7	359 911	6282 997	11
360 496	6282 531	7	359 948	6283 041	8
360 484	6282 441	6	360 100	6283 209	8

TABLE EIGHT. Amphibian and reptile species known from the general region of Ludlow, indicating those trapped, observed or expected on the Mining lease. Species not so indicated are unlikely to occur on the Mining lease because of lack of suitable habitat. CWC indicates species recorded at the nearby Capel Wetlands Centre (from Bamford 1997).

Species		Comments
FROGS		
Myobatrachidae (ground frogs)		
Quacking Froglet	*Crinia georgiana*	(CWC)
Glauert's Froglet	*Crinia glauerti*	(CWC)
Sandplain Froglet	*Crinia insignifera*	trapped (CWC)
Green-bellied Froglet	*Geocrinia leai*	(CWC)
Moaning Frog	*Heleioporus eyrei*	trapped (CWC)
Pobblebonk	*Limnodynastes dorsalis*	trapped (CWC)
Guenther's Toadlet	*Pseudophryne guentheri*	expected (CWC)
Hylidae (tree frogs)		
Slender Tree Frog	*Litoria adelaidensis*	(CWC)
Motorbike Frog	*Litoria moorei*	(CWC)
REPTILES		
Chelidae (side-neck tortoises)		
South-West Long-necked Tortoise	*Chelodina oblonga*	observed (CWC)
Gekkonidae (geckoes)		
Marbled Gecko	*Phyllodactylus marmoratus*	observed (CWC)
Pygopodidae (legless-lizards)		
Sandplain Worm-Lizard	*Aprasia repens*	expected (CWC)
Burton's Legless-Lizard	*Lialis burtonis*	expected (CWC)
Common Scaleyfoot	*Pygopus lepidopodus*	expected
Agamidae (dragon lizards)		
Bearded Dragon	*Pogona minor*	expected (CWC)
Varanidae (monitors or goannas)		
Gould's Sand Goanna	*Varanus gouldii*	observed (CWC)
Rosenberg's Goanna	*Varanus rosenbergi*	expected (CWC)
Scincidae (skink lizards)		
	Acritoscincus (Bassiana) trilineatum	(CWC)
Fence Skink	*Cryptoblepharus plagiocephalus*	observed (CWC)
	Ctenotus australis	
	Ctenotus impar	expected (CWC)
King's Skink	*Egernia kingii*	expected (CWC)
Salmon-bellied Skink	*Egernia napoleonis*	expected (CWC)
	Glaphyromorphus gracilipes	
	Glaphyromorphus sp.	
Three-toed Skink	*Hemiergis peronii*	trapped (CWC)
	Lerista distinguenda	(?CWC)
	Lerista elegans	trapped (CWC)
	Lerista lineata	expected
Dwarf Skink	*Menetia greyii*	trapped (CWC)
	Morethia lineoocellata	trapped (CWC)
Bobtail	*Tiliqua rugosa*	observed (CWC)

Table 8 (cont.)

Species		Comments
Typhlopidae (blind snakes)		
Southern Blind Snake	*Ramphotyphlops australis*	observed (CWC)
Boidae (pythons)		
South-West Carpet Python	*Morelia spilota imbricata*	expected
Elapidae (front-fanged snakes)		
Crowned Snake	*Drysdalia (Notechis) coronata*	expected
Bardick	*Echiopsis (Notechis) curtus*	expected
Tiger Snake	*Notechis scutatus*	expected (CWC)
Dugite	*Pseudonaja affinis*	observed (CWC)
Jan's Bandy-bandy	*Simoselaps bertholdi*	expected
Gould's Snake	*Suta (Rhinoplocephalus) gouldii*	expected
	Suta (Rhinoplocephalus) nigriceps	expected
	Number of frog species expected (recorded):	4 (3)
	Number of reptile species expected (recorded):	25 (11)

TABLE NINE. Bird species known from the general region of Ludlow and that are expected on the Mining area. Species that were recorded during the March and October field trips, either during censussing or opportunistically, are indicated. Note that waterbirds have been excluded from this list except for those that are likely to visit upland habitats for foraging or breeding. [Int.] indicates introduced species.

Species		March	October
Phasianidae (pheasants and quails)			
Stubble Quail	*Coturnix pectoralis*		
Anatidae (ducks, geese and swans)			
Australian Shelduck	*Tadorna tadornoides*	*	
Pacific Black Duck	*Anas superciliosus*		
Grey Teal	*Anas gibberifrons*		
Australian Wood Duck	*Chenonetta jubata*		
Ardeidae (herons and egrets)			
White-faced Heron	*Egretta novaehollandiae*		
Nankeen Night Heron	*Nycticorax caledonicus*		
Plataleidae (ibis and spoonbills)			
Australian White Ibis	*Threskiornis molucca*		
Straw-necked Ibis	*Threskiornis spinicollis*		
Accipitridae (kites, hawks and eagles)			
White-bellied Sea-Eagle	*Haliaeetus leucogaster*		*
Square-tailed Kite	*Lophoictinia isura*		
Black-shouldered Kite	*Elanus axillaris*		
Whistling Kite	*Haliastur sphenurus*	*	*
Brown Goshawk	*Accipiter fasciatus*		*
Collared Sparrowhawk	*Accipiter cirrhocephalus*	*	
Wedge-tailed Eagle	*Aquila audax*	*	
Little Eagle	*Hieraaetus morphnoides*		*
Falconidae (falcons)			
Peregrine Falcon	*Falco peregrinus*		
Australian Hobby	*Falco longipennis*		
Brown Falcon	*Falco berigora*		*
Nankeen Kestrel	*Falco cenchroides*		
Turnicidae (button-quails)			
Painted Button-quail	*Turnix varia*		
Columbidae (pigeons and doves)			
Laughing Turtle-Dove	*Streptopelia senegalensis* [Int.]		
Common Bronzewing	*Phaps chalcoptera*	*	*
Crested Pigeon	*Ocyphaps lophotes*		
Cacatuidae (cockatoos)			
Short-billed Black-Cockatoo	*Calyptorhynchus latirostris*	*	*
Long-billed Black-Cockatoo	*Calyptorhynchus baudinii*		
Galah	*Cacatua roseicapilla*		
Psittacidae (lorikeets and parrots)			
Purple-crowned Lorikeet	*Glossopsitta porphyrocephala*		
Regent Parrot	*Polytelis anthopeplus*	*	*
Red-capped Parrot	*Purpureicephalus spurius*	*	*
Western Rosella	*Platycercus icterotis*		*

Table 9 (cont.)

Species		March	October
Australian Ringneck	*Barnardius zonarius*	*	*
Elegant Parrot	*Neophema elegans*		
Cuculidae (cuckoos)			
Pallid Cuckoo	*Cuculus pallidus*		
Fan-tailed Cuckoo	*Cuculus pyrrhophanus*		*
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*		
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*		*
Strigidae (hawk-owls)			
Barking Owl (south-west sub-species)	*Ninox connivens connivens*		+
Southern Boobook Owl	*Ninox novaeseelandiae*	*	*
Tytonidae (barn owls)			
Masked Owl (southern sub-species)	*Tyto novaehollandiae novaehollandiae*		+
Barn Owl	*Tyto alba*		
Podargidae (frogmouths)			
Tawny Frogmouth	*Podargus strigoides*	*	
Halcyonidae (forest kingfishers)			
Laughing Kookaburra	*Dacelo novaeguineae* [Int.]	*	*
Sacred Kingfisher	*Todiramphus sanctus*		*
Meropidae (bee-eaters)			
Rainbow Bee-eater	*Merops ornatus*		*
Maluridae (fairy-wrens)			
Splendid Fairy-wren	*Malurus splendens*	*	*
Pardalotidae (pardalotes)			
Spotted Pardalote	*Pardalotus punctatus*	*	
Striated Pardalote	*Pardalotus striatus*	*	*
White-browed Scrubwren	*Sericornis frontalis*	*	
Weebill	*Smicrornis brevirostris*	*	*
Western Gerygone	*Gerygone fusca*	*	*
Inland Thornbill	*Acanthiza apicalis*	*	*
Western Thornbill	*Acanthiza inornata*		
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	*	*
Meliphagidae (honeyeaters)			
Red Wattlebird	*Anthochaera carunculata*	*	*
Little Wattlebird	*Anthochaera chrysoptera*		
Brown-headed Honeyeater	*Melithreptus brevirostris*		
White-naped Honeyeater	*Melithreptus lunatus*		
Brown Honeyeater	*Lichmera indistincta*	*	*
New Holland Honeyeater	*Phylidonyris novaehollandiae*		
White-cheeked Honeyeater	*Phylidonyris nigra*		
Tawny-crowned Honeyeater	*Phylidonyris melanops*		
Western Spinebill	*Acanthorhynchus superciliosus*	*	
Petroicidae (Australian robins)			
Scarlet Robin	*Petroica multicolor*	*	*
Western Yellow Robin	*Eopsaltria griseogularis*		

Table 9 (cont.)

Species		March	October
Neosittidae (sittellas)			
Varied Sittella	*Daphoenositta chrysoptera*	*	*
Pachycephalidae (whistlers)			
Golden Whistler	*Pachycephala pectoralis*	*	*
Rufous Whistler	*Pachycephala rufiventris*	*	*
Grey Shrike-thrush	*Colluricincla harmonica*	*	*
Dicruridae (flycatchers)			
Magpie-lark	*Grallina cyanoleuca*		
Grey Fantail	*Rhipidura fuliginosa*	*	*
Willie Wagtail	*Rhipidura leucophrys*	*	
Campephagidae (cuckoo-shrikes)			
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	*	*
White-winged Triller	*Lalage sueurii*		
Artamidae (woodswallows)			
Black-faced Woodswallow	*Artamus cinereus*	*	
Dusky Woodswallow	*Artamus cyanopterus*		
Grey Butcherbird	*Cracticus torquatus*	*	*
Australian Magpie	*Gymnorhina tibicen*	*	*
Corvidae (ravens and crows)			
Australian Raven	*Corvus coronoides*	*	*
Motacillidae (pipits and true wagtails)			
Richard's Pipit	*Anthus novaeseelandiae*		
Hirundinidae (swallows)			
Welcome Swallow	*Hirundo neoxena*		
Tree Martin	*Hirundo nigricans*		
Sylviidae (old world warblers)			
Rufous Songlark	*Cincloramphus mathewsi*		
Zosteropidae (white-eyes)			
Silvereye	*Zosterops lateralis*	*	*
Number of bird species expected (observed):		85 (36)	(36)

TABLE TEN. Mammal species known from the general region of Ludlow, indicating those trapped, observed or expected on the Mining area. Species not so indicated are considered unlikely to be present. [Int.] indicates introduced species.

Species		Comments
Tachyglossidae (echidnas)		
Echidna	*Tachyglossus aculeatus*	expected
Dasyuridae		
Mardo	*Antechinus flavipes*	
Chuditch	*Dasyurus geoffroii*	expected
Brush-tailed Phascogale	*Phascogale tapoatafa*	expected
Gilbert's Dunnart	*Sminthopsis gilberti*	
Peramelidae (bandicoots)		
Quenda (Southern Brown Bandicoot)	*Isoodon obesulus*	trapped
Phalangeridae (possums)		
Brush-tailed Possum	*Trichosurus vulpecula*	trapped
Pseudocheiridae (ring-tailed possums)		
Western Ring-tailed Possum	*Pseudochierus occidentalis*	expected
Burramyidae (pygmy possums)		
Western Pygmy Possum	*Cercartetus concinnus*	expected
Tarsipedidae (honey possum)		
Honey Possum	*Tarsipes rostratus*	
Macropodidae (kangaroos and wallabies)		
Western Grey Kangaroo	*Macropus fuliginosus*	observed
Brush or Black-gloved Wallaby	*Macropus irma*	expected
Mollosidae (mastiff bats)		
White-striped Bat	*Nyctinomus australis*	observed
	Mormopterus planiceps	expected
Vespertilionidae (vesper bats)		
Gould's Wattled Bat	*Chalinolobus gouldii*	expected
Chocolate Wattled Bat	*Chalinolobus morio*	expected
	Vespedalus (Eptesicus) regulus	expected
	Falsistrellus mackenziei	expected
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	expected
Gould's Long-eared Bat	*Nyctophilus gouldii*	trapped
Greater Long-eared Bat	*Nyctophilus timoriensis*	trapped
Muridae (rats and mice)		
Rakali or Water Rat	*Hydromys chrysogaster*	
House Mouse	*Mus musculus* [Int.]	trapped
Moodit or Southern Bush Rat	*Rattus fuscipes*	
Black Rat	*Rattus rattus* [Int.]	trapped
Leporidae (rabbits and hares)		
Rabbit	*Oryctolagus cuniculus* [Int.]	observed
Canidae (foxes and dogs)		
European Red Fox	*Vulpes vulpes* [Int.]	observed
Felidae (cats)		
Feral Cat	*Felis catus* [Int.]	observed
Number of species expected (observed):		23 (8)

FIGURE ONE. Trapping layout recommended by CALM (the Kingston layout), consisting of 15 assisted pitfall traps (20 l buckets each with an *ca.* 7 m driftfence, 15 medium Elliott Traps and 9 cage traps).

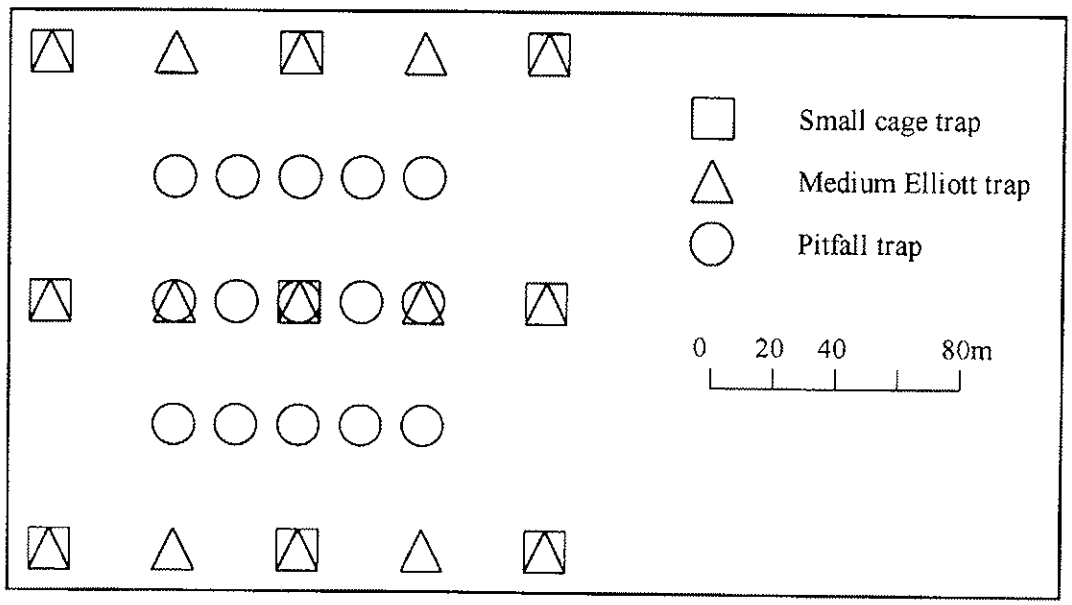
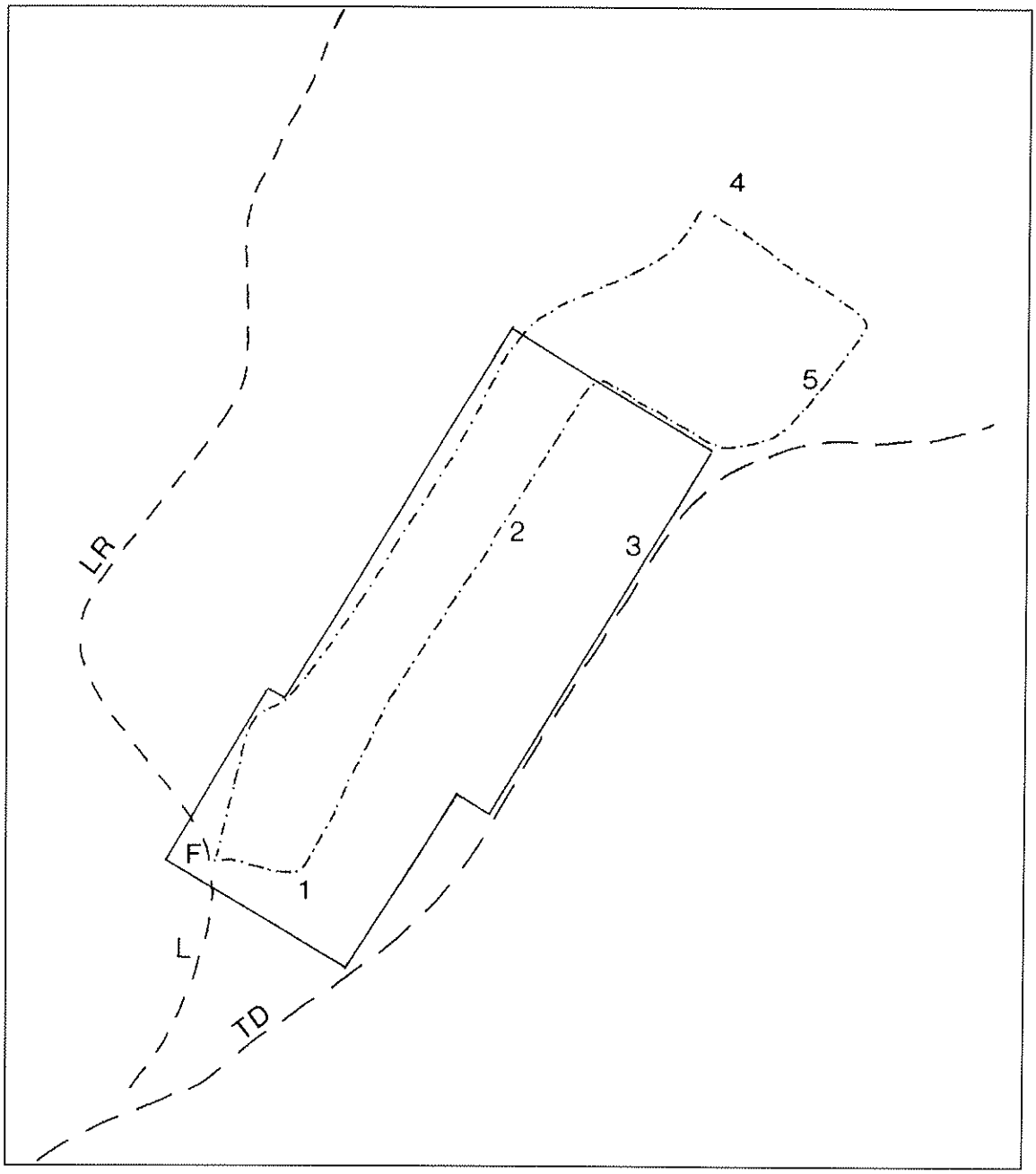


FIGURE TWO. Sketch map of the project area, indicating the route followed during spotlighting surveys undertaken in March and October 2001 (dot-dash line). The Mining lease is enclosed by a solid line. Numbers 1 to 5 indicate the approximate locations of study sites, L indicates Ludlow townsite and F indicates the location of the intersection of Formation and Ludlow Roads, where spotlighting runs began and ended. LR and TD indicate Ludlow Road and Tuart Drive respectively.



REFERENCES

Aplin, K. and Kirkpatrick, P. (2001). In Pursuit of the Frog Fungus. Landscope 16: 10-16.

Bamford, M.J. (1997). Frogs and Reptiles at the RGC Wetlands Centre, Capel, WA. Report on studies from autumn 1993 to autumn 1995. Technical Report No. 32. RGC Wetlands Centre.

Blakers, M., Davies, S.J.J.F., Reilly, P.N. (1984). The Atlas of Australian Birds. RAOU and Melbourne University Press, Melbourne.

Bush, B., Maryan, B., Browne-Cooper, R. and Robinson, D. (1995). A Guide to the Reptiles and Frogs of the Perth Region. University of Western Australia Press, Perth.

Cale, P. (1990). The value of road reserves to the avifauna of the central wheatbelt of Western Australia. Proc. Ecol. Soc. Aust. 16: 359-367.

Christidis, L. and Boles, W.E. (1994). The Taxonomy and Species of Birds of Australia and its Territories. RAOU, Monograph 2.

Cogger, H.G., Cameron, E.E., Sadlier, R.A. and Eggler, P. (1993). The Action Plan for Australian Reptiles. Australian Nature Conservation Agency Endangered Species Programme, Project No. 124.

Dames and Moore (1989). A Study of Corridors for Native Fauna. Ludlow Tuart Forest. Unpublished report prepared for Westralian Sands by Dames and Moore, Perth.

Dell, J., How, A. and Burbidge, A.H. (unpub.). Vertebrate fauna of Tuart Woodlands.

Doyle, F.W. and Carter, J. (1998). Waterbird Usage of the Lakes at the RGC Wetlands Centre, Capel, Western Australia, 1997. Technical Report No. 46. RGC Mineral Sands Ltd.

Garnett, S.T. and Crowley, G.M. (2000). The Action Plan for Australian Birds. Environment Australia, Canberra.

Higgins, P.J. (ed) (1999). Handbook of Australian, New Zealand and Antarctic Birds Vo. 4. Parrots to Dollarbird. Oxford University Press, Melbourne.

Johnstone, R.E. and Storr, G.M. (1998). Handbook of Western Australian Birds. Volume 1 - Non-passerines (Emu to Dollarbird). W.A. Museum, Perth.

Loyn, R. M. (1986). The 20 minute search – a simple method for counting forest birds. Corella 10: 58-60.

Mace, G. and Stuart, S. (1994). Draft IUCN Red List Categories, Version 2.2. Species; Newsletter of the Species Survival Commission. IUCN - The World Conservation Union. No. 21-22: 13-24.

Margules, C., Higgs, A.J. and Rafe, R.W. (1982). Modern Biogeographic Theory; are there any lessons for Nature Reserve Design? Biological Conservation 24: 115-128.

Mills, L.S. and Allendorf, F.W. (1996). The one-migrant-per-generation rule in conservation and management. Conservation Biology 10: 1509-1518.

Noss, R.F. and Harris, L.D. (1986). Nodes, Networks and MUMs; Pereserving Diversity at all Scales. Environmental Management 10: 299-309.

Saunders, D.A. and Hobbs, R.J. (eds) (1991). Nature Conservation 2: The Role of Corridors. Surrey Beatty and Sons: Chipping Norton.

Saunders, D.A., Hobbs, R.J. and Ehrlich, P.R. (eds) (1993). Nature Conservation 3: Reconstruction of Fragmented Ecosystems. Surrey Beatty and Sons: Chipping Norton.

Saunders, D. and Ingram, J. (1995). Birds of South-Western Australia; an atlas of changes in distribution and abundance of the wheatbelt fauna. Surrey Beatty and Sons, NSW.

Simberloff, D. and Cox, J. (1987). Consequences and Costs of Conservation Corridors. Conservation Biology 1: 63-71.

Soule, M.E. and Simberloff, D. (1988). What d Genetics and Ecology tell us about the Design of Nature Reserves? Biological Conservation 35: 19-40.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1983). Lizards of Western Australia. II. Dragons and Monitors. W.A. Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1986). Snakes of Western Australia. W.A. Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1990). Lizards of Western Australia. III. Geckoes and Pygopodids. W.A. Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1999). Lizards of Western Australia. I. Skinks. Revised Edition. W.A. Museum, Perth.

Strahan, R. (ed.). (1983). The Australian Museum Complete Book of Australian Mammals. Angus and Robertson, Sydney.

Tyler, M.J., Smith, L.A. and Johnstone, R.E. (1984). Frogs of Western Australia. W.A. Museum, Perth.

APPENDIX ONE. Capture records and morphometric data for all frog, reptile and mammal specimens caught on the trapping grids during the Cable Sands Ludlow Fauna Survey, March/April and October 2001. Column abbreviations are: Wt = weight (g); Crn = crown length (mm); GW = gonad width (mm); SVL = snout to vent length (mm); Tot = total length (mm). py indicates pouch young. bky indicates young being carried on back.

Appendix 1A: mammal captures on Sites 1 – 5.

Date	Species	Site No.	Trap type	Wt	Crn	GW	sex	Notes
28/03	*Trichosurus vulpecula*	1	cage	2050			F	dry pouch
29/03	*Rattus rattus*	1	cage	1300				
30/03	*T. vulpecula*	1	cage	1650		15	M	young animal
30/03	*T. vulpecula*	1	cage	1500		35	M	
30/03	*T. vulpecula*	1	cage	1700			F	young; 1/3 white tail
30/03	*Isoodon obesulus*	2	cage	1050	84	24	M	tail tip missing
30/03	*Mus musculus*	3	pit				M	
30/03	*T. vulpecula*	5	cage	900			F	virgin pouch
31/03	*T. vulpecula*	1	cage	1700			F	virgin pouch
31/03	*M. musculus*	3	elliott					
31/03	*T. vulpecula*	3	cage	1900		33	M	
31/03	*T. vulpecula*	4	cage	650			F	young
31/03	*T. vulpecula*	5	cage	1850		33	M	
31/03	*Phascogale tapoatafa*	5	cage	195		18.5	M	
01/04	*R. rattus*	1	cage					
01/04	*T. vulpecula*	1	cage					Retrap from 30/03
01/04	*T. vulpecula*	1	cage	1600		28	M	
01/04	*T. vulpecula*	1	cage	1200		20	M	
01/04	*I. obesulus*	2	cage	1050		30	M	
01/04	*M. musculus*	3	pit					
01/04	*M. musculus*	3	pit					
01/04	*M. musculus*	3	elliott					
01/04	*M. musculus*	3	pit					
01/04	*T. vulpecula*	3	cage	1500			F	dry pouch
01/04	*I. obesulus*	5	cage	1500		25	M	
21/10	*R. rattus*	1	cage					
21/10	*T. vulpecula*	1	cage	2200			M	black tail
21/10	*T. vulpecula*	1	cage	1900			M	black tail
21/10	*R. rattus*	2	cage				F	lactating
21/10	*T. vulpecula*	2	cage	2100			M	
21/10	*T. vulpecula*	3	cage	1550	87		M	
22/10	*T. vulpecula*	1	cage	-			F	1 bky
22/10	*M. musculus*	3	elliott					
22/10	*T. vulpecula*	5	cage	1750			M	

Appendix 1a (cont.)

Date	Species	Site No.	Trap type	Wt	Crn	GW	sex	Notes
23/10	*M. musculus*	1	elliott					
23/10	*R. rattus*	1	cage				F	
23/10	*T. vulpecula*	2	cage	2000			M	
23/10	*M. musculus*	3	pit					
23/10	*I. obesulus*	3	cage	1250			F	3 small py
23/10	*T. vulpecula*	5	cage	1700			M	
24/10	*I. obesulus*	1	cage	200			F	juvenile
24/10	*T. vulpecula*	2	cage	1750			M	
24/10	*I. obesulus*	3	cage	1300			F	recapture 23/10
24/10	*T. vulpecula*	3	cage	2000			M	
24/10	*T. vulpecula*	5	cage	1800			M	
24/10	*T. vulpecula*	5	cage	1900			M	
25/10	*T. vulpecula*	1	cage	1850			M	
25/10	*T. vulpecula*	1	cage	-			F	large bky
25/10	*T. vulpecula*	1	cage	2050			M	
25/10	*T. vulpecula*	1	cage	1800			M	
25/10	*I. obesulus*	2	cage	2150			M	
25/10	*T. vulpecula*	2	cage	1900			M	
25/10	*M. musculus*	3	elliott					
25/10	*M. musculus*	3	elliott					
25/10	*T. vulpecula*	3	cage	1650			M	
25/10	*T. vulpecula*	3	cage	1850			F	post-breeding
25/10	*T. vulpecula*	3	cage	1500			M	
25/10	*T. vulpecula*	3	cage	1500			F	post-breeding
25/10	*O. cuniculus*	4	cage					juvenile
25/10	*T. vulpecula*	5	cage	1750			M	

Appendix 1B: Reptile and amphibian captures on Sites 1 – 5.

Date	Species	Site No.	Trap type	SVL	Tot	sex	Notes
28/03	*Lerista elegans*	2	pit				
28/03	*L. elegans*	2	pit				
28/03	*Morethia lineoocellata*	3	pit	44	106		
29/03	*M. lineoocellata*	3	pit	23			
29/03	*Heleioporus eyrei*	3	pit	46			
29/03	*M. lineoocellata*	4	pit	39			
30/03	*M. lineoocellata*	1	pit	38	101		
30/03	*M. lineoocellata*	2	pit	28	60		
30/03	*L. elegans*	2	pit				juvenile
30/03	*L. elegans*	2	pit	28	55		
30/03	*M. lineoocellata*	3	pit	26	60		
30/03	*Menetia greyii*	3	pit	45	98	M	yellow belly

Appendix 1b (cont.)

Date	Species	Site No.	Trap type	SVL	Tot	sex	Notes
30/03	*L. elegans*	3	pit	26	48		
30/03	*L. elegans*	3	pit	27	62		
30/03	*M. lineoocellata*	3	pit	25	56		
30/03	*M. lineoocellata*	3	pit	30	54		
30/03	*M. lineoocellata*	3	pit	40	84		Retrap
30/03	*M. lineoocellata*	3	pit	31	79		
30/03	*Lerista distinguenda?*	3	pit	36	52		
30/03	*M. greyii*	3	pit	22	34		
30/03	*M. greyii*	4	pit	31	71		
30/03	*M. greyii*	5	pit				
31/03	*Hemiergis peroni*	1	pit	25	48		
31/03	*L. elegans*	1	pit	23	45		
31/03	*H. eyrei*	2	pit	47			
31/03	*L. elegans*	2	pit	34	72		
31/03	*M. lineoocellata*	2	pit	29	69		
31/03	*M. greyii*	3	pit	29	34		
31/03	*M. lineoocellata*	3	pit	26	58		
31/03	*M. lineoocellata*	3	pit	27	71		
31/03	*M. greyii*	3	pit	34	80		
31/03	*M. lineoocellata*	3	pit	28	63		
31/03	*M. lineoocellata*	3	pit	28	65		
31/03	*M. lineoocellata*	3	pit				juvenile
31/03	*M. greyii*	4	pit	21	43		
31/03	*M. greyii*	4	pit	23	54		
31/03	*H. eyrei*	4	pit				
31/03	*M. lineoocellata*	5	pit	41	91		
31/03	*M. greyii*	5	pit	36	80		
31/03	*M. greyii*	5	pit	22	48		
31/03	*L. elegans*	5	pit	26	52		
01/04	*L. elegans*	2	pit	23	42		
01/04	*L. elegans*	2	pit	27	50		
01/04	*M. greyii*	2	pit	24	52		
01/04	*M. greyii*	2	pit	22	50		
01/04	*L. elegans*	2	pit	25	48		
01/04	*M. lineoocellata*	3	pit	25	62		
01/04	*H. peroni*	3	pit				juvenile
01/04	*L. elegans*	3	pit				juvenile
01/04	*M. greyii*	3	pit				
01/04	*M. lineoocellata*	3	pit	41	100		
01/04	*M. lineoocellata*	3	pit	30	67		
01/04	*M. greyii*	4	pit	23	54		
01/04	*M. greyii*	4	pit	25	59		

Appendix 1b (cont.)

Date	Species	Site No.	Trap type	SVL	Tot	sex	Notes
01/04	*M. lineoocellata*	4	pit	44	98		
01/04	*M. greyii*	4	pit	20	43		
01/04	*L. elegans*	4	pit	25	45		
21/10	*H. eyrei*	1	pit	45			
21/10	*H. eyrei*	1	pit	50			
21/10	*H. eyrei*	2	pit	52			
21/10	*H. eyrei*	2	pit	42			
21/10	*H. eyrei*	2	pit	41			
21/10	*H. eyrei*	2	pit	52			
21/10	*H. eyrei*	2	pit	56			
21/10	*H. eyrei*	2	pit	56			
21/10	*H. eyrei*	2	pit	43			
21/10	*H. eyrei*	2	pit	50			
21/10	*H. eyrei*	2	pit	37			
21/10	*M. lineoocellata*	2	pit	40	93	M	
21/10	*H. peroni*	2	pit	50	106		
21/10	*H. eyrei*	3	pit	52			
21/10	*H. eyrei*	3	pit	52			
21/10	*H. eyrei*	3	pit	45			
21/10	*H. eyrei*	3	pit	48			
21/10	*H. eyrei*	3	pit	41			
21/10	*H. eyrei*	3	pit	46			
21/10	*H. eyrei*	3	pit	50			
21/10	*H. eyrei*	3	pit	41			
21/10	*Limnodynastes dorsalis*	3	pit	61			
21/10	*H. eyrei*	4	pit	40			
21/10	*H. eyrei*	4	pit	35			
21/10	*H. eyrei*	4	pit	37			
21/10	*H. eyrei*	4	pit	34			
21/10	*H. eyrei*	4	pit	38			
21/10	*H. eyrei*	4	pit	39			
21/10	*H. eyrei*	4	pit	39			
21/10	*H. eyrei*	4	pit	38			
21/10	*H. eyrei*	4	pit	40			
21/10	*H. eyrei*	4	pit	40			
21/10	*H. eyrei*	4	pit	38			
21/10	*H. eyrei*	4	pit	38			
21/10	*H. eyrei*	4	pit	38			
21/10	*H. eyrei*	4	pit	35			
21/10	*H. eyrei*	4	pit	38			
21/10	*H. eyrei*	4	pit	43			
21/10	*H. eyrei*	5	pit	39			
21/10	*H. eyrei*	5	pit	37			

Appendix 1b (cont.)

Date	Species	Site No.	Trap type	SVL	Tot	sex	Notes
21/10	*H. eyrei*	5	pit	35			
21/10	*H. eyrei*	5	pit	42			
21/10	*H. eyrei*	5	pit	50			
21/10	*H. eyrei*	5	pit	53			
21/10	*H. eyrei*	5	pit	27			
21/10	*H. eyrei*	5	pit	41			
21/10	*H. eyrei*	5	pit	40			
21/10	*H. eyrei*	5	pit	38			
21/10	*H. eyrei*	5	pit	36			
21/10	*H. eyrei*	5	pit	39			
21/10	*Crinia. insignifera*	5	pit	21			
21/10	*C. insignifera*	5	pit	23			
22/10	*H. eyrei*	2	pit	53			
22/10	*H. eyrei*	3	pit	40			
22/10	*H. eyrei*	3	pit	41			
22/10	*H. eyrei*	3	pit	47			
22/10	*H. eyrei*	3	pit	49			
22/10	*H. eyrei*	3	pit	51			
22/10	*L. elegans*	3	pit	-			
22/10	*H. eyrei*	4	pit	35			
22/10	*H. eyrei*	4	pit	29			
22/10	*H. eyrei*	5	pit	34			
22/10	*C. insignifera*	5	pit	22		F	
22/10	*C. insignifera*	5	pit	20		F	
22/10	*C. insignifera*	5	pit	18		M	
23/10	*H. eyrei*	1	pit	47			
23/10	*H. eyrei*	2	pit	39			
23/10	*H. eyrei*	2	pit	42			
23/10	*H. eyrei*	3	pit	40			
23/10	*H. eyrei*	3	elliott	47			
23/10	*M. lineoocelata*	3	pit	45	105	M	
23/10	*H. eyrei*	4	pit	38			
23/10	*H. eyrei*	4	pit	34			
24/10	*M. lineoocellata*	2	pit	46	110	M	
24/10	*M. lineoocellata*	3	pit	38	70	M	
24/10	*H. eyrei*	4	pit	35			
24/10	*M. greyii*	4	pit	32	80	M	breeding
24/10	*H. peroni*	4	pit	30	65		
24/10	*H. eyrei*	5	pit	39			
24/10	*Tiliqua rugosa*	5	cage				
24/10	*T. rugosa*	5	cage				

Appendix 1b (cont.)

Date	Species	Site No.	Trap type	SVL	Tot	sex	Notes
25/10	*H. eyrei*	2	pit	55			
25/10	*H. eyrei*	2	pit	50			
25/10	*H. eyrei*	2	pit	45			
25/10	*M. lineoocellata*	2	pit	40	90	M	
25/10	*M. lineoocellata*	2	pit	43	97	M	
25/10	*H. eyrei*	3	cage	-			
25/10	*T. rugosa*	3	cage				
25/10	*M. greyii*	3	pit	32	75	M	breeding
25/10	*M. greyii*	3	pit	30	70	M	breeding
25/10	*M. greyii*	3	pit	30	52	F	
25/10	*M. greyii*	3	pit	35	62	M	
25/10	*L. elegans*	3	pit	40	80		
25/10	*H. eyrei*	4	pit	-			
25/10	*H. eyrei*	4	pit	35			
25/10	*Cryptoblepharus plagiocephalus*	5	pit	43	90		

APPENDIX TWO. Results of spotlighting surveys, 2001 and 1986-1988. See Figure 2 for routes followed in 2001.

Survey 1. 28th March 2001. 1920-2120 hours. Fine evening, little wind, ¼ moon. Route was clockwise from Ludlow North Road/Formation Road intersection.

Distance (km)	Observations
0	Ludlow North Road/Formation Road intersection
0.2	Cat. Grey Kangaroo
0.6	Brush-tailed Possum in *Agonis*
0.75	2 Grey Kangaroos
1.2	Grey Kangaroo. Brush-tailed Possum in *Agonis*
1.3	2 Grey Kangaroos
1.65	Grey Kangaroo
2.0	Grey Butcherbird (roosting)
2.1	Brush-tailed Possum in Tuart
2.4	boundary of National Park; entering National Park
2.5	Ring-tailed Possum in *Agonis*
2.6	Brush-tailed Possum in Tuart
2.7	Brush-tailed Possum in Tuart
3.2	Brush-tailed Possum in *Agonis*
3.55	2 Brush-tailed Possums in *Agonis*
4.0	Brush-tailed Possum in Tuart
4.05	Rabbit. *Nyctinemus australis*
4.15	Brush-tailed Possum on ground
4.5	boundary of National Park; leaving National Park
4.7	unidentified bat
4.85	*Nyctinemus australis*
6.15	Rabbit
6.3	Brush-tailed Possum in Tuart
6.5	5 Grey Kangaroos
6.8	cat or fox seen briefly at distance
7.1	2 Brush-tailed Possums in *Agonis*
7.55	Rabbit
7.7	*Nyctinemus australis*
7.9	Tawny Frogmouth
7.95	Rabbit
8.0	Ludlow North Road/Formation Road intersection

Survey 2. 30th March 2001. 1915-2125 hours. Fine evening, little wind, ¼ moon. Route was anti-clockwise from Ludlow North Road/Formation Road intersection.

Distance (km)	Observations
0	Ludlow North Road/Formation Road intersection
0.1	Rabbit
0.5	2 Brush-tailed Possums in *Agonis*
1.0	2 Brush-tailed Possums on ground
1.3	Rabbit
1.5	Grey Kangaroo
1.7	Tawny Frogmouth
1.95	*Nyctinemus australis*
2.1	3 Brush-tailed Possums; 1 in *Agonis*, 1 on ground, 1 in Tuart
2.15	Tawny Frogmouth
2.4	Grey Kangaroo
3.4	boundary of National Park; entering National Park
3.4	Brush-tailed Possum on ground
3.5	2 Brush-tailed Possums in *Agonis*
3.5	unidentified bat
4.0	Ring-tailed Possum in *Agonis*
4.1	Brush-tailed Possum in Marri
4.2	2 Brush-tailed Possums in Marri
4.3	*Nyctinemus australis*
4.5	Brush-tailed Possum in Marri
4.9	*Nyctinemus australis*
5.2	*Nyctimemus australis*
5.4	*Nyctinemus australis*
5.65	*Nyctinemus australis*
5.85	3 Grey Kangaroos
6.0	*Nyctinemus australis*
6.05	Grey Kangaroo
6.15	boundary of National Park and onto Formation Road; leaving National Park
6.2	Brush-tailed Possum in Tuart. *Nyctinemus australis*
6.25	2 Grey Kangaroos
6.3	*Nyctinemus australis*
6.6	*Nyctinemus australis*
6.8	*Nyctinemus australis*
7.1	*Nyctinemus australis*
7.3	*Nyctinemus australis*
7.5	Brush-tailed Possum in *Agonis*
7.7	3 Grey Kangaroos. 3 Rabbits. *Nyctonemus australis*
8.2	Rabbit
8.5	Ludlow North Road/Formation Road intersection

Survey 3. 31st March 2001. 2015-2120 hours. Fine evening, gusty wind, 1/3 moon. Route was anti-clockwise from Site 5 to the Ludlow North Road/Formation Road intersection.

Distance (km)	Observations
0	Site 5
0.05	Rabbit
0.15	Rabbit
0.2	Brush-tailed Possum in *Agonis*
1.4	Brush-tailed Possum in Tuart
1.8	boundary of National Park; entering Mining Lease
2.6	2 Brush-tailed Possums on ground
4.5	Rabbit
4.7	Ludlow North Road/Formation Road intersection

Survey 4. 20th October 2001. 2025-2200 hours. Mostly fine. Little moon. Route was anti-clockwise from Site 1 to Ludlow North Road/Formation Road intersection.

Distance (km)	Observations
0	Site 1
0.	Brush-tailed Possum in *Agonis*
0.6	2 Grey Kangaroos
0.8	2 Grey Kangaroos
1.1	1 Grey Kangaroo
1.5	2 Grey Kangaroos and 2 Brush-tailed Possums in Tuart
1.85	1 Brush-tailed Possum with large young in pine
2.1	1 Brush-tailed Possum with large young in Tuart
2.05	1 Grey Kangaroo
2.15	1 Brush-tailed Possum in Tuart
2.6	boundary of National Park; entering National Park, leaving lease
3.0	2 Brush-tailed Possums in tuart
3.4	2 Grey Kangaroos
3.6	1 Brush-tailed Possum in Tuart
3.8	1 Grey Kangaroo and 1 Brush-tailed Possum in Tuart
4.6	1 Brush-tailed Possum in *Agonis*
4.7	1 Ring-tailed Possum in *Agonis*
4.9	2 Rabbits
5.1	1 Grey Kangaroo
5.2	boundary of National Park; leaving National Park, entering lease
5.35	1 Brush-tailed Possum in Tuart
5.65	2 Brush-tailed Possums in pine
6.2	1 Brush-tailed Possum on ground and 1 with large young in pine
6.25	1 Brush-tailed Possum in pine
6.3	1 Brush-tailed Possum on ground
6.55	2 Grey Kangaroos and 1 Rabbit
6.8	1 Brush-tailed Possum on ground
6.9	1 Brush-tailed Possum in Marri
7.1	1 Grey Kangaroo
8.0	Ludlow North Road/Formation Road intersection

Survey 5. 21st October 2001. 1945-2130 hours. Fine. Little moon. Route was anti-clockwise from Site 1 to Ludlow North Road/Formation Road intersection.

Distance (km)	Observations
0	Site 1
0.3	1 Grey Kangaroo
0.7	2 Brush-tailed Possums, 1 with a large young, in *Agonis*
0.95	2 Grey Kangaroos
1.25	1 Brush-tailed Possum in *Agonis*
1.3	1 Brush-tailed Possums in Tuart
1.55	1 Brush-tailed Possum in tuart
1.7	1 Brush-tailed Possum in pine
1.75	1 Brush-tailed Possum in dead Tuart
2.1	1 Brush-tailed Possum with a large young in dead Tuart
2.15	*Tadarida australis*
2.4	1 Grey Kangaroo
2.7	boundary of National Park; entering National Park, leaving lease
2.7	1 Brush-tailed Possum with large young in Tuart
2.75	1 Brush-tailed Possum in *Agonis*
3.1	1 Brush-tailed Possum in Banksia and 4 Grey Kangaroos
3.4	1 Brush-tailed Possum on ground
4.15	1 Ring-tailed Possum in *Agonis*
4.5	10 Grey Kangaroos
4.8	3 Boobook Owls calling at Site 5 during 5 minute stop
5.2	2 Grey Kangaroos
5.4	1 Brush-tailed Possum on ground
5.65	2 Brush-tailed Possums on ground
5.75	boundary of National Park; leaving National Park, entering lease
5.75	5 Grey Kangaroos
5.85	1 Brush-tailed Possum in debris of felled pine
6.35	1 Brush-tailed Possum with large young in *Banksia grandis*
6.4	1 Grey Kangaroo
6.8	1 Brush-tailed Possum with large young in *Agonis*
7.0	4 Grey Kangaroos and 1 Rabbit
7.2	1 Brush-tailed Possum with large young in *Agonis* and 2 Kangaroos
7.9	1 Brush-tailed Possum on ground and 40 Grey Kangaroos
8.1	Ludlow North Road/Formation Road intersection

Survey 6. 22nd October 2001. 1930-2120 hours. Fine. Little moon. Route was anti-clockwise from Site 1 to Ludlow North Road/Formation Road intersection.

Distance (km)	Observations
0	Site 1. No owls calling
0.3	1 Grey Kangaroo
0.45	2 Grey Kangaroos
0.6	1 Brush-tailed Possum in *Agonis*
0.8	1 Rabbit
0.9	3 Grey Kangaroos
1.0	1 Rabbit
1.5	Site 2. No owls calling
1.6	1 Brush-tailed Possum in *Agonis*
1.8	1 Brush-tailed Possum with a large young in Tuart
2.25	1 Grey Kangaroo
2.3	1 Brush-tailed Possum in pine
2.6	1 Boobook Owl calling
2.7	boundary of National Park; entering National Park, leaving lease
2.7	2 Brush-tailed Possums in Banksias, 1 Grey Kangaroo and 1 Boobook Owl calling
2.8	1 Rabbit
3.1	1 Brush-tailed Possum in Tuart
3.1	Site 4. No owls calling
3.5	1 Brush-tailed Possum in *Agonis* and 1 Rabbit
4.1	2 Brush-tailed Possums in *Agonis*
4.5	Site 5. No owls calling
4.8	1 Fox
5.6	boundary of National Park; leaving National Park, entering lease
6.2	1 Grey Kangaroo
6.4	2 Grey Kangaroos
6.6	1 Brush-tailed Possum in Tuart and 1 in *Agonis*
6.9	1 Brush-tailed Possum with large young in *Agonis* and 10 Grey Kangaroos
7.2	5 Grey Kangaroos
7.3	1 Brush-tailed Possum on ground
7.6	2 Brush-tailed Possums on ground
7.7	2 Brush-tailed Possums in *Agonis*
7.75	2 Brush-tailed Possums in *Agonis*
8.0	Ludlow North Road/Formation Road intersection

Appendix Two (cont.). Summary of spotlighting surveys conducted in Mining Area from December 1986 to December 1988, extracted from an unpublished report (Westralian Sands).

Date	Dist. km	Brush-tailed Possum	Ring-tailed Possum	Kangaroo	Rabbit	Tawny Frog-mouth	Other
30/12/86	9.0	3	-	2	present	-	-
10/01/87	9.0	2	-	1	present	-	-
12/01/87	9.0	3	-	1	present	-	Phascogale: 1
17/01/87	9.5	1	-	4	8		Phascogale: 1
18/03/87	7.1	3	-	-	1	-	-
22/04/97	7.4	1	-	-	5	-	-
02/06/87	8.5	1	1	2	2	2	Cat: 1
01/07/87	7.9	1	-	8	13	-	-
17/08/87	8.8	7	-	8	8	4	Boobook: 1
15/09/87	9.6	4	-	24	6	-	-
26/10/87	9.2	1	-	3	2	1	Fox: 1
18/11/87	9.1	3	-	8	5	-	Boobook: 2
23/12/87	9.0	3	-	2	1	-	Fox: 1
27/01/88	9.2	3	-	7	8	5	-
03/03/88	9.3	3	-	-	4	1	-
06/04/88	9.9	2	-	4	4	4	-
28/05/88	9.4	1	-	33	12	1	-
15/06/88	9.2	-	-	8	16	3	-
20/07/88	9.2	4	4	6	7	1	Boobook: 1
03/12/88	9.3	1	-	-	3	-	Fox: 1

APPENDIX THREE-A. Results from bird censussing in March, presenting the number of each species seen in each 2 ha search area in each site. Site descriptions and dates and times when bird surveys were carried out are presented in Table 1.

Species	Site 1				Site 2				Site 3				Site 4				Site 5			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Wedge-tailed Eagle													1	-	-	-				
Collared Sparrowhawk																	-	1	-	-
Common Bronzewing													1	-	-	-				
Regent Parrot					-	1			-	1	-	-								
Australian Ringneck	-	1	-	-	-	-	5	4	4	-	7	1	5	-	5	5	1	2	4	8
Red-capped Parrot					1	-	1	-	-	-	1	2	-	-	3	5	-	1	-	2
Laughing Kookaburra	1	-	-	-					2	1	1	1								
Splendid Fairy-wren									-	3	-	-								
Spotted Pardalote									-	1	-	2	-	-	-	-	-	1	-	-
Striated Pardalote					1	-	1	2	-	1	-	-	-	1	1	1	-	2	1	2
Weebill									-	3	-	7	-	3	5	-	3	3	-	-
Western Gerygone	1	-	-	-	-	-	1	1	-	1	-	2	1	2	3	1	1	-	-	-
Inland Thornbill	2	-	-	1	-	-	-	5	-	-	3	-	-	-	7	4	-	-	2	8
Red Wattlebird									1	-	-	1	-	-	-	1	-	1	-	1
Brown Honeyeater									2	2	-	-								
Western Spinebill									-	1	1	-								
Scarlet Robin					1	-	1	1												
Golden Whistler													2	1	1	-	-	1	-	1
Grey Fantail	1	1	1	1	2	1	2	5	3	1	3	1	4	2	5	8	5	3	1	7
Black-faced Cuckoo-shrike													-	-	1	-				
Grey Butcherbird													1	-	1	1	-	3	-	-
Australian Magpie					-	-	-	3									3	-	4	-
Australian Raven	-	3	-	-					-	2	2	-								
Silvereye	3	4	-	-					17	5	15	-								

APPENDIX THREE-B. Results from bird censussing in October, presenting the number of each species seen in each 2 ha search area in each site. Site descriptions and dates and times when bird surveys were carried out are presented in Table 1.

Species	Site 1				Site 2				Site 3				Site 4				Site 5			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
White-bellied Sea-Eagle					-	-	-	1												
Whistling Kite																	-	-	-	2
Brown Goshawk													-	-	-	1				
Brown Falcon													-	-	1	-				
Common Bronzewing																	-	-	1	1
Short-billed Black-Cockatoo													-	-	-	1				
Regent Parrot	-	-	-	2					-	3	1	-	-	1	-	1	-	2	2	
Australian Ringneck	2	-	2	-	-	-	-	2	-	2	15	2	-	5	9	5	2	-	1	2
Red-capped Parrot	1	-	1	1	-	-	-	3					-	1	1	-	-	-	1	-
Fan-tailed Cuckoo																	1	-	-	-
Laughing Kookaburra	-	1			1	-	-	1	1	-	1	-					-	-	-	1
Sacred Kingfisher									-	-	2	-					-	-	2	
Splendid Fairy-wren									5	3							3			
Striated Pardalote	-	-	-	1	1	3	4	3	2	2	4	3	2	3	1	2	3	2	1	4
Weebill					2	2	1	-	2	2	-	5	2	-	-	2				
Western Gerygone	-	4	5	4	1	1	1	1	3	1	3	-	1	1	2	2	1	1	3	1
Inland Thornbill					-	-	2	-	1	2	-	4	2	-			2	-	3	
Yellow-rumped Thornbill	2	-	9	2													2			
Red Wattlebird	3				-	1	-	-	2	2	3	-					5	1	1	4
Brown Honeyeater													-	-	2	-				
Scarlet Robin	2	2	2	-	-	-	-	2	-	-	-	6					-	-	1	
Varied Sittella																	4	-	4	
Golden Whistler	1	2	3	3	-	-	-	1									-	-	1	
Rufous Whistler	1	-	-	1	-	-	-	1												
Grey Fantail	1	2	6	4	1	1	-	-	1	1	2	2	1	1	2	1	1	1	4	4
Grey Butcherbird									-	2	-	1	-	1						
Australian Magpie									-	-	5	-	-	1	-	1	-	-	-	1
Australian Raven	-	-	1	1					-	1	2	-	-	-	1	1				
Silvereye	2	1			-	1											3			

APPENDIX FOUR. Locations and assessment of significant trees. All were large Tuarts with hollows of a suitable size for Brush-tailed Possums. Explanations of columns are as follows:
DBH – diameter at breast height (estimated in metres);
Dist. – the approximate distance to the nearest Tuart;
Canopy touching – whether or not the canopy of the tree touches the canopy of any other tree, scored on scale from 0 (no canopy touching) to 3 (branches interlocking in a clump of trees);
Ladder trees – smaller trees adjacent to and leaning against significant tree, forming a ladder so that possums can readily access the canopy of the significant tree, scored on scale from 0 (no ladder tree) to 2 (extensive contact between significant tree and ladder tree);
Scats – droppings (of Brush-tailed Possums) present on ground beneath tree.
Hollows – the number and apparent usage of hollows was scored from 1 (few hollows not obviously used) to 3 (several hollows with clear usage indicated by polished wood at the entrance of at least one hollow);
Notes – Nest refers to the presence of nest of a bird of prey, probably a Whistling Kite. Bees indicates that Feral Honey Bees are using a hollow in a tree. Clump indicates that the tree is within a clump of smaller trees.

Easting	Northing	DBH (m)	Dist. (m)	Canopy touching	Ladder trees	Scats	Hollows	Notes
360 334	6282 484	1.3	40	0	0	Yes	1	Nest
360 351	6283 026	1.6	4	3	1	Yes	1	
360 331	6283 009	1.8	15	3	1	Yes	1	
360 129	6282 929	1.3	3	2	2	No	1	
360 182	6282 992	1.5	15	1	0	Yes	1	
360 147	6283 009	1.2	5	2	1	Yes	2	
360 149	6283 042	1.8	10	0	1	Yes	2	
360 211	6283 117	1.4	10	2	0	Yes	1	
360 249	6283 161	1.6	5	2	1	Yes	2	
360 374	6283 302	1.2	10	2	1	Yes	2	
360 385	6283 268	1.2	10	1	1	Yes	1	
360 450	6283 403	3.0	2	3	1	Yes	2	
360 460	6283 398	1.0	1	3	1	Yes	1	
360 460	6283 404	1.2	3	3	1	Yes	1	
360 415	6283 117	1.8	5	3	1	Yes	2	
360 357	6283 072	1.4	3	2	1	Yes	2	
359 885	6282 503	1.5	10	1	1	Yes	2	
359 812	6282 459	1.5	5	1	1	Yes	2	
359 753	6282 512	3	7	1	1	Yes	2	
359 556	6282 157	1.8	5	2	1	Yes	1	
359 500	6282 071	1.3	12	2	1	Yes	2	
359 164	6281 915	2.0	20	0	1	Yes	2	
359 361	6282 176	1.2	12	1	1	Yes	2	
360 496	6282 531	1.6	30	2	0	No	3	
360 484	6282 441	1.3	30	1	0	Yes	2	Nest
360 448	6382 412	1.9	40	0	0	No	2	

Appendix 4 (cont.)

Easting	Northing	DBH (m)	Dist. (m)	Canopy touching	Ladder trees	Scats	Hollows	Notes
360 437	6282 329	1.3	80	0	0	No	1	
360 318	6282 212	1.5	50	0	0	Yes	3	
360 075	6282 865	0.8	20	0	0	Yes	1	
360 052	6282 735	0.8	20	1	1	Yes	1	
359 657	6282 283	1.2	20	0	1	Yes	1	Nest
359 676	6282 278	1.7	20	0	0	Yes	2	
359 609	6282 140	1.3	5	3	0	Yes	3	
359 615	6282 146	1.8	5	3	1	Yes	3	
359 625	6282 155	1.3	5	3	1	Yes	1	
359 347	6282 077	0.9	30	0	1	No	1	Nest
359 228	6282 147	2.0	20	1	0	Yes	3	
359 270	6282 121	1.0	10	1	1	No	2	
359 289	6282 300	0.7	15	1	1	No	1	Bees
359 431	6282 379	1.1	30	0	1	No	1	
359 474	6282 287	1.0	35	0	1	No	1	
359 481	6282 278	1.2	35	0	1	Yes	1	
359 715	6282 688	0.5	1	3	2	Yes	1	clump
359 790	6284 846	1.8	30	1	0	Yes	1	
359 840	6282 792	1.2	10	0	1	Yes	1	
359 847	6282 657	1.2	20	1	1	Yes	2	
359 860	6282 776	2.0	20	1	1	Yes	3	
359 911	6282 997	0.9	4	3	2	Yes	2	clump
359 948	6283 041	1.2	10	2	1	Yes	1	
360 100	6283 209	1.5	4	1	1	Yes	2	

APPENDIX FIVE. Categories used in the recognition of conservation significance.

WA Wildlife Conservation Act.

Schedule 1. Fauna which is rare or likely to become extinct, including Conservation Dependent taxa.

Schedule 2. Fauna presumed to be extinct

Schedule 3. Birds protected under an international agreement

Schedule 4. Other specially protected fauna.

WA Department of Conservation and Land Management (species not listed under the Conservation Act, but for which there is some concern).

Priority 1. Taxa with few, poorly known populations on threatened lands.

Priority 2. Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.

Priority 3. Taxa with several, poorly known populations, some on conservation lands.

Priority 4. Taxa in need of monitoring.

International Union for the Conservation of Nature and Natural Resources (IUCN) Based on a 1994 review by Mace and Stuart (1994).

Extinct. Taxa not definitely located in the wild during the past 50 years.

Extinct in the Wild. Taxa known to survive only in captivity.

Critically Endangered. Taxa facing an extremely high risk of extinction in the wild in the immediate future.

Endangered. Taxa facing a very high risk of extinction in the wild in the near future.

Vulnerable. Taxa facing a high risk of extinction in the wild in the medium-term future.

Near Threatened. Taxa that risk becoming Vulnerable in the wild.

Conservation Dependent. Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened.

Data Deficient (Insufficiently Known). Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.