Kemerton Silica Sand

Public Environmental Review
Extension of Kemerton Silica Sand, Dredge Mining

Volume 2: Appendices

November 2009

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MBS ENVIRONMENTAL

KEMERTON SILICA SAND
PUBLIC ENVIRONMENTAL REVIEW
EXTENSION OF KEMERTON SILICA SAND, DREDGE MINING

VOLUME 2
APPENDICES

NOVEMBER 2009

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KEMERTON SILICA SANDS PROJECT
ACID SULFATE SOIL ASSESSMENT
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KEMERTON SILICA SANDS PROJECT ACID SULFATE SOILS ASSESSMENT

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Appendix 1: Acid Soil Test Results

1. INTRODUCTION

The Kemerton Silica Sands (KSS) property is freehold land owned by the proponent. Continuation of dredge mining at the KSS project area is proposed by extending the dredge pond in a generally westwards direction. Following rehabilitation, reformed dredge ponds will remain as lakes and ephemeral wetlands.

The KSS property is located in the Shire of Harvey on the Swan Coastal Plain in the southwest of Western Australia. The KSS property has been mapped on the WAPC (2003) Bulletin 64 maps as generally having moderate to low risk of Acid Sulfate Soil (ASS) occurring at depths of greater than three metres (Figure 1). However, also present are two areas listed as being high risk of ASS at less than three metres from the surface.

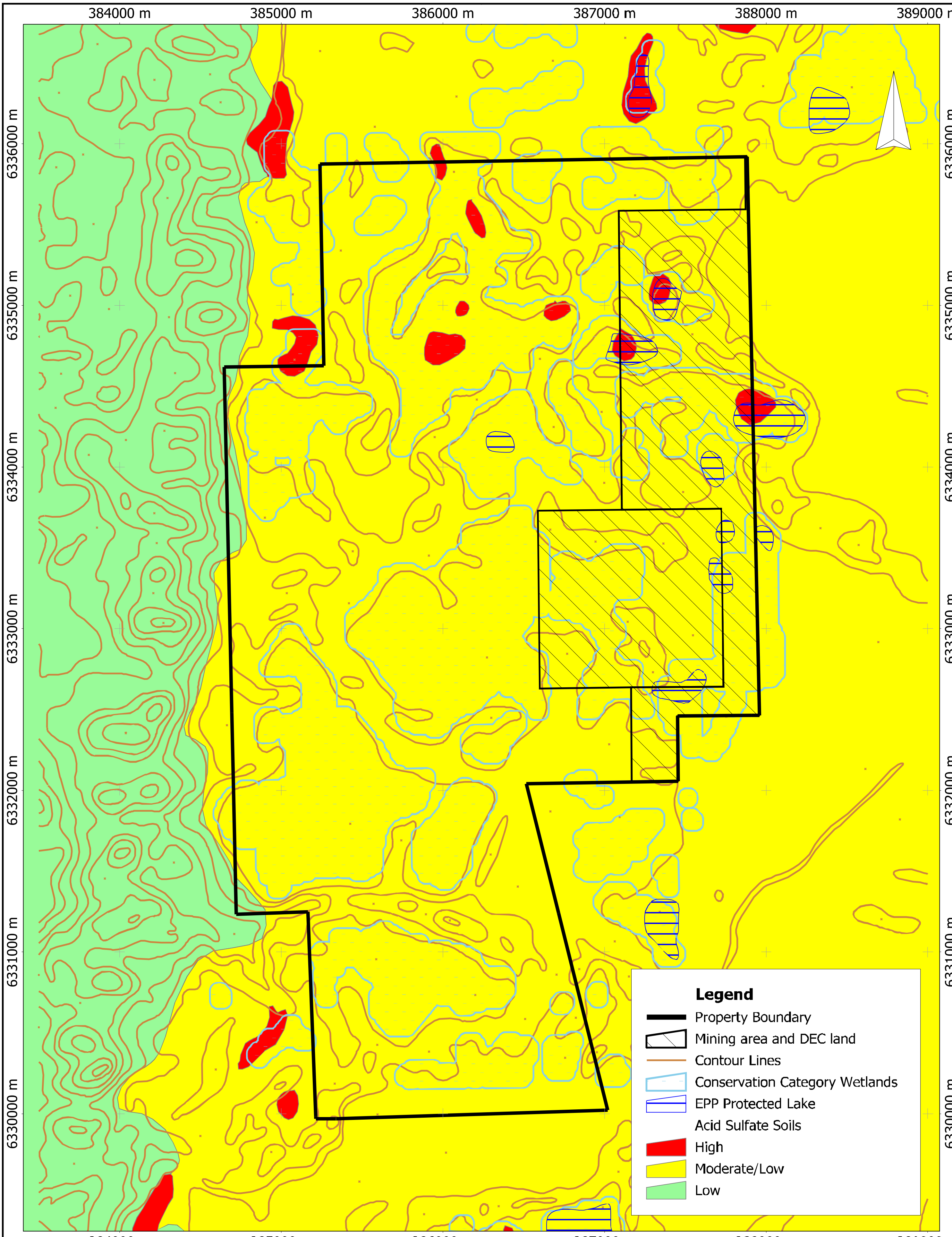
The Department of Environment (DoE) (2003) describes ASS as the common name given to naturally occurring soil or sediment containing iron sulfides over extensive low-lying areas under waterlogged (i.e. anaerobic) conditions. These soils may be found close to the natural ground level but may also be found at depth in the soil profile. When sulfides are exposed to air, oxidation takes place and sulfuric acid is produced where the soil's capacity to neutralise the acidity is exceeded.

In Western Australia, ASS are known to have formed in estuarine areas and coastal lowland areas such as mangroves, tidal flats, salt marshes and swamps, wetland areas, saline inland areas and near mining operations.

Particular areas of concern in Western Australia include:

- Estuarine, floodplain and wetland areas between Perth and Busselton, such as the Peel-Harvey estuarine system and the Vasse River area.
- The northern coastline, including the Pilbara and Kimberley coasts.
- The Scott River Plain, including Toby Inlet.
- Parts of the Wheatbelt where land salinisation has occurred.

The Environmental Protection Authority (EPA) objective is to maintain the integrity, ecological functions and environmental values of the soil and landform.



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Scale: 1:30000
Original Size: A4
Datum: Australian Geocentric 1994 (GDA9

0 1000 m

Kemerton Silica Sands Pty Ltd

Acid Soils Survey

Figure 1

W:\Itochu_KSS\Maps2006\ASS.map 6/03/2007 Layout A4

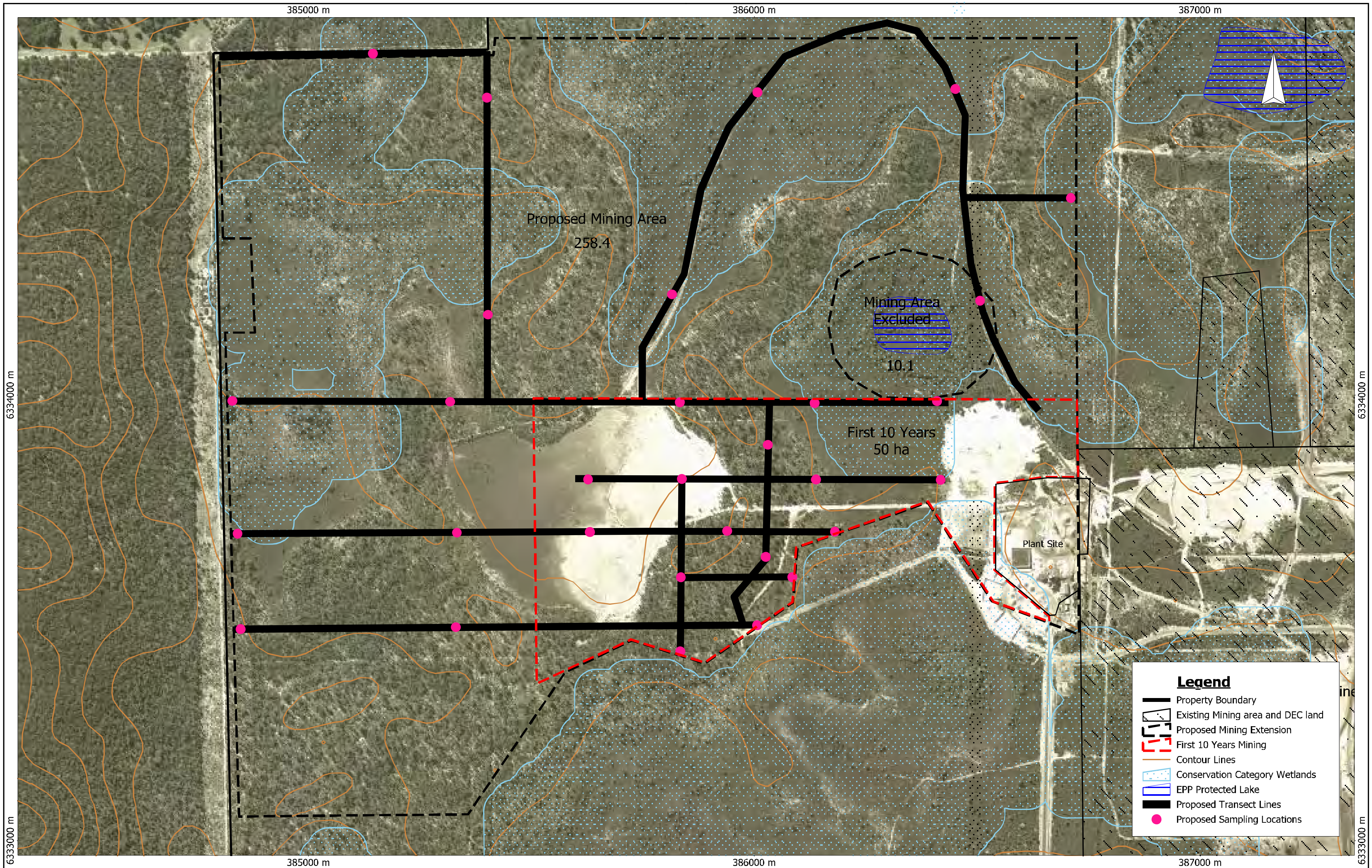
2. BASELINE ACID SOIL ASSESSMENT

Dredge mining operations have occurred for the last ten years on the property, to a depth of approximately 15 metres below the water table. Monitoring undertaken as part of environmental licence conditions has not shown any development of acidity in the dredge pond in the current area of operation, suggesting a very low risk of acid soils development. The dredge pond soils and the returned sand residues which are backfilled below the water table in the dredge pond are exposed to minimal free oxygen, further reducing the rate of any possible acidification. The proposal to expand extraction at the KSS property will continue to use the same dredge mining methods.

MBS liaised with DEC representatives on 3 August 2007, to determine the scope of soil assessment to be conducted over the mine site. Transects proposed for field survey are shown in Figure 2. Initially portions of transects would be sampled as part of the proposal assessment. This would provide an initial indication on the status of potential ASS within the extension areas. Further field survey programs over time would add to this knowledge base.

The field assessment comprised the following elements:

1. Sample from a transect alignment using existing drill lines and access tracks, to minimise the need for further clearing of native vegetation. Drill 30 holes to depths of up to 20 metres. Complete soil descriptions for each location.
2. In line with the low to moderate ASS risk ranking indicated for the mine extension area, sampling is to be undertaken at 250 metre spaced holes in the five to ten year mine area and at 500 metre intervals in future mine areas on transect lines as shown in Figure 2.
3. A reduced level of field assessment at one metre intervals is proposed. The soil profile in the subject area is well known. The existing mining operation dredges white siliceous Bassendean sand to 15 metres below the water table. Exploration drilling undertaken over the area confirms the same soil profile is present over the proposed mine extension area. It is considered the unstratified Bassendean soil profile does not exhibit complexities associated with other soil profiles, where different horizons can have significantly different properties, requiring a more intensive sampling at 0.5 metre layers.
4. The fine sand tailings area shown on Figure 2 is progressively being re-treated through the existing process plant. ASS sampling of this area will commence at approximately three metres below current surface level as the top material will be removed.
5. Conduct field pH (pH_F) and pH after oxidation (pH_{FOX}) testing of all soil samples as this provides an indication of the likelihood of ASS presence. Based on these results, a selection of samples showing the highest ASS field results would be submitted for laboratory analysis using the Suspension Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) analysis method. The SPOCAS method is a standardised set of procedures used in assessing the environmental impact of soils suspected of containing pyrite and other iron sulfides which might lead to an ASS problem if disturbed.



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Original Size: A3
Air Photo 2002
Datum: Australian Geocentric 1994 (GDA94)

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Proposed Acid Sulfate Soil Transects

Figure 2

W:\Itochu_KSS\Maps 2007\ASS.map 6/06/2007 A3 mining Area

3. FIELD ASSESSMENT

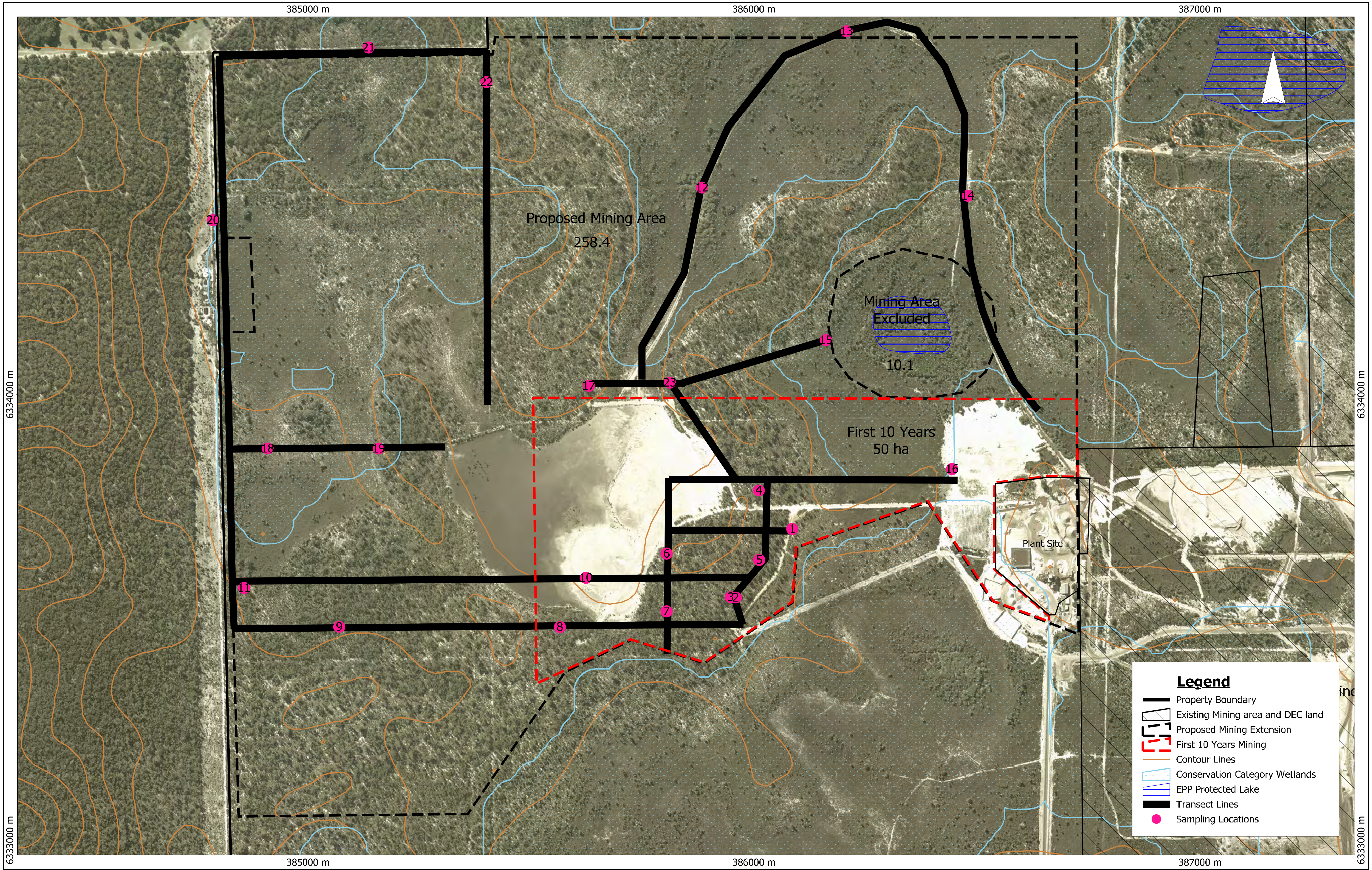
Testing was conducted from the 6 to the 8 August 2007. 23 holes were drilled to depths of up to 30 metres. Samples were taken at one metre intervals. Each one metre sample was placed into a labelled airtight bag, before being placed into a large polyweave bag for each hole. Soil profiles were described for each hole.

Nine holes were drilled within the five to ten year mine area at 250 metre spacing. The remaining holes were sampled at 500 metre intervals in the future mine area. The hole locations are shown in Figure 3. The majority of the fines and tailings area shown on Figure 3 was unable to be sampled as the area was too soft for access by the drill rig.

In the field, samples were stored in eskies in accordance with the DoE Identification and Investigation of ASS (October 2004). The samples were transferred to a deep freezer within four hours of collection and frozen.

Field pH (pH_F) and pH after oxidation (pH_{FOX}) testing of all soil samples was undertaken in the laboratory from the 13 to 15 August 2007. Based on these results, a selection of samples showing the highest ASS field results were submitted for laboratory analysis using the SPOCAS analysis method.

The samples were delivered to the Chemistry Centre (WA) for analysis in a frozen state.



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Air Photo 2002
Datum: Australian Geocentric 1994 (GDA94)

0 500 m

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Acid Sulfate Soil
Sampling Locations

Figure 3

4. LABORATORY ANALYSIS AND REPORT

4.1 TEST METHODS

The test methods of the Acid Sulfate Soils Laboratory Methods Guidelines (2004) manual were used in this work, specifically Method Code 23 – SPOCAS formed the basis of this work.

The SPOCAS method is a standardised set of procedures useful in assessing the environmental impact of soils suspected of containing pyrite and other iron sulfides which might lead to an ASS problem if disturbed.

After drying at 80°C for a minimum of 48 hours, the dry sample is then sieved through a two millimetre sieve and the greater than two millimetre fraction (which may contain lumps of limestone and shell fragments) is discarded. The sub sample material is then subjected to chemical tests. All results are reported on a dry weight basis.

4.2 SPOCAS METHOD

Step 1: Determination of Potassium Chloride Extractable Sulfur (S_{KCl}), and Total Actual Acidity (TAA)

In this procedure the sample is extracted with potassium chloride solution. The extraction with potassium chloride is used to determine soluble and absorbed sulfur (non-sulfidic sulfur) and the TAA of the sample.

The pH, acidity, and sulfur of the resultant solution are reported as pH_{KCl}, TAA_{KCl}, and S_{KCl} respectively.

Step 2: Determination of the Peroxide Oxidation Sulfur (S_P) and Titratable Peroxide Acidity (TPA)

This step involves oxidation of the sample with hydrogen peroxide to produce maximum acidity from any reduced sulfidic material. The sulfur content (S_P%), the TPA, and pH (pH_{OX}) of the oxidised solution are determined. S_P% will include the soluble, absorbed, and sulfide, sulfur species.

Step 3: Determination of Retained Acidity

Existing acidity in ASS includes 'actual' acidity (TAA) and 'retained' acidity (acidity stored in largely insoluble iron and aluminium sulfate minerals). A dilute hydrochloric acid (HCl) extraction performed on the washed soil residue after peroxide digestion will give S_{HCl}. The net acid soluble sulfur (S_{NAS}) due to sparingly soluble sulfate containing compounds such as jarosite, can be calculated by subtracting S_{KCl} from S_{HCl}. The equivalent acidity is expressed as a-S_{NAS}. For soil samples with pH_{KCl}<4.5 the S_{NAS} must be determined.

Step 4: Determination of the excess Acid Neutralising Capacity (ANC_E)
This determination is optional depending on the peroxide solution pH.
If the solution pH after the peroxide step is >6.5, the material may have an acid neutralization capacity. The fine grinding of the sample for analysis will lead to an over estimation of the effective acid neutralising capacity and an appropriate safety factor must be applied.

Step 5: Peroxide Oxidisable Sulfur (S_{POS})
This step involves calculating the differences between the extracts from Step 2 and Step 1. The peroxide oxidisable sulfur is used to predict the potential acid risk from non-oxidised sulfur compounds:

Peroxide oxidisable sulfur: $S_{POS} = (S_P - S_{KCl})$ %

If it assumed that all the S_{POS} is a result of pyrite oxidation then S_{POS} can be converted to acidity units:

S_{POS} (%S) x 624 = equivalent mol H^+/t

4.3 ACID BASE ACCOUNTING

The acid base accounting approach is used to predict net acidity from the oxidation of sulfidic material. The SPOCAS method is in essence a self contained ABA. The TPA result represents a measure of the net acidity, effectively equivalent to the sum of the soil's potential sulfidic activity and TAA less any neutralising capacity of the sample. Where the pH_{KCl} is <4.5 then the residual acid soluble sulfur (S_{RAS}) component of SPOCAS should be done, since the TPA does not measure retained acidity. In soils that are self neutralising (ie TPA=0), then the HCl titration step in SPOCAS allows calculation of the excess ANC_E.

4.4 INTERPRETATION OF SPOCAS TESTWORK

Interpretation of results from SPOCAS test methods involve comparison of the test results with published action criteria. Table 1 shows the NSW Acid Sulfate Soils Management Advisory Committee (ASSMAC) published Action Criteria.

Table 1: NSW ASSMAC Action Criteria

Type of Material		Action Criteria, <1,000 tonnes		Action Criteria, >1,000 tonnes	
Texture	Approx Clay Content (%<0.002 mm)	Sulfur Trail S_{POS} %	Acid Trail TPA mole H^+/t	Sulfur Trail S_{POS} %	Acid Trail TPA mole H^+/t
Coarse eg sands	5	0.03	18	0.03	18
Medium eg loams/light clays	5 – 40	0.06	36	0.03	18
Fine clays/silts	40	0.1	62	0.03	18

According to the NSW ASSMAC, exceedance of the action criteria indicates risk of an ASS issue and the need for an Acid Sulfate Soil Management Plan (ASSMP) with development approval.

4.5 RESULTS

The rate of the reaction generally indicates the level of sulfides present, but depends also on texture and other soil constituents. A soil containing very little sulfides may only rate a 'X' however a soil containing high levels of sulfides is more likely to rate a 'XXXX' or 'V' although there are exceptions. Other factors including manganese and organic acids may trigger a 'XXXX' or 'V' reaction. Table 2 indicates the reaction scale for PH_{FOX} tests.

Table 2: Soil Reaction Rating Scale from the PH_{FOX} test

Reaction Scale	Rate of Reaction
X	Slight effervescence
XX	Moderate Reaction
XXX	Vigorous Reaction
XXXX OR 'V'	Volcano: very vigorous reaction, gas evolution and heat generation commonly >80°C

Source: Hey *et al.* (2000)

Complete results of the field sampling and the laboratory testing are provided in Appendix 1. Table 3 provides a summary of these results, listing those samples laboratory tested and comparing them with the field assessment results.

The field and laboratory testing undertaken to date indicate the following:

- Field assessment shows the more highly reactive soils, indicated by the difference between the pH_F and pH_{FOX} being greater than four, at generally below 15 metres. This would indicate the soil profile below the base of the dredge pond (which will remain undisturbed and under water) has a greater potential for acid soil generation than the mining profile (the top 15 metres).
- Exceedance of the 'action criteria' for sandy soils is a TPA level greater than 18 Moles H^+/tonne. Table 3 shows that many of the samples selected for laboratory analysis exceed the action criteria. This confirms there are soil locations within the proposed mine profile which are Potentially Acid Forming (PAF). However, they are not universally below 15 metres and are not perfectly correlated with high field measurement results.
- A number of samples recorded extremely high ANC values. Taken in context with other locations which are PAF, the dredge pond may have a significant buffering capacity against acid formation. This is consistent with observation and monitoring results of the existing dredge pond with ten years of active mining showing no appreciable acidification over that time.
- None of the samples tested recorded pH_{KCl} <4.5, indicating that additional testwork is not required to measure retained acidity.

Table 3: Acid Soils Results

Hole Number	Sample Depth (m)	Field Results				Laboratory Results				
		pH_F	Peroxide Reaction	pH_{FOX}	pH_F-pH_{FOX} range >4	pH_{KCl}	pH_{OX}	ANC (Moles H^+/tonne)	TAA (Moles H^+/tonne)	TPA (Moles H^+/tonne)
4	5	8.49	-	5.60		7.7	6.1	<2	<2	<2
	12	8.12	-	5.30		6.3	4	<2	<2	5
	18	7.97	XX	1.53	6.44	6.2	2.8	<2	<2	25
	21	8.15	XXXX	1.62	6.53	5.8	2.6	<2	<2	48
	26	8.52	X	6.14		9.8	8.2	1372	<2	<2
10	3	7.68	-	5.07		9.6	7.1	33	<2	<2
	11	5.93	-	4.53		5.5	3.8	<2	7	27
	16	5.98	-	2.80		5.5	3	<2	5	40
	23	6.20	XXXX	1.47	4.73	5.4	2.3	<2	4	101
	29	6.57	XXXX	1.29	5.28	5.5	2.2	<2	5	369
15	5	6.53	-	5.48		6.4	4	<2	<2	0
	12	6.83	XXX	2.49	4.34	6.8	2.5	<2	<2	59
	17	7.33	XXXX	1.91	5.42	6.7	2.8	<2	<2	43
	22	8.51	-	6.65		9.7	8	2168	<2	<2
	26	8.49	X	6.24		9.5	8.3	2170	<2	<2
20	3	4.99	X	1.91		9.4	5.7	<2	<2	<2
	7	6.82	-	4.94		5.1	3.2	<2	28	142
	12	7.02	-	4.21		6.3	3.9	<2	<2	11
	18	7.28	XXX	1.91	5.37	5.5	2.5	<2	<2	74
	25	7.68	XXXX	1.51	6.17	5.1	2.4	<2	5	148
	27	7.94	X	1.92	6.02	5.4	2.4	<2	3	81

5. CONCLUSION

The results of the initial sampling indicate that most of the potential high acid generating soils are below the base of the final dredge pond depth (15 metres), will not be disturbed and will remain below the water table.

There are some high potential acid generating soils within the mine profile of the proposed mine extension area. There are also high acid neutralising soils, providing a significant in situ buffering capacity for the dredge pond environment.

An ASSMP will be prepared as a component of the project assessment to address possible acid generation issues.

Monitoring is recommended to detect any changes that may occur as the project is implemented.

Sampling of soils in advance of mining to quantify PAF will be incorporated into the ASSMP.

6. REFERENCES

Acid Sulfate Soils Management Advisory Committee (ASSMAC, NSW). 1998. Acid Sulfate Soils Laboratory Methods Guidelines manual.

Acid Sulfate Soils Laboratory Methods Guidelines. 2004. Department of Natural Resources and Mines, Queensland, June 2004.

Hey, K.M., Ahern, C.R. and Watling, K.M. 2000. Using Chemical Field Tests to Identify Acid Sulfate Soils Likelihood. Acid Sulfate Soils: Environmental Issues, Assessment and Management, Technical Papers, Brisbane, June 2000. Department of Natural Resources.

WA Department of Environment. 2003. General Guidance on Managing Acid Sulfate Soils.

WA Department of Environment. 2004. Identification and Investigation of Acid Sulfate Soils. Acid Sulfate Soils Guideline Series.

Western Australian Planning Commission. 2003. Planning Bulletin No. 64: Acid Sulfate Soils.

APPENDICES

APPENDIX 1:
ACID SOIL TEST RESULTS

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
Hole 1												
15/08/2007	1	1	Brown sand	6.83	-	5.33						
15/08/2007	1	2	Brown sand	6.25	-	4.35						
15/08/2007	1	3	Brown sand	4.32	-	3.80						
15/08/2007	1	4	Coffee rock	4.94	-	4.12						
15/08/2007	1	5	Water table, coffey rock	5.09	-	3.88						
15/08/2007	1	6	Coffee rock	5.28	-	4.06						
15/08/2007	1	7	White sand	5.27	-	4.06						
15/08/2007	1	8	White sand	5.45	-	4.57						
15/08/2007	1	9	Light brown fine sand	5.35	-	4.85						
15/08/2007	1	10	Brown sand	5.70	-	4.90						
15/08/2007	1	11	Brown/grey sand	5.82	-	5.11						
15/08/2007	1	12	Brown/grey sand	5.92	-	5.20						
15/08/2007	1	13	Brown/grey sand	5.91	-	5.52						
15/08/2007	1	14	Brown/grey sand	6.13	-	4.24						
15/08/2007	1	15	Grey fine sand	6.52	X	2.64						
15/08/2007	1	16	Grey fine sand	6.68	X	1.80	4.88					
15/08/2007	1	17	Grey fine sand	6.68	XX	1.96	4.72					
15/08/2007	1	18	Grey fine sand	7.76	X	5.82						
15/08/2007	1	19	Grey fine sand	6.98	X	3.96						
15/08/2007	1	20	Dark grey sand	7.63	XX	4.38						
15/08/2007	1	21	Dark grey sand	7.98	-	6.76						
15/08/2007	1	22	Dark grey sand	8.62	-	6.48						
15/08/2007	1	23	Dark grey sand	8.71	-	6.86						
15/08/2007	1	24	Dark grey sand	8.15	-	6.67						
15/08/2007	1	25	Dark grey sand	8.60	-	6.83						
15/08/2007	1	26	Shells	8.37	-	6.81						
15/08/2007	1	27	Dark grey coarse sand	8.30	-	6.20						
15/08/2007	1	28	Dark grey coarse sand	8.57	-	6.24						
15/08/2007	1	29	Dark grey coarse sand	8.54	X	6.44						
Hole 2												
15/08/2007	2	1	Grey sand	6.48	-	5.69						
15/08/2007	2	2	Grey sand	6.79	X	6.26						
15/08/2007	2	3	Dark brown sand	6.64	-	5.45						
15/08/2007	2	4	Dark brown sand	6.67	X	5.51						
15/08/2007	2	5	Dark brown sand	6.62	-	5.38						
15/08/2007	2	6	Dark brown sand	6.26	-	5.41						
15/08/2007	2	7	Dark brown sand, water table	6.36	-	5.81						
15/08/2007	2	8	Brown sand	6.58	-	5.88						
15/08/2007	2	9	Finer, light brown sand	6.74	-	5.99						
15/08/2007	2	10	Finer, light brown sand; lots of wa	6.62	-	6.31						
15/08/2007	2	11	Finer, light brown sand	6.40	-	5.48						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	2	12	Brown/grey sand	6.32	-	5.52						
15/08/2007	2	13	Brown/grey sand	5.95	-	4.93						
15/08/2007	2	14	Brown/grey sand, slightly coarser	6.15	X	3.85						
15/08/2007	2	15	Brown/grey sand, slightly coarser	6.02	-	3.63						
15/08/2007	2	16	Brown/grey sand, slightly coarser	5.96	X	2.10						
15/08/2007	2	17	Fine grey sand	5.94	XXXX	1.40	4.54					
15/08/2007	2	18	Fine grey sand	6.22	XXXX	1.68	4.54					
15/08/2007	2	19	Fine grey sand	6.35	XXX	1.66	4.69					
15/08/2007	2	20	Dark grey sand	6.17	X	1.40	4.77					
15/08/2007	2	21	Dark grey sand	6.65	XX	2.19	4.46					
15/08/2007	2	22	Dark grey sand	6.37	XXXX	1.39	4.98					
15/08/2007	2	23	Fine dark grey sand	6.70	X	5.42						
15/08/2007	2	24	Fine dark grey sand	7.56	-	5.90						
15/08/2007	2	25	Fine dark grey sand	7.73	-	6.13						
15/08/2007	2	26	Fine dark grey sand	7.63	-	5.97						
15/08/2007	2	27	Very coarse dark grey sand	7.71	X	5.77						
15/08/2007	2	28	Very coarse dark grey sand	7.69	X	5.80						
15/08/2007	2	29	Very coarse dark grey sand, shells	7.96	-	6.17						
Hole 3												
15/08/2007	3	1	Red/ brown sand	7.39	X	6.28						
15/08/2007	3	2	Red/ brown sand	5.93	-	5.34						
15/08/2007	3	3	Red/ brown sand	5.38	-	5.04						
15/08/2007	3	4	Coffee rock	5.47	-	4.37						
15/08/2007	3	5	Coffee rock	6.42	-	5.08						
15/08/2007	3	6	Coffee rock	6.27	-	5.04						
15/08/2007	3	7	Water table, coffee rock	6.44	-	5.95						
15/08/2007	3	8	Coffee rock	6.86	-	5.65						
15/08/2007	3	9	Light brown sand	6.55	-	5.68						
15/08/2007	3	10	Light brown sand	6.25	-	3.64						
15/08/2007	3	11	Light brown sand	6.68	-	6.01						
15/08/2007	3	12	Light grey sand	6.81	-	3.72						
15/08/2007	3	13	Light grey sand	7.14	-	6.23						
15/08/2007	3	14	Light grey sand	7.06	-	5.51						
15/08/2007	3	15	Light grey sand	7.33	-	4.23						
15/08/2007	3	16	Fine grey sand	7.30	X	1.83	5.47					
15/08/2007	3	17	Fine grey sand	7.30	XXXX	1.96	5.34					
15/08/2007	3	18	Fine grey sand	8.81	XXX	2.00	6.81					
15/08/2007	3	19	Fine grey sand	9.37	-	6.45						
15/08/2007	3	20	Coarse Grey sand, very wet	9.24	-	7.01						
15/08/2007	3	21	Coarse Grey sand, very wet	9.14	-	6.92						
15/08/2007	3	22	Coarse Grey sand, very wet	9.05	-	7.03						
15/08/2007	3	23	Coarse Grey sand, very wet	8.84	-	7.17						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	3	24	Coarse Grey sand, very wet	9.56	-	7.15						
15/08/2007	3	25	Coarse Grey sand, very wet	9.39	-	6.66						
15/08/2007	3	26	Coarse Grey sand, very wet; some	9.88	X	6.49						
15/08/2007	3	27	Coarse dark grey sand/shells	9.75	X	6.57						
15/08/2007	3	28	Coarse dark grey sand/shells	10.07	X	7.00						
15/08/2007	3	29	Coarse dark grey sand/shells	10.93	X	6.59	4.34					
Hole 4												
15/08/2007	4	1	Dark grey sand	7.64	-	5.80						
15/08/2007	4	2	Dark grey sand	8.09	-	5.67						
15/08/2007	4	3	Ligter grey sand	8.41	-	5.76						
15/08/2007	4	4	Yellow sand	8.47	-	5.66						
15/08/2007	4	5	Yellow sand	8.49	-	5.60		7.7	6.1	<2	<2	<2
15/08/2007	4	6	White sand	8.49	-	5.70						
15/08/2007	4	7	Light yellow sand	8.29	-	6.04						
15/08/2007	4	8	Light yellow sand	8.11	-	6.06						
15/08/2007	4	9	Water table	8.13	-	6.05						
15/08/2007	4	10	Brown sand	8.08	-	5.90						
15/08/2007	4	11	Brown sand	8.20	-	5.85						
15/08/2007	4	12	Brown sand	8.12	-	5.30		6.3	4	<2	<2	5
15/08/2007	4	13	Dark brown sand	8.14	-	5.59						
15/08/2007	4	14	Dark brown sand	7.71	-	3.36	4.35					
15/08/2007	4	15	Dark brown sand	7.81	-	4.23						
15/08/2007	4	16	Coarse dark brown sand	7.70	-	3.36	4.34					
15/08/2007	4	17	Coarse dark brown sand	7.86	-	3.73	4.13					
15/08/2007	4	18	Coarse white/grey sand	7.97	XX	1.53	6.44	6.2	2.8	<2	<2	25
15/08/2007	4	19	Coarse white/grey sand	7.89	X	2.06	5.83					
15/08/2007	4	20	Coarse white/grey sand	7.92	XXX	1.62	6.30					
15/08/2007	4	21	Coarse white/grey sand	8.15	XXXX	1.62	6.53	5.8	2.6	<2	<2	48
15/08/2007	4	22	Coarse white/grey sand	7.73	XXXX	1.53	6.20					
15/08/2007	4	23	Coarse white/grey sand	7.65	X	5.73						
15/08/2007	4	24	Very wet, fine grey sand	7.91	X	6.44						
15/08/2007	4	25	Dark grey coarse sand	8.14	X	5.92						
15/08/2007	4	26	Dark grey coarse sand	8.52	X	6.14		9.8	8.2	1372	<2	<2
15/08/2007	4	27	Dark grey coarse sand	8.32	X	6.55						
15/08/2007	4	28	Dark grey coarse sand	8.21	X	6.22						
15/08/2007	4	29	Dark grey coarse sand	8.36	X	6.36						
15/08/2007	4	30	Rocks/shells, very coarse grey sand	8.65	X	6.07						
15/08/2007	4	31	Rocks/shells, very coarse grey sand	8.64	X	6.07						
15/08/2007	4	32	Rocks/shells, very coarse grey sand	8.84	X	6.01						
Hole 5												
13/08/2007	5	1	Light brown sand	6.88	X	5.34						
13/08/2007	5	2	Light brown sand	6.78	X	5.17						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
13/08/2007	5	3	Light brown sand	6.57	X	5.05						
13/08/2007	5	4	Light brown sand	6.46	-	4.47						
13/08/2007	5	5	Light brown sand	5.59	-	4.37						
13/08/2007	5	6	Dark brown sand	5.58	-	4.13						
13/08/2007	5	7	Dark brown sand	5.47	-	4.20						
13/08/2007	5	8	Dark brown sand; water table	5.54	-	4.10						
13/08/2007	5	9	Dark brown sand	5.89	-	4.56						
13/08/2007	5	10	Dark brown sand	6.16	-	4.54						
13/08/2007	5	11	Light brown sand	6.62	-	4.89						
13/08/2007	5	12	Light brown/grey sand	7.32	-	5.15						
13/08/2007	5	13	Light brown/grey/white sand	7.75	-	5.82						
13/08/2007	5	14	Light brown/grey/white sand	7.34	-	5.05						
13/08/2007	5	15	Brown sand	7.33	-	2.92	4.41					
13/08/2007	5	16	Brown/grey sand	7.96	-	1.99	5.97					
13/08/2007	5	17	Brown/grey sand	7.66	X	1.85	5.81					
13/08/2007	5	18	Dark grey sand	7.85	XXX	2.21	5.64					
13/08/2007	5	19	Dark grey sand	7.62	XX	2.65	4.97					
13/08/2007	5	20	Light grey sand	7.48	X	1.99	5.49					
13/08/2007	5	21	Light grey sand	7.36	XXXX	1.78	5.58					
13/08/2007	5	22	Very wet, dark grey sand	8.20	XXX	6.22						
13/08/2007	5	23	Very wet, dark grey sand	8.76	-	6.19						
13/08/2007	5	24	Very wet, dark grey sand; few shel	8.84	-	6.32						
13/08/2007	5	25	Coarse dark grey sand/shells	8.45	X	6.26						
13/08/2007	5	26	Fine grey sand	8.73	X	6.47						
13/08/2007	5	27	Fine grey sand	8.50	-	6.58						
13/08/2007	5	28	Coarse dark grey sand/shells	8.54	X	6.08						
13/08/2007	5	29	Grey clay	8.34	XX	6.29						
Hole 6												
13/08/2007	6	1	Fine grey sand	6.71	-	5.70						
13/08/2007	6	2	Fine yellow sand	6.85	-	5.60						
13/08/2007	6	3	Fine yellow sand	6.00	-	4.81						
13/08/2007	6	4	Fine dark yellow sand	5.57	-	4.08						
13/08/2007	6	5	Fine dark yellow sand	5.77	-	5.16						
13/08/2007	6	6	Fine lighter yellow sand	5.69	-	5.47						
13/08/2007	6	7	Fine pale brown snad	5.51	-	4.13						
13/08/2007	6	8	Rfine brown sand	5.49	-	4.20						
13/08/2007	6	9	Fine dark brown sand	5.67	-	4.75						
13/08/2007	6	10	Water table	5.69	-	5.20						
13/08/2007	6	11	Fine dark brown sand	5.40	-	4.86						
13/08/2007	6	12	Fine dark brown sand	5.63	-	4.80						
13/08/2007	6	13	Fine dark brown sand	5.56	-	4.74						
13/08/2007	6	14	Fine dark brown sand	5.58	-	3.21						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
13/08/2007	6	15	Fine dark brown sand	5.50	-	3.27						
13/08/2007	6	16	Fine dark brown sand	5.81	-	4.52						
13/08/2007	6	17	Fine light brown sand	4.76	-	4.76						
13/08/2007	6	18	Fine light brown sand	5.93	-	5.31						
13/08/2007	6	19	Fine light brown sand	6.07	-	5.20						
13/08/2007	6	20	Fine light brown sand	5.85	-	3.54						
13/08/2007	6	21	Fine light brown sand	5.86	-	3.74						
13/08/2007	6	22	Fine light grey sand	5.70	-	2.49						
13/08/2007	6	23	Coarse grey sand	5.58	-	1.93						
13/08/2007	6	24	Coarse grey sand	5.92	XXXX	1.36	4.56					
13/08/2007	6	25	Light grey coarse sand	6.47	XX	1.70	4.77					
13/08/2007	6	26	Light grey coarse sand	6.70	XX	1.80	4.90					
13/08/2007	6	27	Some shells	7.16	X	5.39						
13/08/2007	6	28	Light grey coarse sand	7.31	X	6.01						
13/08/2007	6	29	Light grey coarse sand	8.03	X	6.19						
13/08/2007	6	30	Light grey coarse sand	8.62	X	6.13						
13/08/2007	6	31	Very coarse grey sand/shells	8.89	X	5.80						
13/08/2007	6	32	Limestone	8.84	X	5.98						
Hole 7												
13/08/2007	7	1	Brown sand	7.27	X	4.93						
13/08/2007	7	2	Fine light brown sand	7.03	X	5.02						
13/08/2007	7	3	Fine light brown sand	5.28	X	4.31						
13/08/2007	7	4	Fine brwon sand	4.89	X	3.75						
13/08/2007	7	5	Fine brwon sand	5.10	-	3.82						
13/08/2007	7	6	Fine yellow/brown sand	5.28	-	3.53						
13/08/2007	7	7	water table	5.40	-	3.88						
13/08/2007	7	8	Fine yellow/brown sand	5.63	-	4.57						
13/08/2007	7	9	Fine yellow/brown sand	5.49	-	4.38						
13/08/2007	7	10	Fine yellow/brown sand	5.78	-	4.86						
13/08/2007	7	11	Fine yellow/brown sand	5.66	-	4.59						
13/08/2007	7	12	Fine yellow/brown sand	5.78	-	3.97						
13/08/2007	7	13	Fine yellow/brown sand	5.53	-	3.63						
13/08/2007	7	14	Fine yellow/brown sand	5.68	-	3.24						
13/08/2007	7	15	Fine yellow/brown sand	5.75	X	2.70						
13/08/2007	7	16	Fine light brown/grey sand	5.99	X	4.63						
13/08/2007	7	17	Fine light brown/grey sand	6.08	X	2.07	4.01					
13/08/2007	7	18	Fine light brown/grey sand	6.15	X	1.88	4.27					
13/08/2007	7	19	Slightly darker fine brown/grey sar	6.36	X	1.85	4.51					
13/08/2007	7	20	Slightly darker fine brown/grey sar	6.42	X	1.55	4.87					
13/08/2007	7	21	Fine grey sand	6.59	X	1.64	4.95					
13/08/2007	7	22	Fine dark grey sand	6.64	X	1.70	4.94					
13/08/2007	7	23	Fine dark grey sand	6.57	XXXX	1.49	5.08					

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
13/08/2007	7	24	Fine dark grey sand	6.45	XXXX	1.41	5.04					
13/08/2007	7	25	Fine dark grey sand	6.70	XXX	1.73	4.97					
13/08/2007	7	26	Fine dark grey sand	6.74	XXX	1.70	5.04					
13/08/2007	7	27	Slightly coarse dark grey sand	6.64	XXX	1.64	5.00					
13/08/2007	7	28	Few shells	6.54	XXX	1.60	4.94					
13/08/2007	7	29	Lots of shells/coarse sand	7.26	XXX	5.71						
Hole 8												
15/08/2007	8	1	Fine yellow sand	6.84	X	5.45						
15/08/2007	8	2	Fine yellow sand	6.83	X	5.18						
15/08/2007	8	3	Fine yellow sand	6.86	X	5.65						
15/08/2007	8	4	Fine yellow sand	6.85	X	5.58						
15/08/2007	8	5	Light yellow sand	6.94	X	5.46						
15/08/2007	8	6	Light brown sand	6.56	-	4.26						
15/08/2007	8	7	Light brown sand	6.79	-	4.72						
15/08/2007	8	8	Light brown sand	6.68	-	4.47						
15/08/2007	8	9	Water table	6.50	-	5.18						
15/08/2007	8	10	Light brown sand	6.72	-	4.48						
15/08/2007	8	11	Fine brown sand	6.29	-	4.54						
15/08/2007	8	12	Fine brown sand	6.43	-	5.16						
15/08/2007	8	13	Fine brown sand	6.56	-	5.07						
15/08/2007	8	14	Fine brown sand	6.61	-	2.53	4.08					
15/08/2007	8	15	Fine brown sand	6.61	-	4.80						
15/08/2007	8	16	Fine brown sand	6.92	-	4.72						
15/08/2007	8	17	Fine brown sand	6.44	-	2.90						
15/08/2007	8	18	Fine brown sand	6.31	-	4.41						
15/08/2007	8	19	Fine brown sand	6.74	-	4.78						
15/08/2007	8	20	Fine brown sand	6.17	X	2.74						
15/08/2007	8	21	Fine brown sand	6.80	X	5.58						
15/08/2007	8	22	Fine brown sand	6.77	XX	1.77	5.00					
15/08/2007	8	23	Slightly coarse borwn sand	6.92	X	2.70	4.22					
15/08/2007	8	24	Slightly coarse borwn sand	7.06	X	3.48						
15/08/2007	8	25	Slightly coarse borwn sand	7.48	X	4.73						
15/08/2007	8	26	Slightly coarse borwn sand	8.83	X	6.37						
15/08/2007	8	27	Coarse grey sand some shells	8.58	X	5.97						
15/08/2007	8	28	Dark grey coarse sand	9.04	XX	6.26						
15/08/2007	8	29	Dark grey coarse sand	8.35	X	5.85						
15/08/2007	8	30	Shells	8.85	X	6.36						
Hole 9												
15/08/2007	9	1	Fine white sand	5.54	X	5.19						
15/08/2007	9	2	Fine brown snad	6.03	-	5.70						
15/08/2007	9	3	Fine light brown/grey sand	6.73	-	5.26						
15/08/2007	9	4	Fine light brown/grey sand	5.24	-	5.55						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	9	5	Fine brown sand	5.88	-	4.61						
15/08/2007	9	6	Fine darker brown sand	5.48	X	5.07						
15/08/2007	9	7	Water table	5.77	-	5.04						
15/08/2007	9	8	Fine darker brown sand	-	-	-						
15/08/2007	9	9	Fine darker brown sand	-	-	-						
15/08/2007	9	10	Fine darker brown sand	5.22	-	5.44						
15/08/2007	9	11	Fine darker brown sand	5.84	-	5.01						
15/08/2007	9	12	Fine brown sand	5.80	-	5.88						
15/08/2007	9	13	Fine brown sand	6.32	-	5.66						
15/08/2007	9	14	Fine brown sand	6.39	-	5.67						
15/08/2007	9	15	Fine brown sand	6.32	-	5.86						
15/08/2007	9	16	Fine brown sand	6.81	-	6.56						
15/08/2007	9	17	Fine brown sand	6.82	-	6.45						
15/08/2007	9	18	Fine brown/grey sand	6.93	-	6.60						
15/08/2007	9	19	Fine brown/grey sand	6.77	-	5.80						
15/08/2007	9	20	Fine brown/grey sand	6.89	-	5.80						
15/08/2007	9	21	Fine brown/grey sand	6.96	-	5.52						
15/08/2007	9	22	Fine brown/grey sand	7.07	-	5.85						
15/08/2007	9	23	Fine grey sand	7.41	-	6.23						
15/08/2007	9	24	Fine grey sand	6.86	-	5.22						
15/08/2007	9	25	Fine grey sand	6.87	-	6.02						
15/08/2007	9	26	Fine grey sand	7.18	XX	2.32	4.86					
15/08/2007	9	27	Coarse grey sand	7.32	X	3.51						
15/08/2007	9	28	Coarse grey sand	7.71	-	6.21						
15/08/2007	9	29	Coarse grey sand, shells	8.00	-	6.37						
15/08/2007	9	30	Clay	8.33	X	6.87						
Hole 10												
14/08/2007	10	1	Fine grey sand	7.14	-	4.75						
14/08/2007	10	2	Fine grey sand	7.68	-	4.98						
14/08/2007	10	3	Fine grey sand	7.68	-	5.07		9.6	7.1	33	<2	<2
14/08/2007	10	4	Fine dark brown sand	4.94	-	3.48						
14/08/2007	10	5	Fine dark brown sand	5.51	-	4.19						
14/08/2007	10	6	Fine dark brown sand	5.78	-	4.19						
14/08/2007	10	7	water table	5.56	-	3.79						
14/08/2007	10	8	Fine brown sand	5.81	-	4.60						
14/08/2007	10	9	Fine brown sand	6.01	-	4.35						
14/08/2007	10	10	Fine brown sand	5.92	-	4.53						
14/08/2007	10	11	Fine brown sand	5.93	-	4.53		5.5	3.8	<2	7	27
14/08/2007	10	12	Fine brown sand	6.08	-	4.04						
14/08/2007	10	13	Fine brown sand	5.95	-	5.28						
14/08/2007	10	14	Fine brown sand	6.20	-	3.68						
14/08/2007	10	15	Lighter brown sand	6.13	-	3.89						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	10	16	Lighter brown sand	5.98	-	2.80		5.5	3	<2	5	40
14/08/2007	10	17	Lighter brown sand	6.07	XXX	2.05	4.02					
14/08/2007	10	18	Lighter brown sand	6.14	X	2.22						
14/08/2007	10	19	Lighter brown sand	6.09	X	2.29						
14/08/2007	10	20	Lighter brown sand	6.11	X	2.03	4.08					
14/08/2007	10	21	Lighter brown sand	5.92	X	1.65	4.27					
14/08/2007	10	22	Fine brown/grey sand	6.11	XX	1.44	4.67					
14/08/2007	10	23	Fine brown/grey sand	6.20	XXXX	1.47	4.73	5.4	2.3	<2	4	101
14/08/2007	10	24	Fine brown/grey sand	6.15	XX	3.66						
14/08/2007	10	25	Fine grey sand	6.20	XX	1.56	4.64					
14/08/2007	10	26	Fine grey sand	6.22	XX	1.52	4.70					
14/08/2007	10	27	Coarse grey sand	6.44	XX	1.61	4.83					
14/08/2007	10	28	Coarse grey sand	6.72	XXX	1.54	5.18					
14/08/2007	10	29	Coarse grey sand	6.57	XXXX	1.29	5.28	5.5	2.2	<2	5	369
14/08/2007	10	30	Very dark brown/black rocky sand	7.19	XXX	2.60	4.59					
14/08/2007	10	31	Shells, rocky, grey sand	8.10	X	6.17						
Hole 11												
14/08/2007	11	1	Fine light brown sand	6.66	-	4.93						
14/08/2007	11	2	Fine light brown sand	6.65	-	5.38						
14/08/2007	11	3	Fine dark brown sand	4.78	-	4.74						
14/08/2007	11	4	Fine dark brown sand	4.62	-	3.93						
14/08/2007	11	5	Fine dark brown sand	5.26	-	4.28						
14/08/2007	11	6	Water table	4.84	-	4.23						
14/08/2007	11	7	Sludgy	4.77	-	4.31						
14/08/2007	11	8	Fine dark brown sand	4.63	-	4.07						
14/08/2007	11	9	Fine dark brown sand	4.72	-	4.21						
14/08/2007	11	10	Fine dark brown sand	5.30	-	4.95						
14/08/2007	11	11	Fine light brown sand	5.38	-	4.79						
14/08/2007	11	12	Fine grey/brown sand	5.58	-	4.38						
14/08/2007	11	13	Fine light grey/brown sand	5.99	-	5.38						
14/08/2007	11	14	Fine light grey/brown sand	5.75	-	4.18						
14/08/2007	11	15	Fine light grey/brown sand	5.53	-	5.71						
14/08/2007	11	16	Fine light grey/brown sand	5.72	X	3.25						
14/08/2007	11	17	Fine light grey/brown sand	5.99	-	4.14						
14/08/2007	11	18	Fine light grey/brown sand	6.00	X	1.98	4.02					
14/08/2007	11	19	Fine light grey/brown sand	5.98	-	2.37						
14/08/2007	11	20	Fine grey sand	5.71	-	2.08						
14/08/2007	11	21	Fine grey sand	6.80	XXX	1.84	4.96					
14/08/2007	11	22	Fine grey sand	7.89	-	5.75						
14/08/2007	11	23	Fine grey sludge	7.94	-	5.82						
14/08/2007	11	24	Fine grey sludge	8.43	-	5.84						
14/08/2007	11	25	Rocky coarse sand	8.53	X	5.96						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	11	26	Coarse sand/shells	8.62	-	6.35						
14/08/2007	11	27	Coarse sand/shells	8.69	X	5.98						
Hole 12												
15/08/2007	12	1	Fine dark brown sand	4.29	X	2.73						
15/08/2007	12	2	Fine dark brown sand	7.19	X	5.73						
15/08/2007	12	3	Fine dark brown sand	6.17	X	6.06						
15/08/2007	12	4	Water table	7.57	-	5.94						
15/08/2007	12	5	Fine dark brown sand	6.73	X	5.68						
15/08/2007	12	6	Fine dark brown sand	7.80	-	5.05						
15/08/2007	12	7	Fine dark brown sand	6.59	X	5.97						
15/08/2007	12	8	Fine brown sand	7.12	-	4.86						
15/08/2007	12	9	Fine brown sand	6.72	-	5.37						
15/08/2007	12	10	Light brown sand	7.13	-	5.79						
15/08/2007	12	11	Light brown sand	6.56	-	3.73						
15/08/2007	12	12	Light brown sand	7.48	-	2.82	4.66					
15/08/2007	12	13	Light brown sand	6.55	-	5.77						
15/08/2007	12	14	Light brown sand	7.04	X	2.53	4.51					
15/08/2007	12	15	Light brown sand	6.60	-	4.86						
15/08/2007	12	16	Light brown sand	6.94	-	5.80						
15/08/2007	12	17	Light grey sand	6.72	-	2.32	4.40					
15/08/2007	12	18	Light grey sand	7.35	X	2.28	5.07					
15/08/2007	12	19	Grey sand	6.90	X	2.96						
15/08/2007	12	20	Grey sand	7.55	XX	1.90	5.65					
15/08/2007	12	21	Dark grey sand	7.04	XX	1.83	5.21					
15/08/2007	12	22	Dark grey sand	7.25	XX	1.89	5.36					
15/08/2007	12	23	Very wet, fine dark grey sand	6.86	X	5.45						
15/08/2007	12	24	Very wet, fine dark grey sand	7.36	-	6.03						
15/08/2007	12	25	Slightly coarser dark grey sand	7.27	X	5.63						
15/08/2007	12	26	Slightly coarser dark grey sand	7.88	X	4.67						
15/08/2007	12	27	Slightly coarser dark grey sand	7.40	X	5.51						
15/08/2007	12	28	Coarse shelly grey sand	8.53	X	6.10						
Hole 13												
15/08/2007	13	1	Fine brown sand	6.61	X	4.31						
15/08/2007	13	2	Fine brown sand	6.47	X	4.28						
15/08/2007	13	3	Fine brown sand	6.75	-	4.64						
15/08/2007	13	4	Fine brown sand	6.53	-	5.52						
15/08/2007	13	5	Water table	6.48	-	5.49						
15/08/2007	13	6	Lighter brown sand	6.09	-	4.31						
15/08/2007	13	7	Lighter brown sand	6.64	-	5.02						
15/08/2007	13	8	Lighter brown sand	6.76	-	5.20						
15/08/2007	13	9	Lighter brown sand	6.71	-	5.65						
15/08/2007	13	10	Lighter brown sand	6.65	XX	2.67						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	13	11	Light brown coarser sand	6.96	XXX	1.86	5.10					
15/08/2007	13	12	Light brown coarser sand	6.89	XXX	1.64	5.25					
15/08/2007	13	13	Light brown coarser sand	6.55	XXX	1.56	4.99					
15/08/2007	13	14	Light brown coarser sand	6.41	XXX	1.52	4.89					
15/08/2007	13	15	Light brown coarser sand	7.02	XXX	1.55	5.47					
15/08/2007	13	16	Light brown coarser sand	7.08	XXX	1.59	5.49					
15/08/2007	13	17	Light brown coarser sand	6.56	XXXX	1.40	5.16					
15/08/2007	13	18	Fine dark brown sand	6.48	XXXX	1.40	5.08					
15/08/2007	13	19	Fine dark brown sand	6.94	XXXX	1.21	5.73					
15/08/2007	13	20	Light brown/grey sand	7.76	X	5.74						
15/08/2007	13	21	Light brown/grey sand	7.85	X	6.10						
15/08/2007	13	22	Light brown/grey sand	8.15	X	6.23						
15/08/2007	13	23	Light brown/grey sand	8.29	-	6.70						
15/08/2007	13	24	Very wet fine brown/grey sand	8.48	X	6.13						
15/08/2007	13	25	Very wet fine brown/grey sand	7.95	X	6.00						
15/08/2007	13	26	Rocks, shells grey coarse sand	8.93	X	6.10						
15/08/2007	13	27	Rocks, shells grey coarse sand	8.97	X	6.10						
Hole 14												
15/08/2007	14	1	Very fine grey/brown snad	6.59	X	6.19						
15/08/2007	14	2	Fine dark brown sand	6.37	X	4.83						
15/08/2007	14	3	Fine dark brown sand	6.40	-	4.81						
15/08/2007	14	4	Water table	5.90	-	4.34						
15/08/2007	14	5	Fine dark brown sand	5.28	-	4.05						
15/08/2007	14	6	Fine dark brown sand	5.27	-	4.16						
15/08/2007	14	7	Fine dark brown sand	5.65	X	3.85						
15/08/2007	14	8	Fine dark brown sand	5.98	-	4.72						
15/08/2007	14	9	Fine dark brown sand	6.21	X	4.01						
15/08/2007	14	10	Fine light brown sand	5.83	X	3.48						
15/08/2007	14	11	Fine light brown sand	6.25	X	4.64						
15/08/2007	14	12	Fine light brown sand	6.44	X	2.64						
15/08/2007	14	13	Fine light brown sand	6.05	X	2.53						
15/08/2007	14	14	Slightly coarser brown sand	6.59	X	2.56	4.03					
15/08/2007	14	15	Slightly coarser brown sand	6.52	XX	1.80	4.72					
15/08/2007	14	16	Slightly coarser brown sand	6.80	XXX	1.73	5.07					
15/08/2007	14	17	Slightly coarser brown sand	6.71	XX	1.51	5.20					
15/08/2007	14	18	Very fine, slightly clayey dark bro	6.35	XXX	1.57	4.78					
15/08/2007	14	19	Coarse grey sand	7.68	X	5.74						
15/08/2007	14	20	Coarse grey sand	8.09	-	5.98						
15/08/2007	14	21	Coarse grey sand	8.16	X	5.84						
15/08/2007	14	22	Coarse grey sand	7.95	-	6.09						
15/08/2007	14	23	Coarse grey sand	8.29	-	6.06						
15/08/2007	14	24	Coarse grey sand	8.16	X	5.91						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	14	25	Coarse grey sand	8.34	X	5.84						
15/08/2007	14	26	Very coarse grey , rocky sand	8.68	X	5.90						
15/08/2007	14	27	Very coarse grey , rocky sand	8.98	X	5.98						
Hole 15												
14/08/2007	15	1	Fine dark brown sand	6.54	-	5.01						
14/08/2007	15	2	Fine dark brown sand	5.77	-	4.48						
14/08/2007	15	3	Fine dark brown sand	5.61	X	4.85						
14/08/2007	15	4	Fine dark brown sand	5.78	-	4.99						
14/08/2007	15	5	Fine light brown/white sand	6.53	-	5.48		6.4	4	<2	<2	0
14/08/2007	15	6	Fine light brown/white sand	6.70	-	5.54						
14/08/2007	15	7	Fine light brown sand	6.91	X	5.57						
14/08/2007	15	8	Water table	6.39	X	5.08						
14/08/2007	15	9	Fine light brown sand	6.22	X	4.94						
14/08/2007	15	10	Fine light brown sand	6.62	X	1.96	4.66					
14/08/2007	15	11	Fine light brown sand	6.57	XXXX	1.69	4.88					
14/08/2007	15	12	Slightly coarser light brown sand	6.83	XXX	2.49	4.34	6.8	2.5	<2	<2	59
14/08/2007	15	13	Slightly coarser light brown sand	7.05	XX	2.85	4.20					
14/08/2007	15	14	Finer brown sand	6.85	XX	2.26	4.59					
14/08/2007	15	15	Finer brown sand	7.09	X	2.24	4.85					
14/08/2007	15	16	Finer brown sand	6.74	XXX	1.86	4.88					
14/08/2007	15	17	Finer brown sand	7.33	XXXX	1.91	5.42	6.7	2.8	<2	<2	43
14/08/2007	15	18	Finer brown sand	7.68	XXX	1.81	5.87					
14/08/2007	15	19	Finer brown sand	8.11	-	6.21						
14/08/2007	15	20	Fine beige/grey sand	8.40	-	6.74						
14/08/2007	15	21	Fine beige/grey sand	8.28	-	6.56						
14/08/2007	15	22	Very fine grey sand	8.51	-	6.65		9.7	8	2168	<2	<2
14/08/2007	15	23	Very fine grey sand	8.26	-	6.87						
14/08/2007	15	24	Very fine grey sand	8.02	-	6.66						
14/08/2007	15	25	Coarse grey sand	8.45	X	6.27						
14/08/2007	15	26	Coarse grey sand	8.49	X	6.24		9.5	8.3	2170	<2	<2
14/08/2007	15	27	Shells	8.32	X	6.12						
Hole 16												
14/08/2007	16	1	Fine grey/brown sand	6.25	-	6.00						
14/08/2007	16	2	Fine grey/brown sand	7.99	-	6.04						
14/08/2007	16	3	Fine dark brown sand	7.44	-	5.57						
14/08/2007	16	4	Coffee rock	6.96	-	5.66						
14/08/2007	16	5	Coffee rock	6.85	-	5.37						
14/08/2007	16	6	Coffee rock	6.45	-	4.96						
14/08/2007	16	7	Coffee rock	6.25	-	4.86						
14/08/2007	16	8	Water table	6.27	-	5.30						
14/08/2007	16	9	Coffee rock	6.15	-	4.92						
14/08/2007	16	10	Coffee rock	6.45	-	5.50						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	16	11	Fine light brown sand	6.26	-	5.48						
14/08/2007	16	12	Fine light brown sand	6.48	-	5.68						
14/08/2007	16	13	Fine light brown sand	6.71	-	4.40						
14/08/2007	16	14	Fine light brown sand	6.81	X	2.06	4.75					
14/08/2007	16	15	Fine light brown sand	6.75	XXX	1.80	4.95					
14/08/2007	16	16	Fine light brown sand	7.04	XX	1.84	5.20					
14/08/2007	16	17	Fine light brown sand	7.34	XXX	2.33	5.01					
14/08/2007	16	18	Fine light brown sand	7.73	XX	5.49						
14/08/2007	16	19	Very wet, fine grey sand	7.78	X	6.35						
14/08/2007	16	20	Very wet, fine grey sand	8.14	X	6.48						
14/08/2007	16	21	Very wet, fine grey sand	8.34	X	6.14						
14/08/2007	16	22	Slightly coarse grey sand	8.72	X	6.21						
14/08/2007	16	23	Slightly coarse grey sand	8.80	X	6.33						
14/08/2007	16	24	Slightly coarse grey sand	8.66	X	6.41						
14/08/2007	16	25	Slightly coarse grey sand	8.78	X	6.43						
14/08/2007	16	26	Coarse grey/shelly sand	8.99	X	6.05						
14/08/2007	16	27	Very shelly	8.90	X	6.12						
Hole 17												
14/08/2007	17	1	Fine dark grey sand	7.14	-	5.44						
14/08/2007	17	2	Fine dark grey sand	7.58	-	5.66						
14/08/2007	17	3	Fine light grey sand	7.63	-	5.69						
14/08/2007	17	4	Fine grey/brown sand	5.80	-	4.06						
14/08/2007	17	5	Fine grey/brown sand	4.35	-	3.42						
14/08/2007	17	6	Fine grey/brown sand	4.65	-	3.71						
14/08/2007	17	7	Water table, brown coffee rock	4.75	-	3.94						
14/08/2007	17	8	Brown coffee rock	4.86	-	4.24						
14/08/2007	17	9	Brown coffee rock	4.85	-	4.36						
14/08/2007	17	10	Brown coffee rock	5.28	-	5.32						
14/08/2007	17	11	Fine light grey sand	6.11	-	5.80						
14/08/2007	17	12	Fine light grey sand	6.31	-	5.88						
14/08/2007	17	13	Fine light grey sand	6.56	-	5.86						
14/08/2007	17	14	Fine light grey sand	6.58	-	5.90						
14/08/2007	17	15	Fine light grey sand	6.48	-	5.97						
14/08/2007	17	16	Fine grey/white sand	6.50	-	6.02						
14/08/2007	17	17	Fine grey/white sand	6.48	XXX	5.30						
14/08/2007	17	18	Fine grey/brown sand	5.86	XX	1.93						
14/08/2007	17	19	Fine grey/brown sand	6.56	XXX	1.97	4.59					
14/08/2007	17	20	Fine grey/brown sand	7.18	XX	4.60						
14/08/2007	17	21	Fine grey/brown sand	7.02	XXX	2.05	4.97					
14/08/2007	17	22	Coarse grey sand	7.29	XXX	2.00	5.29					
14/08/2007	17	23	Coarse grey sand	7.81	XXX	2.01	5.80					
14/08/2007	17	24	Coarse dark grey sand some shells	7.96	XXX	2.13	5.83					

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	17	25	Coarse sand	8.21	X	6.02						
14/08/2007	17	26	Coarse sand	8.27	X	6.13						
14/08/2007	17	27	Coarse dark grey sand some shells	8.25	X	6.22						
14/08/2007	17	28	Clayey sand	8.25	X	6.38						
14/08/2007	17	29	Clayey sand	8.49	X	6.04						
Hole 18												
14/08/2007	18	1	Fine grey/brown sand	5.30	-	5.91						
14/08/2007	18	2	Fine grey/brown sand	6.07	-	5.94						
14/08/2007	18	3	Fine grey/brown sand	6.11	-	5.18						
14/08/2007	18	4	Water table	6.78	-	5.92						
14/08/2007	18	5	Brown coffee rock	6.67	-	5.81						
14/08/2007	18	6	Brown coffee rock	6.59	-	5.51						
14/08/2007	18	7	Brown coffee rock	6.88	-	6.30						
14/08/2007	18	8	Brown coffee rock	6.88	-	6.28						
14/08/2007	18	9	Fine yellow/grey sand	6.65	-	6.03						
14/08/2007	18	10	Fine yellow/grey sand	6.91	-	6.03						
14/08/2007	18	11	Fine grey/biege sand	6.98	-	5.99						
14/08/2007	18	12	Fine grey/biege sand	6.81	-	6.02						
14/08/2007	18	13	Fine grey/biege sand	6.94	-	5.83						
14/08/2007	18	14	Coarse grey/brown sand	6.65	-	4.95						
14/08/2007	18	15	Coarse grey/brown sand	6.85	-	5.78						
14/08/2007	18	16	Coarse grey/brown sand	6.33	-	4.26						
14/08/2007	18	17	Coarse grey/brown sand	6.26	-	2.36						
14/08/2007	18	18	Very wet coarse grey/brown sand	6.52	X	5.21						
14/08/2007	18	19	Very wet coarse grey/brown sand	6.83	X	2.76	4.07					
14/08/2007	18	20	Very wet coarse grey/brown sand	6.75	X	6.05						
14/08/2007	18	21	Fine grey sand	6.89	X	4.88						
14/08/2007	18	22	Fine grey sand	6.76	XX	1.53	5.23					
14/08/2007	18	23	Fine dark grey sand	6.72	XXX	1.59	5.13					
14/08/2007	18	24	Fine dark grey sand	6.62	XX	1.46	5.16					
14/08/2007	18	25	Coarse grey/brown sand	6.64	XX	1.48	5.16					
14/08/2007	18	26	Coarse grey/brown sand	6.87	XX	1.65	5.22					
14/08/2007	18	27	Coarse grey/brown sand	7.07	XX	1.39	5.68					
14/08/2007	18	28	Fine light grey/brown sand few she	7.66	X	4.16						
14/08/2007	18	29	Fine white sand/clay/shells	8.63	X	6.00						
Hole 19												
15/08/2007	19	1	Fine light brown sand	7.03	-	4.23						
15/08/2007	19	2	Fine light brown sand	6.70	-	5.29						
15/08/2007	19	3	Fine light brown sand	6.30	-	5.04						
15/08/2007	19	4	Fine dark brown sand	6.39	-	4.61						
15/08/2007	19	5	Fine dark brown sand	5.76	-	4.83						
15/08/2007	19	6	Fine dark brown sand	6.29	-	5.25						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	19	7	Water table	6.05	-	5.93						
15/08/2007	19	8	Fine brown sand	6.46	-	6.58						
15/08/2007	19	9	Fine brown sand	6.67	-	6.54						
15/08/2007	19	10	Fine brown sand	6.58	-	5.80						
15/08/2007	19	11	Fine brown sand	6.47	-	5.77						
15/08/2007	19	12	Fine brown sand	6.22	-	5.21						
15/08/2007	19	13	Fine brown sand	6.48	-	6.38						
15/08/2007	19	14	Fine brown sand	6.50	-	5.02						
15/08/2007	19	15	Fine beige sand	6.43	X	4.17						
15/08/2007	19	16	Fine beige sand	6.38	-	5.30						
15/08/2007	19	17	Fine beige sand	6.41	-	2.55						
15/08/2007	19	18	Fine beige/grey sand	6.46	X	2.93						
15/08/2007	19	19	Fine beige/grey sand	6.48	X	2.70						
15/08/2007	19	20	Fine beige/grey sand	6.73	X	2.52	4.21					
15/08/2007	19	21	Fine grey sand	6.67	-	3.15						
15/08/2007	19	22	Very wet, fine grey/brown sand	6.78	XXX	1.96	4.82					
15/08/2007	19	23	Very wet, fine grey/brown sand	6.78	XX	2.02	4.76					
15/08/2007	19	24	Very wet, fine grey/brown sand	7.05	XXX	1.84	5.21					
15/08/2007	19	25	Very wet, fine grey/brown sand	7.02	X	2.17	4.85					
15/08/2007	19	26	Very wet, fine grey/brown sand	6.94	XX	1.87	5.07					
15/08/2007	19	27	Dark brown/black sandy/clay	7.38	X	2.04	5.34					
15/08/2007	19	28	Dark brown/black sandy/clay	7.74	X	5.71						
Hole 20												
15/08/2007	20	1	Fine light brown sand	5.38	X	2.23						
15/08/2007	20	2	Fine light brown sand	5.39	X	2.06						
15/08/2007	20	3	Fine light brown sand	4.99	X	1.91		9.4	5.7	<2	<2	<2
15/08/2007	20	4	Fine dark brown sand	5.03	-	4.44						
15/08/2007	20	5	Fine dark brown sand	6.34	-	4.35						
15/08/2007	20	6	Fine dark brown sand	6.41	-	4.98						
15/08/2007	20	7	Water table	6.82	-	4.94		5.1	3.2	<2	28	142
15/08/2007	20	8	Fine brown sand	6.45	-	4.84						
15/08/2007	20	9	Fine light brown sand	6.51	-	5.48						
15/08/2007	20	10	Fine light brown sand	6.54	-	5.24						
15/08/2007	20	11	Fine light brown sand	6.74	-	6.44						
15/08/2007	20	12	Fine beige sand	7.02	-	4.21		6.3	3.9	<2	<2	11
15/08/2007	20	13	Fine beige sand	7.23	-	5.46						
15/08/2007	20	14	Fine beige sand	7.19	-	5.34						
15/08/2007	20	15	Fine beige sand	7.23	-	5.55						
15/08/2007	20	16	Fine beige/grey sand	7.32	-	5.35						
15/08/2007	20	17	Fine beige/grey sand	7.36	X	2.16	5.20					
15/08/2007	20	18	Slightly coarse grey sand	7.28	XXX	1.91	5.37	5.5	2.5	<2	<2	74
15/08/2007	20	19	Slightly coarse grey sand	7.31	X	1.92	5.39					

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results			pH pFox range >4	Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)		pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	20	20	Slightly coarse grey sand	7.11	XX	1.59	5.52					
15/08/2007	20	21	Slightly coarse grey sand	7.23	XXX	1.66	5.57					
15/08/2007	20	22	Fine grey/brown sand	7.01	XX	1.56	5.45					
15/08/2007	20	23	Very wet	7.26	XXXX	1.53	5.73					
15/08/2007	20	24	Very wet	7.38	X	2.01	5.37					
15/08/2007	20	25	Very wet	7.68	XXXX	1.51	6.17	5.1	2.4	<2	5	148
15/08/2007	20	26	Coarse grey sand	7.88	XXX	1.72	6.16					
15/08/2007	20	27	Coarse grey sand	7.94	X	1.92	6.02	5.4	2.4	<2	3	81
15/08/2007	20	28	Coarse grey sand, rocks	8.68	X	6.20						
15/08/2007	20	29	Clay, rocks	8.95	X	6.57						
Hole 21												
14/08/2007	21	1	Fine light brown sand	4.39	-	4.43						
14/08/2007	21	2	Fine light brown sand	4.64	-	4.86						
14/08/2007	21	3	Fine dark brown sand	5.30	-	4.82						
14/08/2007	21	4	Fine dark brown sand	6.27	-	5.30						
14/08/2007	21	5	Fine dark brown sand	6.33	-	5.22						
14/08/2007	21	6	Fine dark brown sand	5.98	-	5.12						
14/08/2007	21	7	Water table	6.60	-	6.19						
14/08/2007	21	8	Fine brown sand	6.63	-	5.65						
14/08/2007	21	9	Fine brown sand	6.24	-	5.04						
14/08/2007	21	10	Fine brown sand	6.17	-	5.76						
14/08/2007	21	11	Fine brown sand	6.15	-	4.20						
14/08/2007	21	12	Fine beige sand	6.20	-	5.60						
14/08/2007	21	13	Fine beige sand	6.66	-	5.28						
14/08/2007	21	14	Fine beige sand	6.55	-	5.36						
14/08/2007	21	15	Fine beige sand	6.30	-	3.35						
14/08/2007	21	16	Fine beige/grey sand	6.81	X	6.34						
14/08/2007	21	17	Fine beige/grey sand	9.78	XX	2.44	7.34					
14/08/2007	21	18	Fine beige/grey sand	6.63	XX	2.04	4.59					
14/08/2007	21	19	Fine beige/grey sand	7.38	X	5.89						
14/08/2007	21	20	Slightly coarse grey/brown sand	7.54	X	2.55	4.99					
14/08/2007	21	21	Slightly coarse grey/brown sand	6.89	XXX	1.89	5.00					
14/08/2007	21	22	Grey sand	6.95	XXX	1.77	5.18					
14/08/2007	21	23	Grey sand	6.85	X	1.69	5.16					
14/08/2007	21	24	Very wet	6.99	X	4.38						
14/08/2007	21	25	Very wet	7.27	X	2.34	4.93					
14/08/2007	21	26	Slightly coarse grey/brown sand	7.45	XXX	1.82	5.63					
14/08/2007	21	27	Slightly coarse grey/brown sand	7.35	XXXX	1.52	5.83					
14/08/2007	21	28	Coarse dark brown/grey sandey/sla	7.77	XX	4.25						
14/08/2007	21	29	Rocks/clay	8.63	X	5.95						
Hole 22												
14/08/2007	22	1	Fine grey sand	8.32	-	5.77						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	22	2	Fine yellow sand	8.32	-	5.94						
14/08/2007	22	3	Fine yellow sand	8.10	-	5.78						
14/08/2007	22	4	Fine yellow sand	8.28	-	5.78						
14/08/2007	22	5	Very fine light yellow sand	8.50	-	5.76						
14/08/2007	22	6	Very fine light yellow sand	8.54	-	5.71						
14/08/2007	22	7	Very fine light yellow sand	8.45	-	5.81						
14/08/2007	22	8	Very fine light yellow sand	8.60	-	5.83						
14/08/2007	22	9	Very fine white sand	8.42	-	5.76						
14/08/2007	22	10	Moist fine grey sand	8.62	-	6.16						
14/08/2007	22	11	Moist fine grey sand	8.70	-	5.81						
14/08/2007	22	12	Moist fine grey sand	8.36	-	5.93						
14/08/2007	22	13	Water table, beige sand	7.53	-	6.30						
14/08/2007	22	14	Fine beige sand	7.73	-	6.02						
14/08/2007	22	15	Fine beige sand	7.64	-	5.82						
14/08/2007	22	16	Fine beige sand	7.61	-	5.89						
14/08/2007	22	17	Fine beige sand	7.37	-	5.80						
14/08/2007	22	18	Fine light grey/beige sand	7.39	-	6.26						
14/08/2007	22	19	Fine light grey/beige sand	7.43	-	5.24						
14/08/2007	22	20	Fine light grey/beige sand	7.59	-	6.30						
14/08/2007	22	21	Fine light grey/beige sand	7.70	-	4.40						
14/08/2007	22	22	Fine light grey/beige sand	7.67	XX	1.96	5.71					
14/08/2007	22	23	Fine light grey/beige sand	7.47	XXX	2.26	5.21					
14/08/2007	22	24	Fine grey/beige sand	7.38	XX	1.85	5.53					
14/08/2007	22	25	Fine grey/beige sand	7.56	XX	1.70	5.86					
14/08/2007	22	26	Slightly coarse grey/brown sand	7.54	XXX	1.84	5.70					
14/08/2007	22	27	Slightly coarse grey/brown sand	7.39	X	1.77	5.62					
14/08/2007	22	28	Slightly coarse grey/brown sand	7.40	X	2.61	4.79					
14/08/2007	22	29	Slightly coarse grey/brown sand	7.34	XX	1.80	5.54					
14/08/2007	22	30	Coarse grey sand	7.28	XXX	1.85	5.43					
14/08/2007	22	31	Coarse grey sand	7.30	X	1.77	5.53					
14/08/2007	22	32	Coarse grey/brown sand	7.88	X	2.15	5.73					
14/08/2007	22	33	Coarse grey sand	7.92	XXXX	1.78	6.14					
14/08/2007	22	34	Shells	8.18	X	5.56						
Hole 23												
15/08/2007	23	1	Fine dark grey sand	8.83	-	7.07						
15/08/2007	23	2	Fine light grey sand	9.06	-	7.03						
15/08/2007	23	3	Fine dark grey sand	9.05	-	7.24						
15/08/2007	23	4	Fine brown sand rocks	8.78	-	6.75						
15/08/2007	23	5	Fine dark brown sand	8.04	-	6.68						
15/08/2007	23	6	Fine dark brown sand	7.77	-	6.06						
15/08/2007	23	7	Water table	7.33	-	6.64						
15/08/2007	23	8	Fine dark brown sand	7.64	-	6.42						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	23	9	Fine dark brown sand	7.28	-	6.57						
15/08/2007	23	10	Fine dark brown sand	6.98	-	6.40						
15/08/2007	23	11	Fine light brown sand	6.58	-	6.38						
15/08/2007	23	12	Fine light brown sand	6.80	-	6.56						
15/08/2007	23	13	Fine light brown sand	7.16	-	7.14						
15/08/2007	23	14	Fine light brown sand	7.12	-	6.63						
15/08/2007	23	15	Fine light brown sand	7.10	X	6.80						
15/08/2007	23	16	Fine light brown sand	6.94	-	8.51						
15/08/2007	23	17	Fine light brown sand	6.92	X	7.98						
15/08/2007	23	18	Fine light brown sand	6.98	X	8.52						
15/08/2007	23	19	Fine light brown sand	7.19	-	8.11						
15/08/2007	23	20	Fine light brown sand	7.32	-	8.96						
15/08/2007	23	21	Fine light brown sand	7.40	-	7.78						
15/08/2007	23	22	Fine grey sand	7.52	-	8.47						
15/08/2007	23	23	Slightly coarse grey sand	7.62	-	8.00						
15/08/2007	23	24	Slightly coarse dark grey sand	7.54	-	8.61						
15/08/2007	23	25	Slightly coarse dark grey/brown sa	7.61	-	7.77						
15/08/2007	23	26	Slightly coarse dark grey/brown sa	7.47	X	8.55						
15/08/2007	23	27	Coarse grey sand	7.54	-	7.77						
15/08/2007	23	28	Coarse dark grey sand	7.40	XXX	2.66	4.74					
15/08/2007	23	29	Coarse dark grey sand	7.99	X	6.35						
15/08/2007	23	30	Shells	8.20	X	6.65						

APPENDIX 2:
KEMERTON SILICA SANDS PROJECT
ACID SULFATE SOIL INTERPRETATION
JANUARY 2009
MBS ENVIRONMENTAL

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MEMORANDUM

Attention:	Mark Gell	From:	David Allen
Company:	Kemerton Silica Sand Pty Ltd	Date:	29 January 2009
Subject:	Acid Sulfate Soil Interpretation	Project:	KSSENV

Please advise if any part of this transmission failed or was misdirected

Recently Rehabilitated Area South of North Lake, Acid Sulfate Soil Investigation - Interpretation of Results

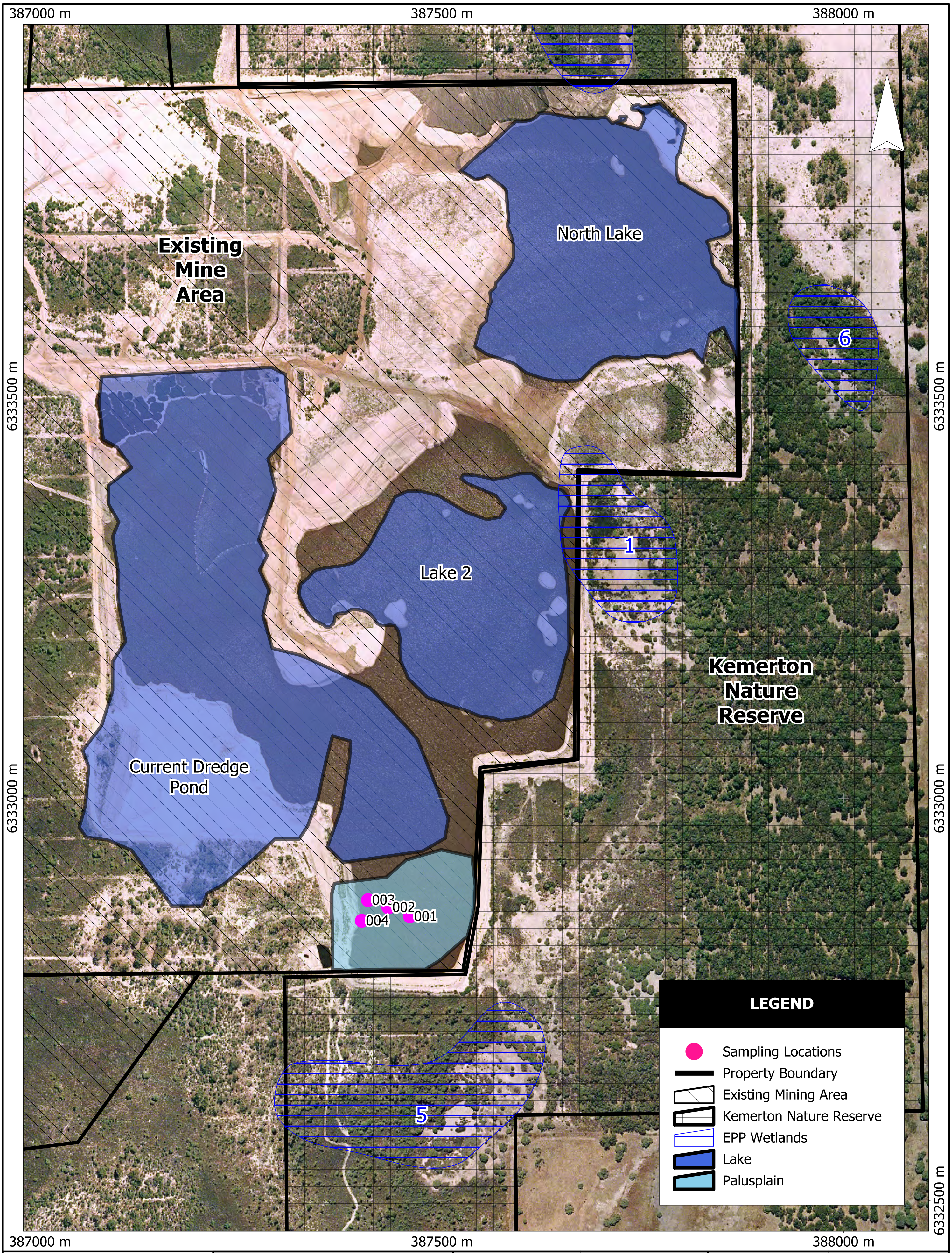
1. Background

The Kemerton Silica Sand (KSS) property is located in the Shire of Harvey on the Swan Coastal Plain in the southwest of Western Australia. The KSS property has been mapped on the WAPC (2003) Bulletin 64 maps as generally having moderate to low risk of Acid Sulfate Soil (ASS) materials occurring at depths of greater than three metres. However, also present are two areas identified as being high risk of containing ASS materials at less than three metres from the surface.

The Department of Environment and Conservation (DEC) describes ASS as the common name given to naturally occurring soil or sediment containing iron sulphides over extensive low-lying areas under waterlogged (i.e. anaerobic) conditions. These soils may be found close to the natural ground level but may also be found at depth in the soil profile. When sulphide materials are exposed to air, oxidation occurs and free sulphuric acid is produced where the soil's capacity to neutralise the acidity is exceeded. Soils that have acidified as a result of oxidation of ASS materials are referred to as Actual Acid Sulfate Soils (AASS). Soils that have potential to produce acidity upon exposure to air and water are referred to as Potential Acid Sulfate Soils (PASS). PASS materials may be naturally acidic, neutral or alkaline before exposure to oxidising conditions.

In mid 2007, a new area south of the North Lake was rehabilitated using topsoil and spreading of brush and logs. The area is shown in Figure 1. McCullough and Lund (2008) stated in a monitoring report that low $Cl:SO_4$ ratios in the newly rehabilitated area may indicate some acid mine drainage/ASS-type oxidation from disturbance of the intermediate 'coffee rock' layer which may contain PASS.

In response to this observation, four samples of soil from the KSS property were submitted for chemical analysis by the Chemistry Centre (WA) to determine the potential for acid generation following oxidation of ASS materials. An assessment of the soil to generate acidity using the Suspension Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) are assessed in this Memorandum.



Environmental + Water Resource Consultants MBS ENVIRONMENTAL 4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale: 1:6000 Original Size: A4 Air Photo Date: Grid: Australia MGA94 (50) 0 250 m	Kemerton Silica Sand Pty Ltd	Acid Sulfate Soil Sampling Newly Rehabilitated Area Figure 1

W:\Kemerton Silica Sand\Drawings\Maps 2009\ASS.map 28/01/2009 Acid Sulfate Soils Survey Rehab area Layout

2. Sample Descriptions

Four samples from Kemerton were delivered by Mark Gell to MBS on 24 December 2008. The samples were taken at 25 to 35 centimetre depths because the water table was still high at the time of sampling. The samples were marked ASS 001 to 004. ASS001 to ASS003 were taken from a reconstructed soil profile and ASS 004 was sampled from a soil dump (mud pushed up onto the surface to dry). The samples are described as follows:

- ASS 001: Light yellow-grey sandy soil.
- ASS 002: Grey sandy soil.
- ASS 003: Organic grey-black sandy soil.
- ASS 004: Grey sandy soil.

The sampling was conducted in accordance with current DEC guidelines for ASS. All samples were kept in a frozen condition in the period following collection from the field and delivery to the laboratory on 29 December 2008.

3. Results

Results from the analysis of the <2 millimetre fraction of each sample are presented in Table 1. A complete report of analysis issued by the Chemistry Centre (WA) is included as an attachment to this Memorandum.

Table 1: Results for the Analysis of Four Samples of Soil from Kemerton

Sample	pH_{KCl}	pH_{ox}	S_p	S_{KCl}	S_{pos}	ANC_e	TAA	TPA
			%	%	%	moles H^+/tonne		
ASS 001	6.4	6.4	<0.01	<0.01	<0.01	<2	<2	<2
ASS 002	6.0	5.6	0.02	<0.01	0.02	<2	8	<2
ASS 003	6.1	3.5	0.01	<0.01	0.01	<2	8	33
ASS 004	5.8	5.2	0.03	0.01	0.02	<2	13	<2

Note:

pH_{KCl}	=	pH of sample in KCl solution.
pH_{ox}	=	pH of sample in KCl solution following treatment with hydrogen peroxide.
S_p	=	Soluble sulfur in solution following treatment with hydrogen peroxide.
S_{KCl}	=	Soluble sulfur in KCl solution of the untreated sample.
S_{pos}	=	Peroxide oxidisable sulphur.
ANCe	=	Excess Acid Neutralisation Capacity.
TAA	=	Titratable Actual Acidity.
TPA	=	Titratable Peroxide Acidity.

4. Discussion

The Action Criteria for management of PASS sand textured soils in Western Australia are 0.03 % S_{pos} by the sulfur trail and a TPA value of 18 mole H^+ per tonne by the acid trail. Based on these criteria, material represented by sample ASS 003 may require specific ASS management plan implementation.

The Chemistry Centre report noted anomalous behaviour by this sample during the test procedure. The reported value for S_{pos} is at the lower reporting limit for the method

(0.01%) and well below the Action Criterion by the sulphur trail of 0.03%. This result indicates the sample contains only trace amounts of pyritic material.

The reported value for TPA of 33 mole H^+ per tonne was obtained in only one of five replicate determinations, with results for the four replicates being below the lower reporting limit for the method (2 mole H^+ per tonne). The report indicated that the pH values of the test solutions increased significantly upon destruction of excess hydrogen peroxide. With the four replicate samples, the test solutions recorded an alkaline pH values.

A possible explanation for this behaviour is that the peroxide acidity was caused by oxidation of small amounts of reduced ferrous ion (Fe^{2+}) associated with humic organic matter, which is commonly recorded in podsol soils such as subsoil of the Bassendean Dune System. The process of acidity generated by oxidation of reduced iron species is well known and is referred to as 'ferrolysis' (Equation 1). It appears that the 'ferrolysis' reaction is reversible in this situation once the strongly oxidising conditions caused by the presence of excess hydrogen peroxide are removed. Removal of excess hydrogen peroxide provides conditions that enable reduction of the oxidised iron (Fe^{3+}) by humic substances in the soil, thereby consuming the acidity generated by the peroxide treatment.

$$Fe^{2+} + O_2 + 10H_2O \rightarrow 4Fe(OH)_3 + 8H^+ \qquad \text{Equation 1}$$

The TAA and ANC_e values recorded for all samples are typical of natural Bassendean sands.

Note that if the sample was tested by an alternative procedure approved for assessment of ASS materials, analysis for chromium-reducible sulphur and TAA, the expected test results would be below the corresponding Action Criteria.

5. Conclusion

Three of the four samples tested contain insignificant amounts of ASS materials. The other sample (ASS 003) was reported with value for TAA that exceeded the Action Criteria for sands, despite containing only trace amounts of pyritic material. It was noted that the reported value of 33 mole H^+ per tonne was obtained in only one of five replicate determinations, with the results for the other four determinations being <2 mole H^+ per tonne.

It is considered extremely unlikely that significant amounts of acidity will be generated by disturbance of this soil. In terms of ASS management of these soil samples, no specific management protocols are required, although an ASS Management Plan has been prepared for any future ASS issues that may arise.

If you have any queries regarding the contents of this memorandum please do not hesitate to contact me on (08) 9226 3166 or by email at dallen@mbsenvironmental.com.au.

Yours sincerely
MBS Environmental

DAllen

David Allen
Senior Environmental Geochemist

Enc. Laboratory Report by Chemistry Centre (WA), Lab No 08E1129

REPORT FOR

DAVID ALLEN

MBS ENVIRONMENTAL

Purchase Order :KSSENV

ON

ACID SULFATE SOIL TESTING
BY
SUSPENSION PEROXIDE OXIDATION COMBINED ACIDITY AND SULFATE METHOD (SPOCAS)
According to the:
Acid Sulfate Soils Laboratory Methods Guidelines 2004,
Department of Natural Resources and Mines, Queensland

CHEMISTRY CENTRE REPORT NO 08E1129
7 JANUARY 2009

CHEMISTRY CENTRE (WA)
Natural Resources Chemistry Laboratory
125 Hay Street
East Perth WA 6004

WORLD RECOGNISED ACCREDITATION

SAMPLE IDENTIFICATION

Four samples of frozen soil were received for analysis on 29/12/08. On receipt at the Chemistry Centre the samples were identified and allocated a Laboratory Number.

TEST METHODS

The test methods of the Acid Sulfate Soils Laboratory Methods Guidelines manual were used in this work, specifically Method Code 23 – SPOCAS (Suspension Peroxide Oxidation Combined Acidity and Sulfate).

The SPOCAS method is a standardised set of procedures useful in assessing the environmental impact of soils suspected of containing pyrite and other iron sulfides, which might lead to an acid sulfate soil problem if disturbed.

SAMPLE PREPARATION

The samples were dried at 80 ^{o}C for 48 hours and sieved to remove coarse material >2 mm. After grinding to <150 microns, sub samples of the milled homogenised material were then subjected to chemical tests. All results are reported on a dry weight basis.

TEST PROCEDURES

SPOCAS METHOD

Step 1: Determination of Potassium Chloride Extractable pH, Potassium Chloride Extractable Sulfur (S_{KCl} %) and Titratable Actual Acidity (TAA). Method Codes 23A, 23Ce and 23F.

In this procedure the sample is extracted with potassium chloride solution. The extraction with potassium chloride is used to determine soluble and absorbed sulfur (non-sulfidic sulfur) and the titratable actual acidity of the sample (**TAA**). The sulfur is determined using inductively coupled plasma atomic emission spectrometry (ICPAES).

The pH, acidity, and sulfur content of the resultant solution are reported as **pH_{KCl}, TAA_{KCl},** and **S_{KCl}** respectively.

Step 2: Determination of the Peroxide pH (pHox), Peroxide Sulfur (S_P%), and Titratable Peroxide Acidity (TPA). Method Codes 23B, 23De, and 23G.

This step involves oxidation of the sample with hydrogen peroxide to produce maximum acidity from any reduced sulfidic material. The sulfur content (**S_P%**), the Titratable Peroxide Acidity (**TPA**), and pH (**pHox**) of the oxidised solution are determined. **S_P%** will include the soluble, absorbed, and sulfide, sulfur species.

Step 3: Determination of Retained Acidity (a-SNAS). Method Code 20J.

Existing acidity in acid sulfate soils includes **'actual'** acidity (TAA) and **'retained'** acidity (acidity stored in largely insoluble iron and aluminium sulfate minerals). A dilute hydrochloric acid (HCl) extraction performed on the sample will give S_{HCL}. The net acid soluble sulfur (S_{NAS}) due to sparingly soluble sulfate containing compounds such as jarosite, can be calculated by subtracting S_{KCL} from S_{HCL}. The equivalent acidity is expressed as a-S_{NAS}. For soil samples with pH_{KCl}<4.5 the S_{NAS} must be determined.

Step 4: Determination of the Excess Acid Neutralising Capacity (ANCe). Method Code 23Q.

This determination is optional depending on the peroxide solution pH.
If the solution pH after the peroxide step is >6.5, the material may have an acid neutralization capacity. The fine grinding of the sample for analysis will lead to an over estimation of the effective acid neutralising capacity and an appropriate safety factor must be applied.

Step 5: Peroxide Oxidizable Sulfur (S_{POS}). Method Code 23Ee.

This step involves calculating the differences between the extracts from Step 2 and Step 1. The peroxide oxidizable sulfur is used to predict the potential acid risk from non-oxidised sulfur compounds.

Peroxide oxidizable sulfur: $S_{POS} = (S_P - S_{KCl})\%$

RESULTS

See attached spreadsheet: 08E1129 Results

ACID BASE ACCOUNTING (ABA)

The acid base accounting approach is used to predict net acidity from the oxidation of sulfidic material. The SPOCAS method is in essence a self-contained ABA. The **TPA** result represents a measure of the net acidity, effectively equivalent to the sum of the soil's potential sulfidic activity and actual acidity **(TAA)** less any neutralising capacity of the sample. Where the pH_{KCl} is <4.5 then the residual acid soluble sulfur (**S_{RAS}**) component of SPOCAS should be done, since the TPA does not measure **retained acidity**. In soils that are self neutralising (i.e. TPA=0), then the HCL titration step in SPOCAS allows calculation of the **excess acid neutralising capacity** (**ANC_E**)

GUIDE TO INTERPRETATION OF SPOCAS TESTWORK

Interpretation of results from SPOCAS test methods involves determination of action criteria and comparison of the test results with the criteria. The NSW ASSMAC has published Action Criteria as follows:

Type of Material		Action Criteria, <1,000 tonnes		Action Criteria, >1,000 tonnes	
Texture	**Approx Clay Content (%<0.002 mm)**	**Sulfur Trail S_{POS} %**	**Acid Trail TPA mole H^+/t**	**Sulfur Trail S_{POS} %**	**Acid Trail TPA mole H^+/t**
Coarse e.g. sands	≤5	0.03	18	0.03	18
Medium e.g. loams/light clays	5 – 40	0.06	36	0.03	18
Fine clays/silts	≥40	0.1	62	0.03	18

According to the NSW ASSMAC, exceeding these criteria may result in an acid sulfate soil issue and the need for an acid sulfate soil management plan with development approval.

INTERPRETATION OF RESULTS OF SPOCAS TESTS FROM THIS WORK

No single method, including SPOCAS, will provide all the answers to the complex chemistry involved in reactions of acid sulfate soils. However results from SPOCAS test procedures will provide guidance to identification of potential ASS issues.

The fine grinding required for analysis will increase the acid neutralising capacity for acid reducing components of the sample and will result in a lower TPA than would be expected, or a higher excess acid neutralising capacity than in the original material.

Sample 08E1129/003 exceeded the guideline limits for TPA in sand. This sample exhibited very unusual behaviour. Even though it had an acidic pH on oxidation it became alkaline upon the destruction of the hydrogen peroxide. This behaviour was replicated four times in five digestions:

pH ox	pH after destruction of H_2O_2	TPA Moles H^+/tonne
3.5	7.0	<2
3.2	4.7	33
3.2	6.9	<2
3.5	6.9	<2
3.4	7.7	<2

The reason for this behaviour is unknown.

The Department of Environment does not accept ANCe values, without confirmatory field kinetic testing, as an argument to reduce the level of management required for the disturbance of ASS.

RECOMMENDATIONS

Sample 08E1129/003 be treated in accordance with Reference 1.

REFERENCES

1 **Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998** Queensland Acid Sulfate Soils Investigation Team (QASSIT) October 1998, C.R.Ahern, M.R. Ahern, and B Powell.

2. **Acid Sulfate Soils Laboratory Methods Guidelines 2004**, Department of Natural Resources and Mines, Queensland, 2004.

This is a NATA endorsed test report issued by the Chemistry Centre (WA), NATA Registered Laboratory No 0008, Date of Registration 1 November 1950. This report shall not be reproduced except in full. Unless notified, all samples will be disposed of 60 days after the issue of this report. Solution extracts are not stored: samples are reanalysed if queries arise after reporting.

BARRY PRICE
SENIOR CHEMIST AND RESEARCH OFFICER
NATURAL RESOURCES CHEMISTRY LABORATORY

7 January 2009

APPENDIX 3:
GROUNDWATER MONITORING REVIEW
JULY 2005 TO JUNE 2008
(GWL 60367 (2 & 3))
ROCKWATER PROPRIETARY LIMITED

Rockwater
PROPRIETARY LIMITED

KEMERTON SILICA SAND PTY LTD

GROUNDWATER MONITORING REVIEW
JULY 2005 TO JUNE 2008
(GWL 60367(2&3))

SEPTEMBER 2008

REPORT FOR
KEMERTON SILICA SAND PTY LTD

258.0/08/01

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I Licence to Take Water GWL 60367(2), GWL 60367(3) and Department of Environment Licence 6593/3
II Monitoring Data
III Water Chemistry Data

1 INTRODUCTION

1.1 GENERAL

Kemerton Silica Sand Pty Ltd (KSS) mines and processes silica sand, most of which is exported from the Port of Bunbury to Asia for glass manufacturing. The KSS property spans the northern boundary of the Kemerton Industrial Estate, approximately 35 km north of Bunbury and 150 km south of Perth (Fig. 1). The site is located within the groundwater management sub-areas Kemerton Industrial Park North and Kemerton North, which are part of the South West Coastal Groundwater Area.

The mining operation utilises a suction cutter dredge, from which the sand slurry is pumped to a Run of Mine (ROM) storage area, where it is de-slimed and stockpiled. Sand from stockpiles is fed into a processing plant where it is screened, washed and the heavy minerals removed using gravity separation. Processed sand is stockpiled by cyclones and subsequently transported by truck to the port.

Groundwater from two production bores, KMB7 and KMB14, is used for processing in the plant (Fig. 2). The plant water circuit incorporates a thickener, which enables the majority of process water to be recirculated. A small proportion of the process water is used to return the coarse tailings and thickened slimes to the Dredge Pond. ROM stacker overflow is also returned via a pipeline to the Dredge Pond. The return of all waste streams to the Dredge Pond, at an average flow of approximately 800,000 kL/year, maintains the water level in the pond.

1.2 GROUNDWATER WELL LICENCE

1.2.1 Licence and Monitoring Conditions

Groundwater extraction from the Kermerton Silica Sand Borefield is authorised by the Department of Water (DoW) under Groundwater Well Licenses (GWL) 60367(2) which was amended on 20 August 2007 and reissued as GWL 60367(3) with a new allocation limit, additional chemistry conditions and monitoring locations. Copies of the licences are included in Appendix I and licence data are summarised in Tables 1 and 2.

In addition, under Department of Environment Licence 6593/4 (Appendix I), salinities in every monitoring bore are to be measured on a monthly basis. This report has previously been included in the Annual Monitoring report (environmental) for (reporting under licence condition W2a), which is required to be submitted to the Department of Environment by 31 October each year.

Table 1: Groundwater Licences

Licence	Issue Date	Expiry Date	Water Entitlement	Monitoring Requirements
GWL 60367(2)	14-Oct-03	20-Aug-07	1,000,000 kL/a	Condition 2
GWL 60367(3)	20-Aug-07	30-Jun-13	660,000 kL/a	Schedule 1
				Schedule 2

Table 2: GWL 60367 Monitoring Requirements

GWL	Condition			Period	Bores	Report	Submit
60367(3)	Schedule 1		***Water Meters***				
			Install and maintain cumulative water meters	-	KMB 7, 14	Annually	31-Jul
			Record volume of groundwater extracted	Monthly			
	Schedule 2		***Groundwater Monitoring Program***				
			Record water levels & operating status	Monthly	KMB 7, 14 KMB 2, 4 , 5, 6, 8, & 13 KMB 9, 10, 11 & 12	Annually	31-Aug
			Obtain water samples and analyse for -				
			pH, (TDS) Total Dissolved Solids	Quarterly			
			TTA (Total Titrateable Acidity)	Annually			
			TN (Total Nitrogen)				
			Nox as N (Nitrate / Nitrate as N)				
			TP (Total Phosphorus				
			SO42- (Sulphate)				
			Cl- (Chloride)				
60367(2)	Condition 2	a	Maintain bore schedule	-	Monitoring & Production Bores	Annually	
		b	Measure & record pumpages	Monthly	Production Bores		
		c	Measure & record water levels noting pumping status	Monthly	Monitoring & Production Bores		
		d	Measure & record salinities	Monthly	Pumping		
	Condition 5		Assess pumping and monitoring program	Annually			

1.2.2 Compliance with Monitoring Conditions

This report is prepared as a triennial report in fulfilment of GWL 60367(3) Schedule 2, Condition 7, and is based on data collected by KSS. The monitoring programme carried out over the review period (July 2005 to June 2008) was in full compliance to the conditions of GWL 60367(2). Revision of the monitoring programme should have occurred with the introduction of GWL 60367(3) in August 2007. This oversight has lead to only partial compliance with the monitoring conditions in the final year of the review period, however this mistake was accidental and once KSS become aware of the error a broader monitoring programme was introduced. The new monitoring programme will ensure full compliance for the 2008/2009 review. Table 3 outlines the data collected over the review period and indicates the extent of future monitoring that will be carried out by KSS.

Table 3: Data Collection as Required by GWL 60367(3)

	Extraction	Water level	pH quarterly				TDS quarterly				Annual data to be collected in March/April					
	monthly	monthly	Sept/Oct	Dec/Jan	Mar/Apr	Jun/Jul	Sept/Oct	Dec/Jan	Mar/Apr	Jun/Jul	**TTA**	**TN**	**TP**	**NOx as N**	**SO4**	**Cl**
KMB7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	see note #	✓	✓
KMB14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	see note #	✓	✓
KMB2	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓
KMB4	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓
KMB5	NA	✓														
KMB6	NA		✓	✓	✓	✓	✓	✓	✓	✓						
KMB8	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓
KMB9	NA	✓														
KMB10	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	
KMB11	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓						
KMB12	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓
KMB13	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓

Notes:

✓ = data have been collected and provided for the 2005/2008 Review

= data have not been collected

NA = not applicable

\# = nitrate-N is provided but not NOx as N (nitrate-N plus nitrite-N)

Water levels are monitored in KMB1, which is not in the list of monitoring sites

KMB5 and KMB9 removed in 2001 from the list of sites where monitoring was required but monitoring at both sites has been re-instated by GWL6063(3)

The available TP, SO4 and Cl data are for either or both of July 2007 and January 2008, not March/April.

2 CLIMATE

The Kemerton site has a Mediterranean-type climate, characterised by warm dry summers and cool wet winters. Rainfall data have been collected at the Kemerton Silica Sand mine since mid-1998. Long-term climatic data have been recorded from 1951 at the Wokalup Agricultural Research Station (Bureau of Meteorology Station Number 9642) approximately 8 km east of the mine site, and from 1913 at Parkfield (Bureau of Meteorology Station Number 9634), approximately 10 km southwest of the mine site. The locations of these stations are shown on Figure 1 and rainfall data presented in Figure 3 and Table 4.

The data suggest that rainfall on the coastal plain increases from west to east, with Wokalup consistently receiving higher annual rainfalls. A pattern of declining average annual rainfall has also emerged and each station recorded below average annual rainfalls in 2007.

Rainfall over the final year of the review period (July 2007 to June 2008) was 948 mm at the mine site, 1043 mm at Wokalup and 471 mm at Parkfield (excluding the months of August and September 2007 as rainfall data were not recorded).

Calender year totals for 2007 are:

- 810 mm at the mine site, about 4% less than the site's average of 859 mm/a (1998 – 2008);
- 854 mm at Wokalup, only slightly greater than the short-term average of 849 mm/a (1998 – 2008), however, the long-term average (1951 – 2008) at Wokalup is 965 mm/a, indicating a decline of about 10% in annual rainfall over the record period; and
- 667 mm at Parkfield (using long-term averages for August and September 2007), about 8 % less than the short-term average of 722 mm/a, and about 18 % less than the long-term average (1913 – 2008) of 816 mm/a.

Rainfall over the review period shows annual variation from 186 mm at the mine site to 358 mm at Wokalup. Several months of data were not recorded at Parkfield and the site was excluded from the assessment of rainfall variation over the review period.

In 2006 below-average rainfall was recorded at all three stations. The mine site received 646.5 mm, Wokalup received 515 mm and Parkfield 475.0 mm. These below-average rainfalls were typical of the region.

The average annual evaporation at Wokalup is about 1,806 mm. The data illustrate that average monthly rainfall exceeds average monthly evaporation only during the winter months of May to August (Table 4, Fig. 3), indicating potential for groundwater recharge occurs during this period.

Table 4: Rainfall and Evaporation Data 2005/2008

Month	Kemerton Mine Site		Wokalup Agricultural Research Station			Parkfield	
	Rainfall 2007/2008 (mm)	Average Rainfall[1] (mm)	Rainfall 2007/2008 (mm)	Average Rainfall[1] (mm)	Average Evaporation[2] (mm)	Rainfall 2007/2008 (mm)	Average Rainfall[1] (mm)
Jan-05	0.0	15.4	1.0	13.4	282.1	1.0	13.0
Feb-05	5.5	8.2	4.0	7.7	240.8	9.0	4.5
Mar-05	13.5	12.0	27.9	19.8	210.8	24.0	18.9
Apr-05	34.5	49.2	39.6	49.8	129.0	63.6	42.9
May-05	275.0	126.2	249.4	110.0	83.7	252.7	108.3
Jun-05	201.5	149.8	188.6	144.9	63.0	197.2	141.4
Jul-05	201.5	154.5	81.5	154.5	65.1	52.0	120.9
Aug-05	75.0	151.8	140.2	149.9	77.5	110.8	123.7
Sep-05	143.5	103.1	154.8	103.6	96.0	85.4	73.2
Oct-05	142.0	56.3	92.9	50.3	136.4	58.6	37.2
Nov-05	81.5	26.7	38.4	31.5	180.0	44.9	23.3
Dec-05	26.0	11.5	27.4	13.3	241.8	18.2	14.6
Jan-06	27.5	15.4	30.6	13.4	282.1	36.6	13.0
Feb-06	36.0	8.2	1.2	7.7	240.8	nr	4.5
Mar-06	1.5	12.0	4.2	19.8	210.8	12.0	18.9
Apr-06	7.5	49.2	22.0	49.8	129.0	38.9	42.9
May-06	33.5	126.2	29.5	110.0	83.7	16.4	108.3
Jun-06	28.0	149.8	14.2	144.9	63.0	22.8	141.4
Jul-06	26.5	154.5	139.7	154.5	65.1	122.8	120.9
Aug-06	169.5	151.8	168.2	149.9	77.5	137.8	123.7
Sep-06	180.0	103.1	60.0	103.6	96.0	43.8	73.2
Oct-06	63.0	56.3	23.9	50.3	136.4	19.2	37.2
Nov-06	45.0	26.7	21.9	31.5	180.0	24.7	23.3
Dec-06	28.5	11.5	0.0	13.3	241.8	nr	14.6
Jan-07	0.0	15.4	19.0	13.4	282.1	21.0	13.0
Feb-07	8.5	8.2	13.0	7.7	240.8	3.0	4.5
Mar-07	19.0	12.0	24.4	19.8	210.8	11.6	18.9
Apr-07	49.0	49.2	48.6	49.8	129.0	31.8	42.9
May-07	80.0	126.2	85.6	110.0	83.7	52.7	108.3
Jun-07	121.0	149.8	107.8	144.9	63.0	173.1	141.4
Jul-07	189.5	154.5	181.9	154.5	65.1	110.3	120.9
Aug-07	146.5	151.8	178.8	149.9	77.5	nr	123.7
Sep-07	105.5	103.1	128.5	103.6	96.0	nr	73.2
Oct-07	60.0	56.3	61.0	50.3	136.4	33.9	37.2
Nov-07	3.0	26.7	3.2	31.5	180.0	2.4	23.3
Dec-07	28.0	11.5	21.2	13.3	241.8	32.0	14.6
Jan-08	0.0	15.4	0.0	13.4	282.1	0.0	13.0
Feb-08	12.0	8.2	15.4	7.7	240.8	7.0	4.5
Mar-08	1.0	12.0	2.8	19.8	210.8	3.6	18.9
Apr-08	138.0	49.2	173.4	49.8	129.0	101.1	42.9
May-08	114.0	126.2	129.6	110.0	83.7	134.9	108.3
Jun-08	150.5	149.8	147.4	144.9	63.0	144.3	141.4
Total Jan05-Dec07	2656.0		2434.1			1864.2	
Total Jan07-Dec07	*810.0*		*854.0*			*471.8* [4]	
Total Jul07-Jun08	*948.0*		*1043.2*			*569.5* [4]	
Average Jan - Dec[1]		*858.6*		*848.7*			*721.9* [3]
Average Jan - Dec1							
Long-term Average				965.1 *(1951-2008)*	1806.2 *(1951-2004)*		816 *(1913-2008)*

Notes: 1 Average since 1998
2 Average total monthly evaporation, 1951 - 2004.
3 Data not registered are substituted by long-term averages
4 Excludes data not regisisterd
nr = not registered

3 HYDROGEOLOGY

3.1 PHYSIOGRAPHY

The mining operation is located on the Swan Coastal Plain within the Bassendean Dune System. The mine area has a low irregular topography; dune crests have elevations of up to 25 m AHD whilst interdunal depressions have elevations of about 10 m AHD. The Wellesley River flows towards the southwest, just east of the mine site (Fig. 1).

3.2 GEOLOGY

The mine area is underlain by about 30 m of Quaternary to Tertiary-age superficial formations (Allen, 1976), which rest unconformably on the Cretaceous-age Leederville Formation. The superficial formations comprise fine to medium grained quartz sand, with minor clay and clayey sand (Bassendean Sand), overlying a basal 5 to 10 metres of shelly sand and limestone (Ascot Formation).

3.3 GROUNDWATER OCCURRENCE

The superficial formations form an unconfined aquifer (Superficial aquifer) from which water supplies can be obtained. Groundwater in the Superficial aquifer is derived from rainfall recharge, which is generally seasonal, resulting in seasonal water table fluctuations of approximately two metres. The water table beneath the site varies from at or near ground level, resulting in seasonal wetlands in topographic depressions, to over 10 m depth beneath higher areas.

The groundwater flows southeastwards below the property from the Mialla Mound towards the Wellesley River, within the Myalup groundwater flow system (Deeney, 1989). Groundwater discharges into the river, some is lost by evapotranspiration mainly from wetlands, a small proportion may leak into the underlying Leederville aquifer at the base of the Superficial aquifer, and some moves southwestwards within the Superficial aquifer.

The salinity of groundwater in the Superficial aquifer varies from less than 100 mg/L TDS (total dissolved solids) to approximately 750 mg/L TDS. Salinity variations depend mainly on the location with respect to groundwater recharge and discharge sites (fresher groundwater near recharge areas and higher salinity near discharge areas), and the timing of salinity measurements compared to groundwater recharge events. The higher salinity groundwater is generally associated with saline plumes on the down-hydraulic-gradient sides of wetlands. Groundwater salinity may also be higher near the Wellesley River (Deeney, 1989).

4 BOREFIELD

The borefield comprises two production bores, KMB7 and KMB14, located to the west of the plant site (Fig. 2). A schedule of operating production bores and monitoring bores is summarised in Table 5.

Table 5: Schedule of Production and Monitoring Bores and Wetland Monitoring Sites

Bore ID	MGA Coordinates		Reduced Level Top of Casing (m AHD)	Depth (m bTOC)	Screen/Slots (m bTOC)	Comments
	mE	mN				
Production Bores						
KMB7	386256	6333377	15.684	29	16.5 – 28.5	Equipped Grundfos, SP8A-15; Installed January 2004.
KMB14	385962	6333541	16.475	30.4	16.6 – 28.6	Equipped Southern Cross, 8-Stage turbine, Model NAD2F; Constructed
Monitoring Bores						
KMB1	385376	6333178	17.597	24	11.0 – 23.4	Monitoring no longer required under GWL 60367(3)
KMB2	386291	6334148	16.814	23.8	11.0 – 23.0	
KMB3	-	-	14.708	24	10.0 – 24.0	Decommissioned in Feb. 2001 (covered by southern extension to Dredge Pond).
KMB4	386934	6333876	16.028	23	11.0 – 23.0	
KMB5	386845	6333151	16.334	22.1	10.1 – 22.1	Monitoring ceased in 2001, recommenced in August 2008.
KMB6	386838	6333181	15.596	19	1.5 – 19.0	Test pumped for 24 hours at 370 kL/day.
KMB8	386188	6333690	15.667	N/A	N/A	
KMB9	387680	6333275	14.456	N/A	N/A	Monitoring ceased in 2001, recommenced in August 2008.
KMB10	388091	6335099	15.28	N/A	N/A	
KMB11	388354	6335564	16.156	N/A	N/A	
KMB12	388642	6335103	13.829	N/A	N/A	
KMB13	385862	6332997	16.06	N/A	N/A	Silted-up Feb. 2001. Cleared and monitoring recommenced May 2002.
Wetland Sites						
Site ID	**MGA Coordinates**		**Reduced Level of Gauge (m AHD)**			
	mE	**mN**				
WL3	387669	6333999	15.369	N/A	N/A	Staff gauge; seasonal wetland.
WL4	386332	6334151	15.198	N/A	N/A	Staff gauge; seasonal wetland.
WL6	387969	6333577	13.653	N/A	N/A	Staff gauge; seasonal wetland.
WL7	387985	6334292	15.601	N/A	N/A	Staff gauge; seasonal wetland.

The production bores are constructed to about 30 m depth, with the basal 12 m consisting of 195 mm diameter stainless steel screens set in fine to medium-grained sand and limestone. Eleven monitoring bores are scattered around the mine site (Fig. 2); these bores are constructed with 50 mm uPVC which is slotted over the basal 12 to 18 m.

Monitoring bore KMB3 was decommissioned and removed in 2001 as it was located within a planned extension to the dredge pond.

Four wetlands near the mine site are monitored using *in situ* measuring staff gauges, locations for which are shown on Figure 2.

5 GROUNDWATER EXTRACTION

Groundwater extraction over the three-year review period totalled 872,772 kL. Annual extraction totals for each year of operation are presented in Table 6, and for the review period are;

- 310,290 kL for 2005/2006, about 31% of the annual water entitlement of 1,000,000 kL;
- 338,258 kL for 2006/2007, about 34% of the annual water entitlement of 1,000,000 kL; and
- 224,224 kL for 2007/2008, about 34% of the annual water entitlement of 660,000 kL.

Water efficiency initiatives were introduced by KSS in 2003 and since that time water usage has decreased in all but one year (2006/2007). Principally, this has been achieved by more efficient use of water in the circuit.

Table 6: Annual Groundwater Extraction

Period	KMB 7 (kL)	KMB 14 (kL)	Total (kL)	Use of Annual Entitlement
Feb 1996–June 1996	164,528	200,079	364,607	36%
July 1996–June 1997	533,190	393,747	926,937	93%
July 1997–June 1998	503,988	360,202	864,190	86%
July 1998–June 1999	461,931	348,488	810,419	81%
July 1999–June 2000	447,407	328,194	775,601	78%
July 2000–June 2001	480,213	324,586	804,799	80%
July 2001–June 2002	410,596	306,042	716,638	72%
July 2002–June 2003	309,854	233,883	543,737	54%
July 2003–June 2004	96,541	280,472	377,013	38%
July 2004–June 2005	189,374	98,007	287,381	29%
July 2005–June 2006	270,013	40,277	310,290	31%
July 2006–June 2007	260,579	77,679	338,258	34%
July 2007–June 2008	170,297	53,927	224,224	34%

The monthly pumpage for each bore and total monthly pumpage since extraction commenced are shown in Figure 4. In 2007/2008, monthly extraction varied considerably from 3,314 kL in April 2008, up to 40,309 kL in September 2007 (Table 7). Individual bore extractions ranged from 1,640 kL in December 2007 to 36,741 kL in June 2008 for bore KMB7; and from 110 kL in April 2008 to 9,605 kL in September 2007 for bore KMB14.

Table 7: Monthly Groundwater Extraction 2005/2008

Period	KMB 7 (kL)	KMB 14 (kL)	Combined (kL)
Jul-05	29,264	19	29,283
Aug-05	31,041	18	31,059
Sep-05	31,590	14	31,604
Oct-05	23,435	1,322	24,757
Nov-05	23,332	3,236	26,568
Dec-05	14,979	5,222	20,201
Jan-06	19,563	8,667	28,230
Feb-06	11,417	11,026	22,443
Mar-06	17,128	6,439	23,567
Apr-06	22,179	3,863	26,042
May-06	17,662	22	17,684
Jun-06	28,423	429	28,852
Jul-06	17,752	22	17,774
Aug-06	28,423	429	28,852
Sep-06	23,869	12	23,881
Oct-06	29,429	2,530	31,959
Nov-06	21,566	1,473	23,039
Dec-06	18,886	11,976	30,862
Jan-07	17,980	4,283	22,263
Feb-07	13,632	7,046	20,678
Mar-07	21,472	5,038	26,510
Apr-07	13,715	10,168	23,883
May-07	23,045	28,218	51,263
Jun-07	30,810	6,484	37,294
Jul-07	21,355	4,966	26,321
Aug-07	18,511	2,949	21,460
Sep-07	30,704	9,605	40,309
Oct-07	14,622	5,442	20,064
Nov-07	12,812	3,563	16,375
Dec-07	1,640	7,987	9,627
Jan-08	1,938	9,026	10,964
Feb-08	15,130	552	15,682
Mar-08	5,020	9,121	14,141
Apr-08	3,204	110	3,314
May-08	8,620	439	9,059
Jun-08	36,741	167	36,908
Total Extraction	700,889	171,883	872,772

6 RESULTS OF MONITORING

6.1 WATER LEVELS

6.1.1 Production Bores

KMB7

Resting and pumping water-levels have been recorded for KMB7 during the review period (Fig. 5, Table 8). The rest water level in the bore during the three-year review period ranged between 13.1 and 14.6 m AHD, about 1 m to just below ground level.

Pumping water levels ranged from approximately 0.1 to 6.2 m AHD, over the review period, indicating pumping-induced drawdowns of up to 14.5 m. Historically the range of pumping water levels has typically been between 1.4 to 3.0 m AHD. Lower pumping water levels have occurred since May 2006 and are likely to be associated with a reduction in regional water levels due to late onset and reduced amount of rainfall (and therefore recharge), and/or due to reduced bore efficiency. There appears to be an overall trend of declining water levels since pumping began.

Table 8: Monthly Production Bore Water Levels 2005/2008

DATE	KMB 7		KMB 14	
	(m AHD)	Status	(m AHD)	Status
1-Jul-05	2.614	pumping	14.475	rest
1-Aug-05	2.364	pumping	14.585	rest
1-Sep-05	2.654	pumping	14.785	rest
1-Oct-05	2.074	pumping	14.945	rest
1-Nov-05	6.234	pumping	14.865	rest
1-Dec-05	5.624	pumping	14.555	rest
1-Jan-06	2.524	pumping	7.105	pumping
1-Feb-06	14.074	rest	8.185	rest
1-Mar-06	13.434	rest	13.735	pumping
1-Apr-06	0.684	pumping	13.655	rest
1-May-06	13.534	rest	13.455	rest
1-Jun-06	0.134	pumping	13.495	rest
1-Jul-06	0.784	pumping	13.645	rest
1-Aug-06	4.964	pumping	14.165	rest
1-Sep-06	4.734	pumping	14.165	rest
1-Oct-06	5.134	pumping	13.955	rest
1-Nov-06	4.124	pumping	13.875	rest
1-Dec-06	4.164	pumping	13.705	rest
1-Jan-07	3.984	pumping	13.425	rest
1-Feb-07	4.284	pumping	4.185	pumping
1-Mar-07	0.574	pumping	5.935	pumping
1-Apr-07	0.068	pumping	12.745	rest
1-May-07	13.054	rest	13.035	rest
1-Jun-07	5.104	pumping	13.105	rest
1-Jul-07	14.134	rest	2.005	pumping
1-Aug-07	14.474	rest	5.255	pumping
1-Sep-07	14.594	rest	14.425	rest
1-Oct-07	14.464	rest	14.255	rest
1-Nov-07	14.234	rest	14.125	rest
1-Dec-07	14.014	rest	13.925	rest
1-Jan-08	0.364	pumping	13.495	rest
1-Feb-08	2.434	pumping	13.135	rest
1-Mar-08	1.744	pumping	13.315	rest
1-Apr-08	1.634	pumping	13.425	rest
1-May-08	13.584	rest	13.585	rest
1-Jun-08	5.104	pumping	14.245	rest

KMB14

Water level data for KMB14 show pumping and resting water levels (Fig.5, Table 8). Rest water levels in the bore during the final year of review period ranged between 13.1 and 14.4 m AHD, about 1.8 to 3.1 m below ground, and pumping water levels water levels were between 2.0 and 5.2 m AHD. Over the three-year review period rest water levels ranged from 12.7 m (April 2007) to 14.9 m (October 2005) indicating pumping-induced drawdowns of up to 12.9 m below the rest water levels.

Pumping water levels in KMB14 show a declining trend from about mid-2001 until mid-2003 where they remained until early 2005. An increase in pumping water levels post-2003 is possibly due to decreased pumping rates. Pumping water level data for current review period (elevations of 1.5 to 5.2 m AHD) are within the historical range of 0.2 to 8 m AHD, however an overall trend appears to be declining water levels.

6.1.2 Monitoring Bores

Historical groundwater levels in the monitoring bores range between about 10 m AHD and 16 m AHD. The hydrographs all show a seasonal cycle of water table variance over the course of each year (Fig. 6 and Fig.7, Appendix II).

The data suggest a general low hydraulic gradient across the property to the southeast. The monitoring bores are divided into several groups for analysis based on hydrograph trends and forms, and which also reflect the locations of the bores around the site.

KMB1, KMB2 and KMB8 (Northwestern Area)

Bores KMB1, KMB2 and KMB8 are located north of the productions bores (Fig.2). Monthly water level measurements were taken over the review period for KMB1, KMB2 and KMB8. The hydrographs (Fig. 6) illustrate a very similar pattern of change, with a seasonal water level variance of 1.0 to 1.9 m.

Maximum water levels in 2007/2008 range between 14.6 to 14.8 m AHD, about 0.35 m above those measured in the previous review period, reflecting the higher rainfall of 2007 compared to 2006. Water levels receded after the end of summer to between 13.4 and 13.6 m AHD and then rose to above average levels in June 2008 following comparatively high April rainfall (Fig. 3). Low water levels recorded in 2006 reflect the below average rainfall experienced in the region during that year and high water levels, recorded in July 2005, reflect aquifer recharge associated with above average autumn rainfall.

KMB4, KMB5, KMB6 and KMB9 (Central and Southern Areas)

Monitoring bores KMB4, KMB5, KMB6 and KMB9 are located in an area between and south of the Plant Infrastructure and Dredge Pond (Fig. 2). Monthly water level measurements were performed over the review period for KMB4, KMB6 and KMB9. Water levels measurements were not taken for KMB5 over the review period as it was not required under GWL 60367(2).

The hydrographs for the bores show seasonal fluctuations consistent with previous years (Fig. 6). The lowest maximum water level since 1995 was recorded in August 2006 following below-average rainfall in autumn of that year. Levels rose in 2007 accompanying increased rainfall; however, there is an overall trend of decline over the review period. Maximum water levels, recorded in September 2007, were 0.2 to 0.7 m higher than those recorded in 2006, reflecting an increase in rainfall experienced in 2007 compared to the low rainfall in 2006. As in previous years, water levels in KMB9 are about 1 m below those recorded in KMB4 and KMB6.

KMB10, KMB11 and KMB12 (Dredge Pond Area)

Monitoring bores KMB10, KMB11 and KMB12 are located near the dredge pond (Fig. 2). Water level monitoring was performed monthly for all bores. The hydrographs for the bores show water levels in the final year of the review period are slightly higher than those measured in 2006/2007 (Fig. 7). Recording for September 2007 for KMB10 and KMB11 appear to be erroneous (being about 1 m too low and too high respectively).

Water level trends for the three bores over the review period are sub-parallel, with the water level in KMB12 roughly 0.5 m below that in KMB10 and KMB11, a pattern consistent with previous years. Since March 2001, when ROM stacker overflow water has been returned by pipeline directly to the dredge pond, end-of-summer water levels have remained relatively high in these bores, reducing the seasonal variations from about 2.5 m to just below 1.5 m. This suggests that water levels in the bores may be influenced by the water levels that are maintained in the dredge pond and, therefore, there are no trends of decline in water levels.

KMB13 (Borefield Area)

KMB13 is located about halfway between production bores KMB7 and KMB14 (Fig. 2). Water levels have been recorded monthly throughout the review period.

Seasonal variations show a similar pattern to those seen for the other monitoring bores (Fig. 7). Water levels in KMB13 peaked at 14.75 m AHD in September 2005 and dropped to a low of 13.3 m AHD in March 2007. In August 2006 a below-average maximum of 14.1 m was recorded; a reflection of low rainfall. The hydrograph shows low water levels in 2006, reflecting the particularly low rainfall of that year and a return to typical levels in 2007.

6.1.3 Wetlands

Wetland monitoring is not a GWL condition, however monitoring, using permanently installed staff gauges, is carried out on four of the eight wetlands that occur on the KSS property. These wetlands, designated WL3, WL4, WL6 and WL7, are classed as EPP (Environmental Protection Policy) wetlands (Fig. 2).

Water levels are recorded monthly or biannually (Fig. 8). Water levels for both WL3 and WL6 were constant at 13.5 and 12.5 m AHD respectively except for the final month of the review period when WL3 increased 0.2 m and WL6 increased 0.1 m. WL4 fluctuated 0.3 m over the review period from a winter high of 15.1 m AHD (July and October 2005) to dry recordings of 14.8 m AHD throughout 2007 and the summer of 2008. WL7 maintained a constant water level of 13.2 m AHD from January to July 2008 and, while seasonal fluctuations have occurred in previous years, the high levels recorded in January and July 2007 are likely to be typological errors as WL7 was reported to be dry during that time.

The water level data indicate that the wetlands are subject to seasonal inundation as a result of water table rise caused by rainfall recharge to the Superficial aquifer.

6.2 GROUNDWATER QUALITY

The results of water quality analyses are presented in Appendix III.

6.2.1 Production Bores

Salinity

Monthly salinity monitoring data for the production bores, recorded as TDS (Total Dissolved Solids), are presented in Table 9 and Figure 9.

Salinities in KMB7 ranged between 590 and 700 mg/L TDS over the final year of the review period, slightly greater than the Australian drinking-water guideline aesthetic value of 500 mg/L (NHMRC & ARMCANZ 2004). The lowest salinity of 500 mg/L TDS was recorded in July 2006 (the 140 mg/L TDS reading in January 2006 is likely to be an error) and the highest salinity was recorded in May 2008 (690 mg/L TDS). Higher salinity values generally occur at the end of summer before the seasonal flush of fresher water associated with winter rainfall recharge. An overall trend of slightly increasing salinity is evident particularly towards the end of the three-year review period despite the increased rainfall and the overall reduced extraction in 2008. The data are too few to establish if this is a long-term trend and the values fall within the previous range for the bore.

Bore KMB14 produces lower salinity groundwater than KMB7, varying between 190 (August 2005) and 490 mg/L TDS (October 2006) during the three-year review period, lower than the NHMRC & ARMCANZ (2004) aesthetic guideline value. This range is similar to that experienced at that bore during the years 2000 to 2003. Note that the lower salinities in KMB14 experienced during the intervening years of 2004 to 2006 are similar to the levels recorded in 1997 and correspond to a marked reduction in pumpage from the bore beginning in January 2004. Since 2006 salinities have been slightly higher but still within the previous range of values.

Salinity data recorded as EC (electrical conductivity) at 25ºC are presented in Appendix III. Recorded values for the three-year review period range from 980 µS/cm (November 2005) to 1400 µS/cm (February 2006) in KMB7 (the 290 µS/cm reading in January 2006 is likely to be an error) and from 400 µS/cm (August 2005) to 1040 µS/cm (October 2006) in KMB14. The values for both KMB7 and KMB14 lie within the guideline range of 300 to 1500 µS/cm for slightly disturbed lakes and wetlands (ANZEC 2000).

pH

The monthly pH values recorded for KMB7 and KMB14 indicate the groundwater is slightly acidic to slightly alkaline, ranging from pH 6.2 to 8.2 in the final year of the review and from pH 5.4 to 8.2 over the three-year review period (Table 9). Values for both KMB7 and KMB14 show no long-term trends of change and are within the previous ranges of pH

(Fig. 9). Values recorded from KMB14 indicate it typically produces less acidic than water KMB7 with pH values generally below the Australian guideline value for southwest Australian wetlands (7.0 – 8.5; ANZEC 2000). KMB7 recorded pH values within the guideline's range of 6.5 – 8.0 for freshwater lakes (ANZEC 2000) except for July 2007, when pH was recorded at 8.2, and within the aesthetic range of aesthetic drinking-water guidelines of 6.5 – 8.5 (NHMRC & ARMCANZ 2004).

Table 9: Production Bore Water Quality Data

	KMB7						KMB14					
Month	pH	Salinity (TDS mg/L)	Nitrate (mg/L)	Phosphorus (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	pH	Salinity (TDS mg/L)	Nitrate (mg/L)	Phosphorus (mg/L)	Chloride -	Sulphate -
Jul-05	7.37	600	-	-	-	-	5.96	230	-	-	-	-
Aug-05	7.35	580	-	-	-	-	5.65	190	-	-	-	-
Sep-05	7.56	610	-	-	-	-	5.45	220	-	-	-	-
Oct-05	7.30	600	-	-	-	-	5.40	240	-	-	-	-
Nov-05	7.21	460	-	-	-	-	6.71	330	-	-	-	-
Dec-05	7.62	550	<0.05	0.10	160	83	6.88	310	<0.05	0.05	100	70
Jan-06	7.22	140	-	-	-	-	6.93	340	-	-	-	-
Feb-06	7.66	620	-	-	-	-	7.38	340	-	-	-	-
Mar-06	6.95	630	-	-	-	-	6.11	330	-	-	-	-
Apr-06	6.98	620	-	-	-	-	5.55	280	-	-	-	-
May-06	7.04	550	-	-	-	-	NR	NR	-	-	-	-
Jun-06	7.37	630	-	-	-	-	6.91	430	-	-	-	-
Jul-06	6.98	500	-	-	-	-	5.62	220	-	-	-	-
Aug-06	6.96	510	-	-	-	-	5.45	270	-	-	-	-
Sep-06	7.32	640	-	-	-	-	6.85	390	-	-	-	-
Oct-06	6.94	540	-	-	-	-	7.04	490	-	-	-	-
Nov-06	7.03	620	-	-	-	-	6.26	330	-	-	-	-
Dec-06	7.12	610	-	-	-	-	5.88	280	-	-	-	-
Jan-07	7.80	600	<0.2	0.05	150	110	7.30	370	<0.2	0.1	91	55
Feb-07	6.91	510	-	-	-	-	6.37	280	-	-	-	-
Mar-07	7.01	520	-	-	-	-	6.71	310	-	-	-	-
Apr-07	7.04	640	-	-	-	-	6.69	330	-	-	-	-
May-07	6.70	570	-	-	-	-	6.79	380	-	-	-	-
Jun-07	6.94	680	-	-	-	-	6.51	380	-	-	-	-
Jul-07	8.20	700	<0.2	0.08	-	-	8.10	450	<0.2	0.05	-	-
Aug-07	7.34	590	-	-	-	-	6.94	300	-	-	-	-
Sep-07	7.18	640	-	-	-	-	7.10	320	-	-	-	-
Oct-07	7.22	640	-	-	-	-	6.71	340	-	-	-	-
Nov-07	7.11	630	-	-	-	-	6.62	340	-	-	-	-
Dec-07	7.08	610	-	-	-	-	6.26	310	-	-	-	-
Jan-08	7.90	660	<0.2	0.11	150	110	7.00	310	<0.2	0.05	89	64
Feb-08	7.10	680	-	-	-	-	6.71	400	-	-	-	-
Mar-08	7.20	610	-	-	-	-	6.73	330	-	-	-	-
Apr-08	7.17	680	-	-	-	-	6.76	380	-	-	-	-
May-08	7.37	690	-	-	-	-	6.63	360	-	-	-	-
Jun-08	7.42	680	-	-	-	-	6.20	310	-	-	-	-

NR = Data not recored

Nutrients

Nitrate and phosphorus concentrations were measured four times in both production bores during the three-year review period (Table 9, Fig. 10). Nitrate levels remained below the analytical detection limit of 0.2 mg/L, similar to results obtained from previous reviews. Phosphorus levels ranged between the detection limit of 0.05 mg/L and 0.11 mg/L. The highest phosphorus level (0.11 mg/L) was recorded in KMB7 in January 2008, which is above the trigger value of 0.06 mg/L for slightly disturbed wetlands (ANZEC 2000) but within the historical range of 0.05 to 1 mg/L.

Chloride

Chloride concentrations were recored in both production bores in January 2008, January 2007 and December 2005 (Table 9) and the values are below the aesthetic drinking-water guideline of 250 mg/L (NHMRC & ARMCANZ 2004) and within the historical ranges. KMB7 had concentrations of 150 mg/L (January 2007 and 2008) to 160 mg/L (December 2005) and KMB14 had concentrations ranging from 91 mg/L (January 2007) to 100 mg/L (December 2005).

Sulphate

Sulphate concentrations were measured in January 2008, January 2007 and December 2005 (Table 9). Bore KMB7 had a concentrations ranging from 83 mg/L (December 2005) to 110 mg/L (January 2007 and 2008) and bore KMB14 had concentrations of 55 mg/L (January 2007) to 70 mg/L (December 2005), lower than health and aesthetic drinking-water guideline values of 500 and 250 mg/L respectively (NHMRC & ARMCANZ 2004). The sulphate concentrations for KMB7 lie within the range of previous years and concentrations for KMB14 show a slight increase.

6.2.2 Monitoring Bores

Salinity

Monthly salinity data were collected over the review period from KMB1, KMB2, KMB4, KMB6, KMB8, KMB10, KMB11, KMB12 and KMB13 (Table 10, Fig. 11 and Fig. 12). Salinities ranged between 50 mg/L TDS (KMB11 in December 2005) and 670 mg/L TDS (KMB4 in February 2006 and KMB12 in May 2007), but for the most part were between 150 and 600 mg/L TDS (KMB6 in January 2007 appears erroneous when compared to EC values). The values are generally below the drinking-water guideline of 500 mg/L TDS (NHMRC & ARMCANZ 2004).

Salinity data recorded as EC at 25ºC ranged between 110 µS/cm (KMB11 in December 2005) and 1370 µS/cm (KMB4 in February 2006). The values are presented in Appendix III and typically fall within the guideline range for slightly disturbed lakes and wetlands (300 to 1500 µS/cm; ANZEC 2000).

Lower salinities typically occur during winter and spring and are likely to be the result of local rainfall recharge of the superficial aquifer. Additional fluctuations that do occur do not appear to be seasonally related. Overall trends of change are not apparent over the review period.

Table 10: Groundwater Analyses from Monitoring Bores for Selected Months of the Current Review Period.
(Results for all months July 2005 – June 2008 are in Appendix III.)

Bore	Date	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Soluble Iron	Total Phosphorus
Units			µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
KMB1	01-Jul-05	4.70	-	190	100	71	-	0.57	-
	01-Jan-06	3.70	-	300	82	130	-	0.73	-
KMB2	01-Jul-05	6.00	-	130	-	-	-	-	-
	01-Jan-06	5.40	-	140	-	-	-	-	-
KMB4	01-Jul-05	7.00	1060	550	-	-	-	-	-
	01-Jan-06	7.30	1000	510	210	<10	-	-	-
KMB6	01-Jul-05	4.50	310	160	-	-	-	-	-
	01-Jan-06	4.10	310	140	-	-		-	-
KMB8	01-Jul-05	6.00	800	380	-	-	-	-	-
	01-Jan-06	6.00	920	470	-	-	-	-	-
KMB10	01-Jul-05	3.70	460	180	-	-	-	-	-
	01-Jan-06	3.70	290	140	-	-	-	-	-
KMB11	01-Jul-05	6.00	420	210	-	-	-	-	-
	01-Jan-06	5.20	140	60	-	-	-	-	-
KMB12	01-Jul-05	7.50	870	440	-	-		-	-
	01-Jan-06	7.30	930	470	-	-	-	-	-
KMB13	01-Jul-05	5.90	330	160	-	-	-	-	-
	01-Jan-06	5.60	370	180	-	-	-	-	-
KMB1	01-Jul-06	4.68	-	190	100	71	-	0.57	-
	01-Jan-07	3.70	-	300	82	130	-	0.73	-
KMB2	01-Jul-06	5.81	-	100	55	7	-	-	<0.05
	01-Jan-07	5.50	-	280	69	3	-	-	<0.05
KMB4	01-Jul-06	7.17	1010	460	180	29	2.1	0.11	<0.05
	01-Jan-07	7.60	1000	520	190	45	-	0.13	-
KMB6	01-Jul-06	4.87	630	310	-	-	-	-	-
	01-Jan-07	3.10	740	840	-	-	-	0.67	-
KMB8	01-Jul-06	6.32	810	400	230	9	-	2.1	<0.05
	01-Jan-07	7.20	1000	600	180	76	<0.05	-	-
KMB10	01-Jul-06	5.10	190	70	-	9	-	0.19	<0.05
	01-Jan-07	3.40	450	310	-	<10	<0.2	-	<0.05
KMB11	01-Jul-06	5.85	340	160	-	-	-	-	-
	01-Jan-07	5.50	450	310	-	-	-	-	-
KMB12	01-Jul-06	6.00	300	130	-	-	-	-	-
	01-Jan-07	7.80	840	500	120	5	2.6	-	0.05
KMB13	01-Jul-06	6.00	300	130	-	-	-	-	-
	01-Jan-07	5.90	330	170	82	9	<0.2	-	0.05
KMB1	01-Jul-07	4.70	-	320	130	83			
	01-Jan-08	5.80	-	250	120	160	-	0.85	-
KMB2	01-Jul-07	6.30	-	220	120	51	-	-	<0.05
	01-Jan-08	6.50	-	250	78	4	-	-	<0.05
KMB4	01-Jul-07	8.30	-	680	180	47	2.1	0.1	0.5
	01-Jan-08	7.90	-	530	180	61			
KMB6	01-Jul-07	3.90	380	310	-	-	-	-	-
	01-Jan-08	3.80	410	350	-	-	-	-	-
KMB8	01-Jul-07	7.20	1180	640	230	-	-	-	-
	01-Jan-08	7.10	1000	540	210	53	-	3.6	<0.05
KMB10	01-Jul-07	4.30	-	210	-	52	-	0.45	<0.05
	01-Jan-08	3.80	360	240	-	66	-	-	<0.05
KMB11	01-Jul-07	6.70	430	350	-	-	-	-	-
	01-Jan-08	6.10	430	290	-	-	-	-	-
KMB12	01-Jul-07	8.40	850	530	110	4	-	-	-
	01-Jan-08	7.90	820	440	120	5	-	-	0.09
KMB13	01-Jul-07	7.10	310	200	81	6	-	-	<0.05
	01-Jan-08	6.40	280	130	66	6	-	-	<0.05

pH

Groundwater in the monitoring bores was acidic to slightly alkaline during the review period (Table 10 and Appendix III), with pH values ranging from 3.2 (KMB6 in December 2007) to 8.6 (KMB4 in October 2005).

KMB1, KMB2, KMB6, KMB8, KMB10, KMB11 and KMB13 recorded pH values below the Australian guideline range for freshwater lakes and wetlands (6.5 – 8.0) (ANZECC & ARMCANZ 2000). These comparatively low values are likely to be a result of the oxidation of sulphide minerals associated with previous wetting and drying of organic matter in wetland deposits. This is unlikely to be associated with pumping from the borefield as the pumping would have had only marginal effects on water table levels at these sites when compared to changes associated with rainfall variations. It is more likely a result of the comparatively low water table levels associated with low rainfall over recent years.

The pH in KMB4 and KMB12 during the review period was neutral to slightly alkaline with values ranging from 6.8 to 8.4. Historically KMB4 experienced numerous relatively high pH values (above 8.5) from the commencement of monitoring at this bore in 2001 until January 2004. These values are above the standard range for groundwater from the Superficial aquifer in the area. Since April 2004 the values have been approximately neutral. KSS has previously investigated potential mining-related causes of high pH values at KMB4 and inspected the area around the bore site, but has found no reasonable explanation (Rockwater, 2006).

Other Analytes

A suite of other analytes was tested during the review period including total phosphorus, chloride, sulphate and soluble iron (Table 10 and Appendix III). The data are generally consistent with past results. Total phosphorous concentrations continue to be below 0.05 mg/L which is below the trigger value of 0.06 mg/L for slightly disturbed wetlands (ANZEC 2000) and all chloride concentrations were below drinking-water guideline values (NHMRC & ARMCANZ 2004).

Sulphate concentrations were measured in bores KMB1, KMB2, KMB4, KMB8 and KMB10 and ranged from 3 mg/L (KMB2 in January 2007) to 250 mg/L (KMB1 in December 2005). KMB1, KMB2, KMB4, and KMB10 recorded increased concentrations in 2007 compared to 2006; however all concentrations are below health and aesthetic drinking-water guideline values (NHMRC & ARMCANZ 2004). KMB4 had sulphate concentrations during the review period above the previous historical range, suggesting and increasing trend of concentrations at this site.

Variable soluble iron concentrations of 0.15 to 130 mg/L have historically been recorded in KMB8, however more stable concentrations of less than 3.9 mg/L have been recorded since 2006.

Data available from the current review period fall within ranges that could be expected for groundwater in the Superficial aquifer in the area (Deeney, 1989), suggesting that the changes in analyte concentrations are not likely to have been caused by the mining activities. While values recorded are consistent with past results they are also quite variable making it difficult to recognise any definite trends of change.

6.2.3 Dredge Pond

Salinity

Salinity in the dredge pond ranged between 540 and 700 mg/L TDS in 2007/2008, averaging about 620 mg/L TDS, about 40 mg/L above the average for the previous two years of the review period, indicating a trend of increasing salinity (Fig. 13 and Appendix II) .

pH

The pH of the dredge pond was slightly acidic over the review period, with extremes of pH 5.1 in April 2006 and pH 7.1 in December 2005. The results are within the historical range of data for the dredge pond (Fig. 13 and Appendix II).

6.2.4 Wetlands

Salinity and pH data are available only for WL7. WL3, WL4 and WL6 were dry during several of the scheduled sampling events. WL7 recorded a pH of 7.6 and TDS of 2900 mg/L in January 2008 (Appendix III). The pH value of WL7 falls within the range of Australian guideline values for wetlands (ANZECC & ARMCANZ 2000), but is slightly above previously recorded wetland values, which ranged from slightly acidic to neutral (for example pH 5.1 in WL3 in December 2005 and pH 7.1 in WL7 in December 2005).

The data from previous years suggest that higher wetland salinity generally results when water depths are shallow and evaporation is comparatively high, prior to the seasonal drying out of the wetland.

No other analytes were analysed from the wetland water samples during the review period.

7 SUMMARY AND CONCLUSIONS

Borefield extraction by Kemerton Silica Sand Pty Ltd for processing during the period, 1 July 2005 to 30 June 2008, totalled 872,772 kL; comprising 310,290 kL in 2005/2006, 228,258 kL in 2006/2007 and 224,224 kL in 2007/2998. The volume pumped in the final year of the review was 34% the annual water entitlement under new GWL60367(3), and is a reduction in water usage of over 114,000 kL since the previous year. Initiatives introduced by KSS in early 2003 to improve water efficiency in the processing circuit have resulted in more water being recycled and less being discharged to waste, with the pumpage from the borefield being more than halved since then. Total monthly extraction over the review period ranged between 3,314 kL in April 2008 to 40,309 kL in September 2007. Throughout the review KMB14 was used only as secondary bore and typically provided less than 25% of the water supply. KMB7 was the primary water source during the review period, typically providing more than 75% of the total water source.

Rest water levels in production bores KMB7 and KMB14 were 13.1 to 14.9 m AHD, about 0.9 to 3.8 m below ground surface. Pumping-induced drawdowns up to 14.5 m below the rest levels were measured during the review period in KMB7 and up to 12.7 m in KMB14. The trend of declining pumping water levels (increasing drawdown) in KMB14 from mid-2001 to mid-2003 probably reflected decreasing bore efficiency. Pumping water levels in KMB7 are less than 1.5 m to the top to the screen, which may indicate cleaning and redevelopment of the bore, pump and screen are required to maintain bore efficiency.

Apart from seasonal fluctuations, hydrographs from the monitoring bores are stable and show trends similar to those in the previous review period. Maximum water levels in the final year of the review were recorded in October 2007, following groundwater recharge from the winter rains, and were above average in July 2007, following high rainfall in April 2007. Water levels in 2006 were typically below average reflecting the below-average rainfall for that year.

Water levels in the wetlands indicate seasonal inundation occurs after winter recharge to the Superficial aquifer. Water levels over the review period remained fairly constant. The wetlands are often dry or nearly dry limiting scheduled sampling for water analyses.

Groundwater from the production bores is fresh to slightly brackish, ranging between 300 and 700 mg/L TDS, and has acidic to slightly alkaline pH (pH of 5.4 to 8.2). These results are similar to those from previous review periods. Low concentrations of nitrate, total phosphorus, chloride and sulphate, within historical ranges, were measured.

Water quality data from the monitoring bores showed salinity varied from 70 to 840 mg/L TDS, with typical values between 150 and 600 mg/L TDS. Groundwater pH in all bores was acidic to slightly alkaline, ranging between pH 3.2 and 8.6. Acidic groundwater pH values recorded for some bores may be a result of oxidation of sulphides and organic material in wetland deposits, affecting down-gradient water quality. High pH values have been recorded previously for KMB4 (2001 – 2004), but the pH recorded throughout the current review period was neutral. KSS has previously investigated potential causes for these high values and found no evidence to suggest they were influence by their operations. Chemical analyses of groundwater from the monitoring bores for various other analytes during the review period revealed no anomalous results.

The monitoring programme carried out from June 2005 to July 2007 complied with and exceeded the conditions of GWL 60367(2); however, this licence was replaced by GWL 60367(3) in August 2007 and the monitoring programme was not amended to fulfil the new licence conditions. This was an unintentional error and does not reflect the usual practices of KSS, which in the past have conducted the monitoring programme to a high standard and compliance. Amendments to the monitoring programme were implemented immediately following KSS becoming aware of the additional requirements of GWL 60367(3).

Monitoring data indicate that groundwater extraction from KMB7 and KMB14 appears to have minimal impact upon regional groundwater levels and quality.

Dated: 15 September 2008 **Rockwater Pty Ltd**

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REFERENCES

ALLEN, A.D., 1976. Outline of the Hydrogeology of the superficial formations of the Swan Coastal Plain: Western Australia Geological Survey Annual Report for 1975, p. 31 – 42.

ANZECC & ARMCANZ (Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand), 2000. Australian and New Zealand guidelines for fresh and marine water quality. Volume 2, Aquatic ecosystems.

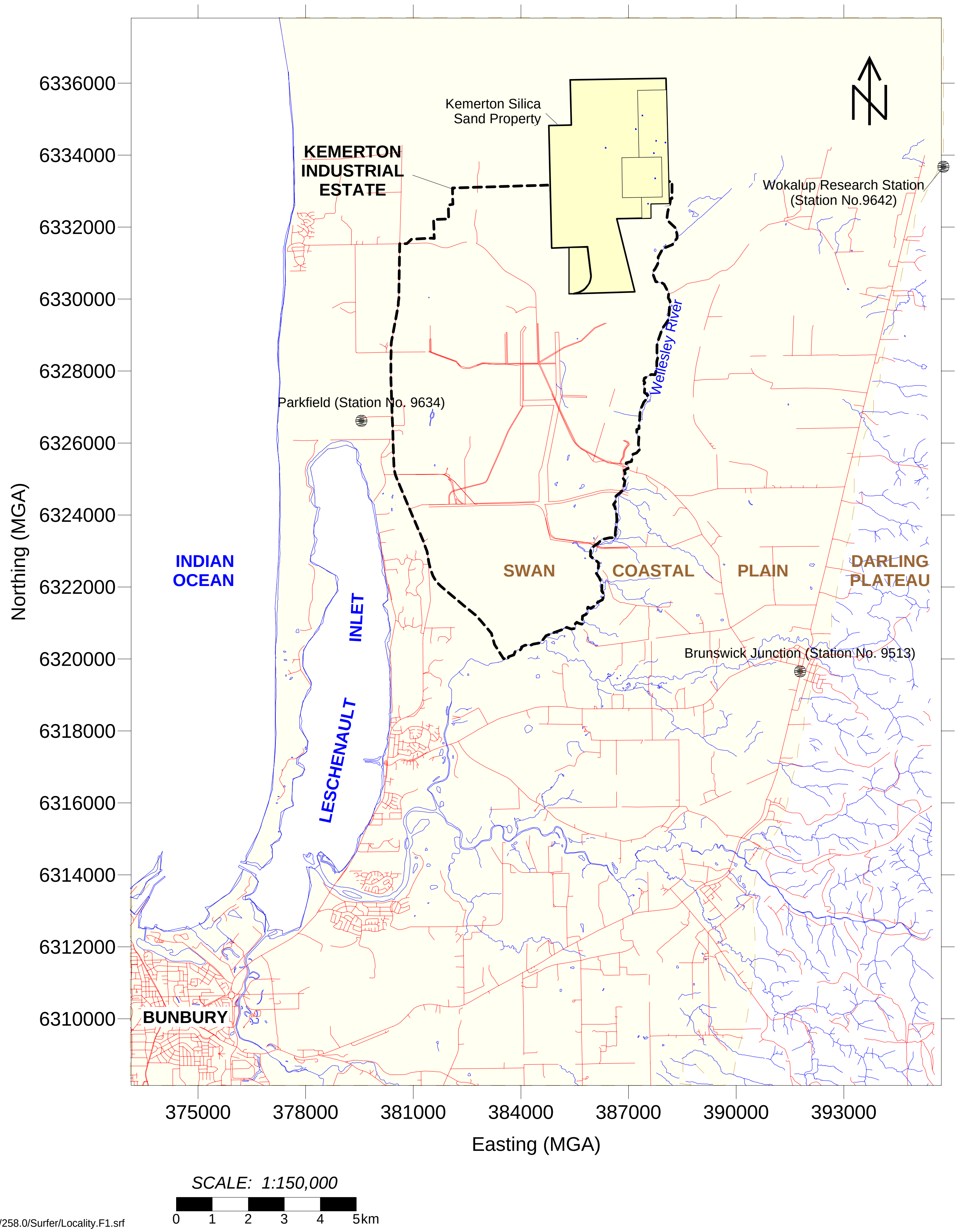
DEENEY, A.C., 1989. Geology and groundwater resources of the superficial formations between Pinjarra and Bunbury, Perth Basin: Western Australia Geological Survey, Report 26, Professional Papers, p. 31-57.

NHMRC & ARMCANZ (National Health and Medical Research Council, Agriculture and Resource Management Council of Australia and New Zealand), 2004. Australian Drinking Water Guidelines: National Water Quality Management Strategy Publication 6, Commonwealth of Australia.

ROCKWATER, 2006. Kemerton Silica Sand Pty Ltd. Groundwater Monitoring Review for July 2006 to June 2007 (GWL No. 60367(2)): Report for Kemerton Silica Sand Pty Ltd (unpublished).

FIGURES

Figure 1



I:/258.0/Surfer/Locality.F1.srf

CLIENT: Kemerton Silica Sand Pty Ltd

PROJECT: Groundwater Monitoring Review

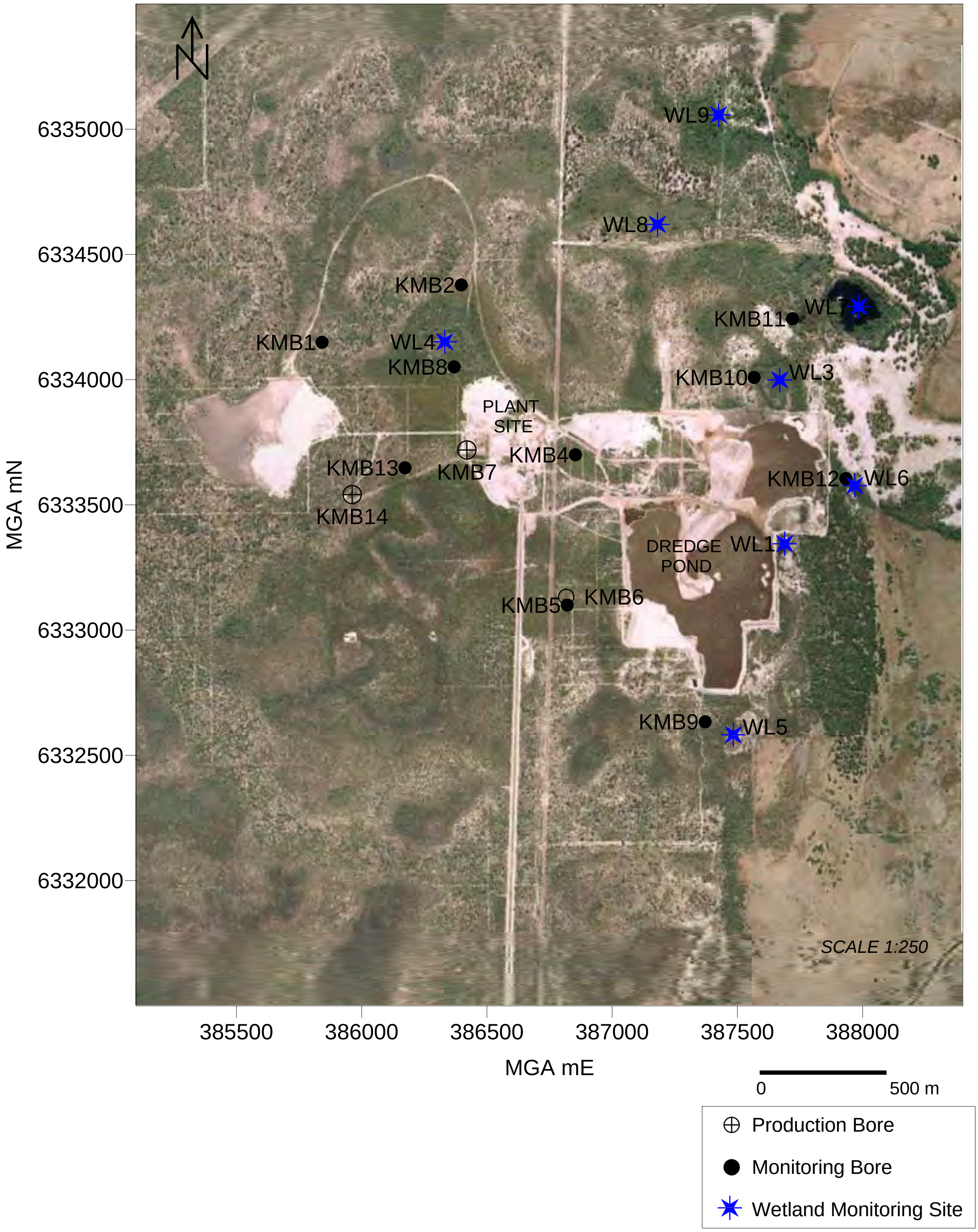
DATE: September 2008

Dwg No: 258.0/08/1-1

LOCALITY MAP

Rockwater Pty Ltd

Figure 2



I:/258.0/Surfer/Monitoring Locations.F2.srf

Image provided by Kemerton Silica Sand P/L 2008

CLIENT:	Kemerton Silica Sand Pty Ltd
PROJECT:	Groundwater Monitoring Review
DATE:	September 2008
Dwg No:	258.0/08/1-2

GROUNDWATER MONITORING LOCATIONS

Rockwater Pty Ltd

Client: Kemerton Silica Sand P/L

Project: Groundwater Monitoring Review

Date: September 2008

Dwg. No: 258.0/08/1-3

I: 258-0 Figures All Rainfall.grf

RAINFALL and EVAPORATION

Kemerton Mine Site, Parkfield and Wokalup

Rockwater Pty Ltd

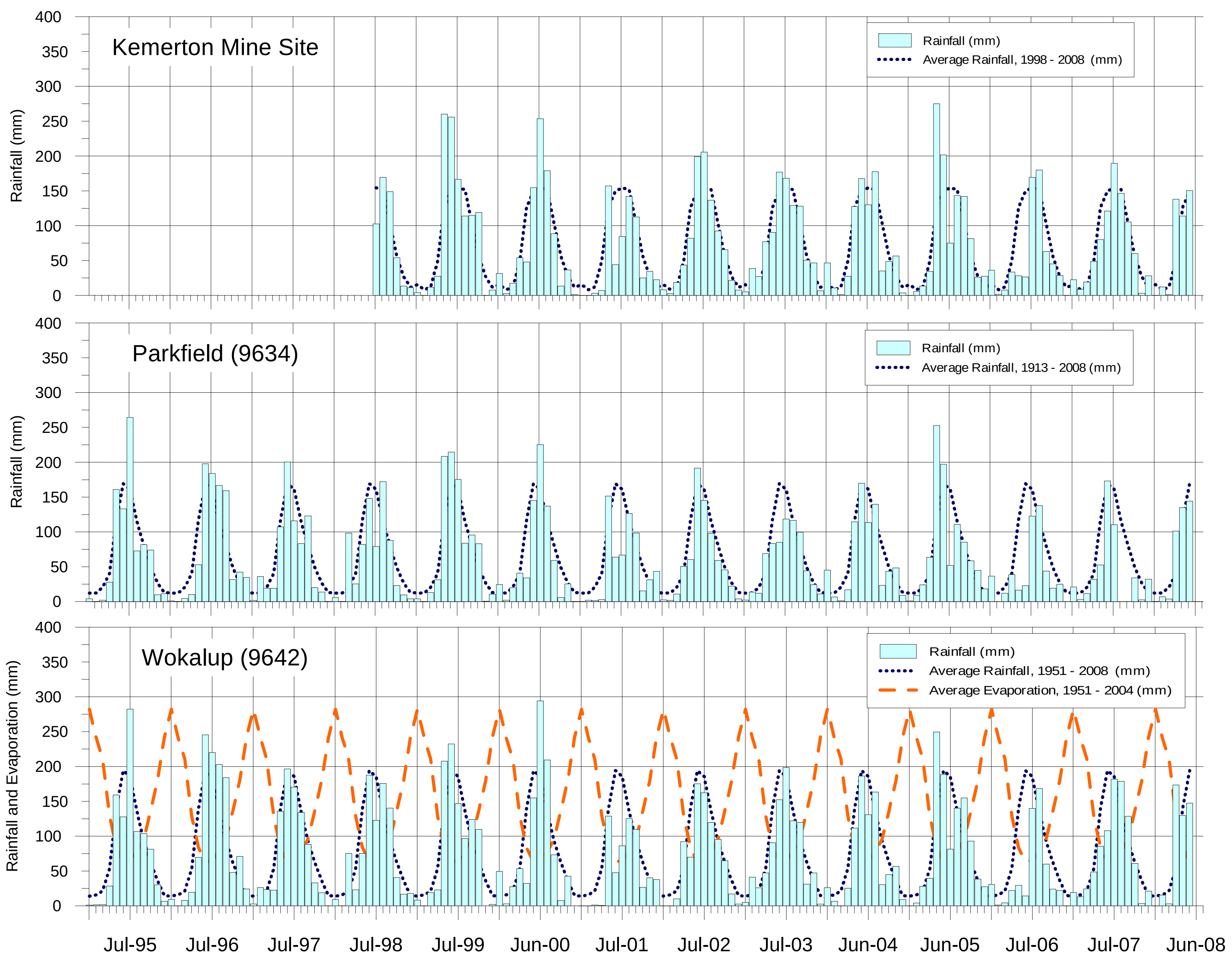
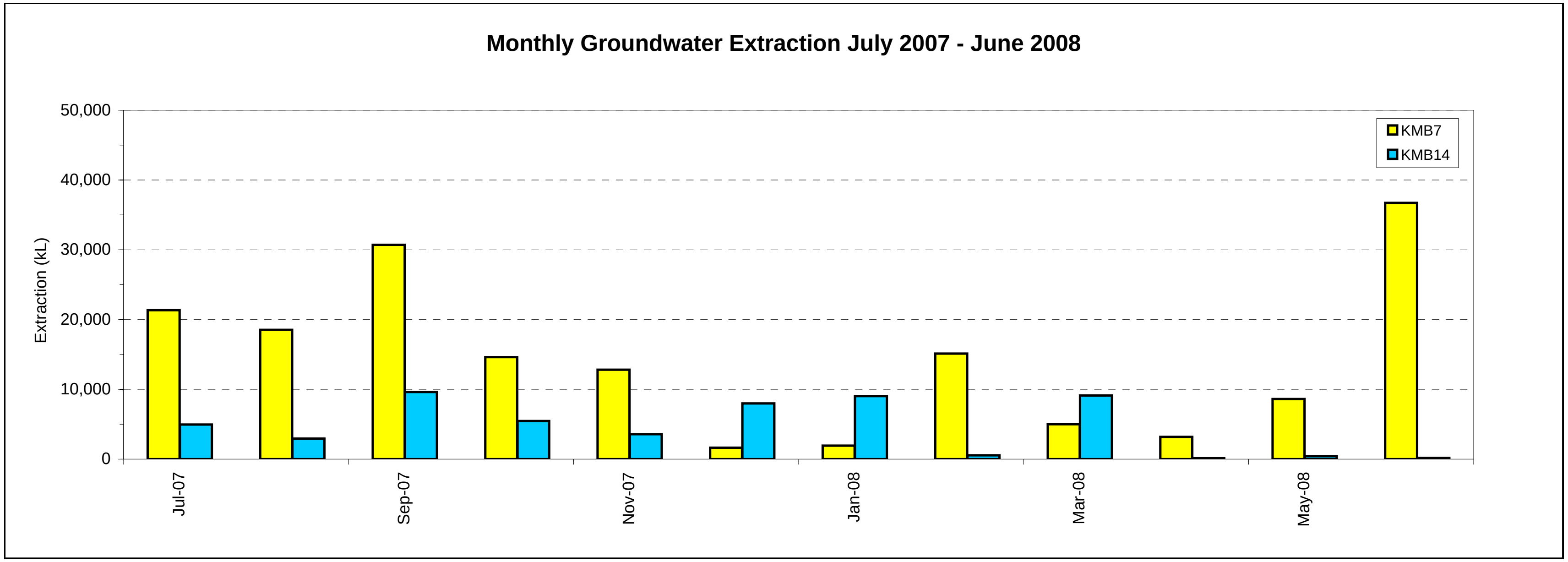
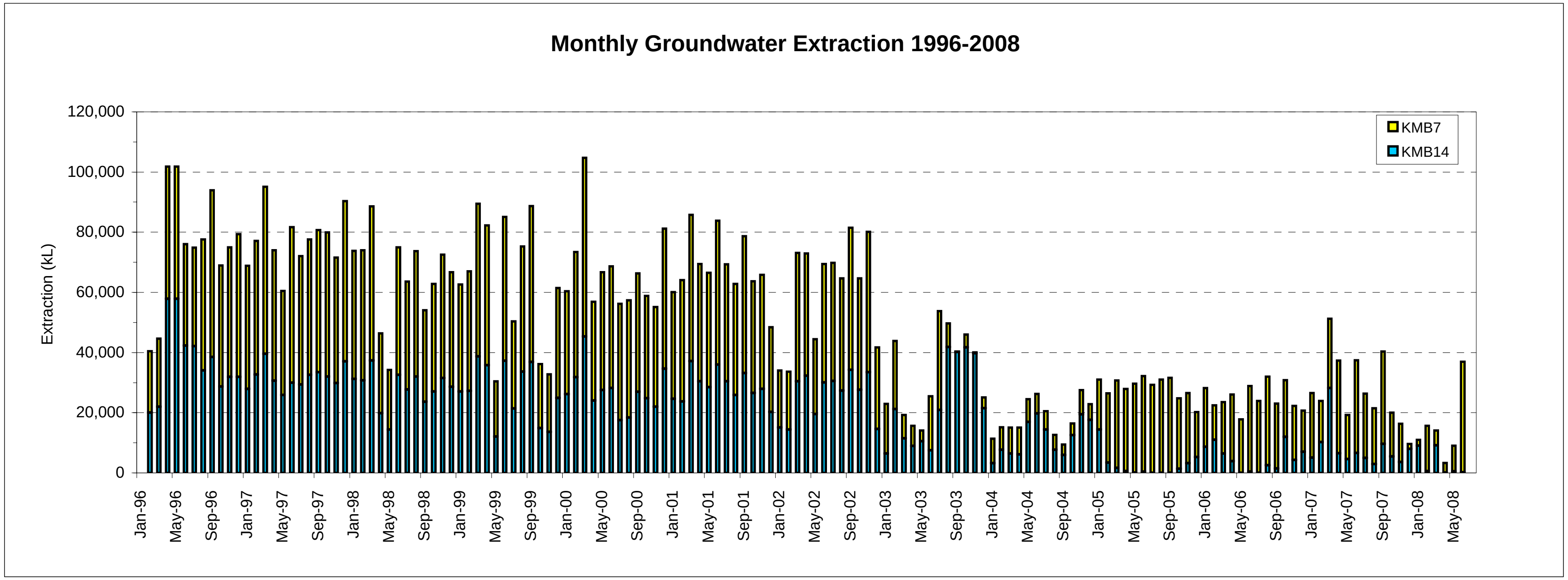


Figure 3





Job number 258.0/08/01
Ref Monitoring Data2008.xls
By CK Sep-2008
Revision 0 Sep-2008

Groundwater Extraction

Rockwater Pty Ltd

Kemerton Silica Sand Pty Ltd
Groundwater Monitoring Review
2007/2008 GWL 60367(2&3)

Figure 4

Job number	258.0/08/01
Ref	Monitoring Data2008.xls
By	CK
	Sep-2008
Revision	0
	Sep-2008

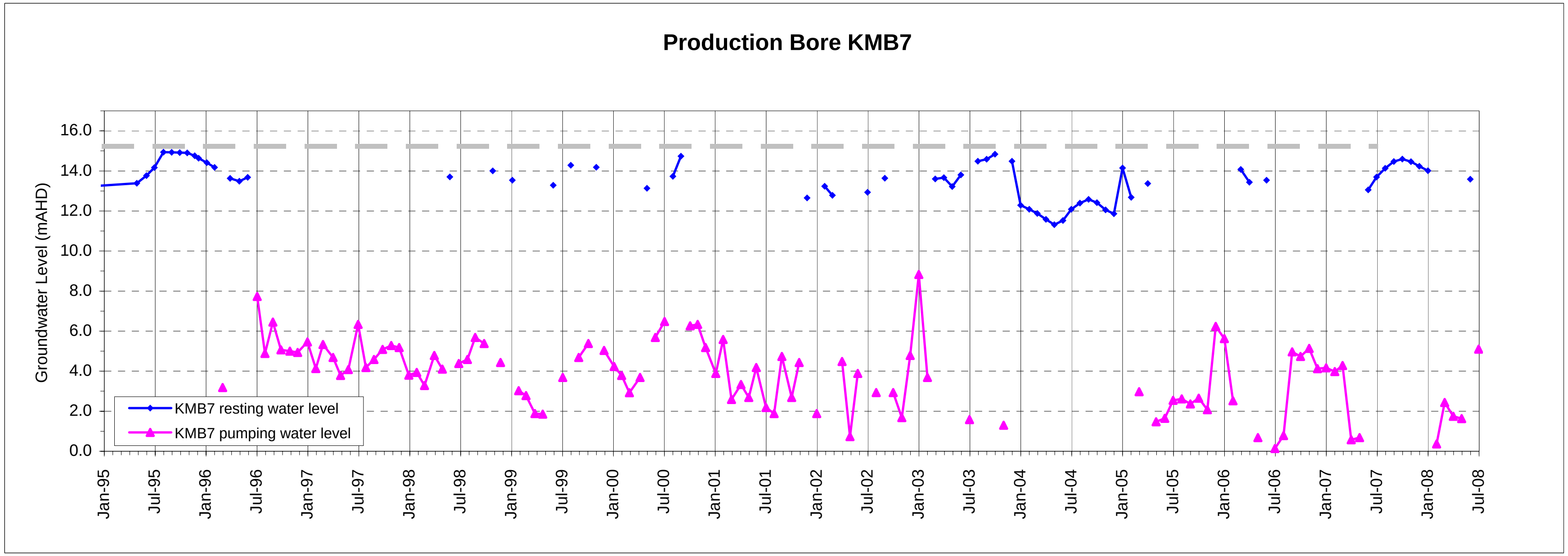
Hydrographs for Production Bores KMB7 and KMB14

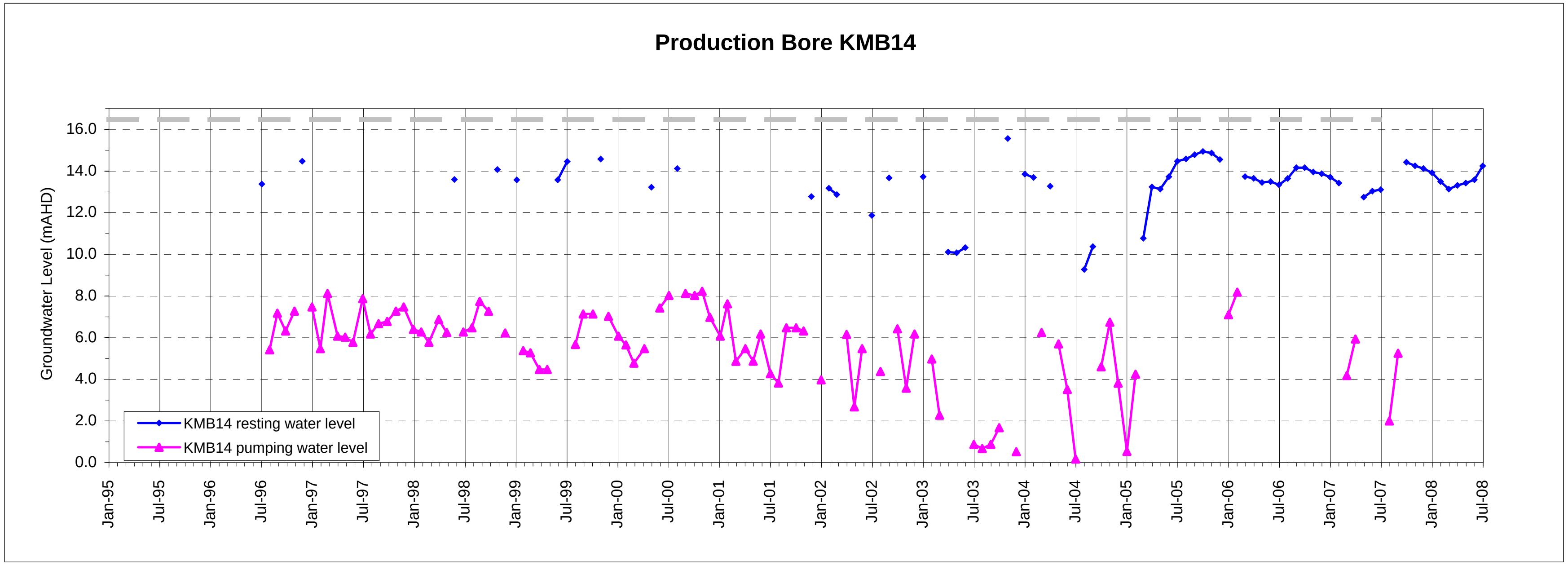
Rockwater Pty Ltd

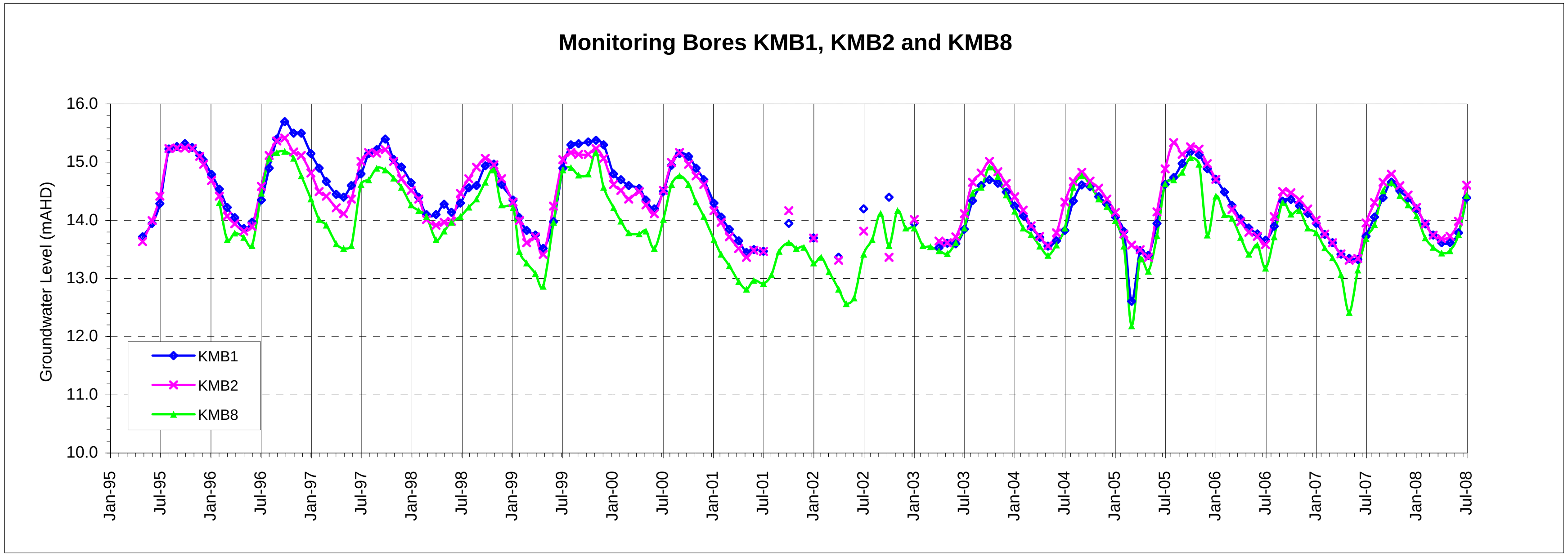
Kemerton Silica Sand Pty Ltd

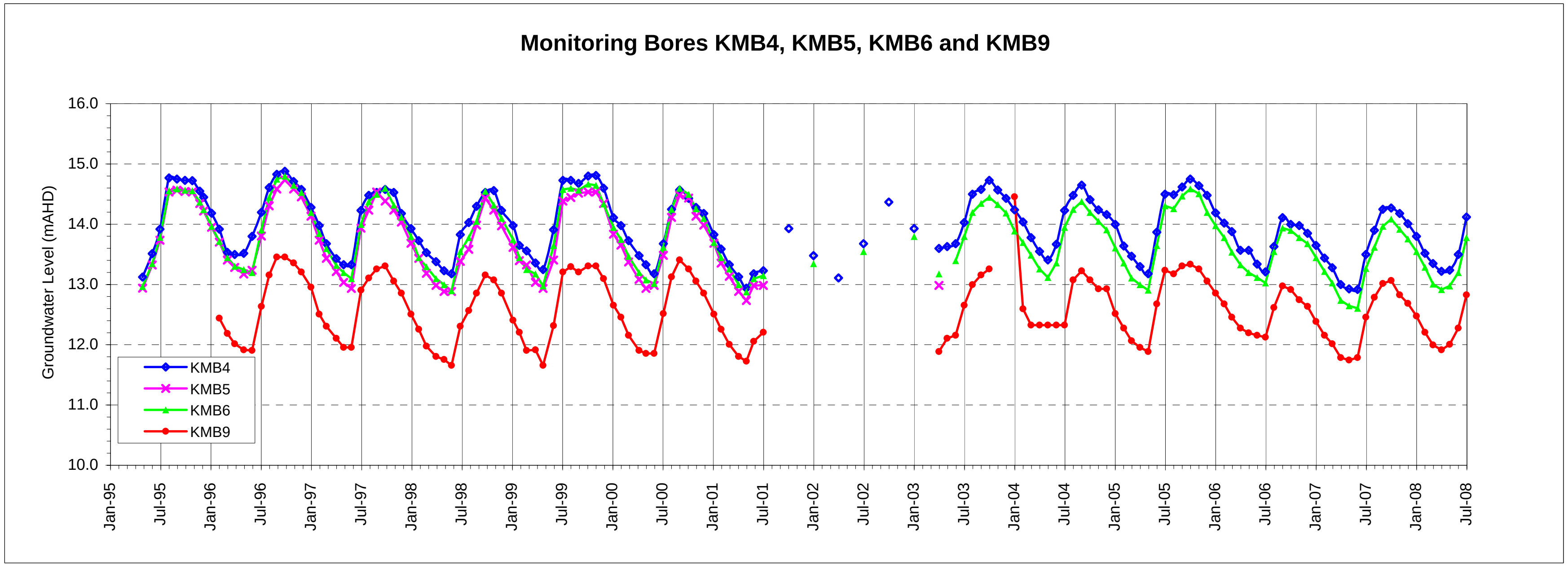
Groundwater Monitoring Review 2007/2008 GWL 60367(2&3)

Figure 5









Job number	258.0/08/01	
Ref	Monitoring Data2008.xls	
By	CK	Sep-2008
Revision	0	Sep-2008

Hydrographs for Monitoring Bores KMB1, KMB2 and KMB8: KMB4, KMB5, KMB6 and KMB9

Rockwater Pty Ltd

Kemerton Silica Sand Pty Ltd

Groundwater Monitoring Review

2007/2008 GWL 60367(2&3)

Figure 6

Job number	258.0/08/01
Ref	Monitoring Data2008.xls
By	CK
	Sep-2008
Revision	0
	Sep-2008

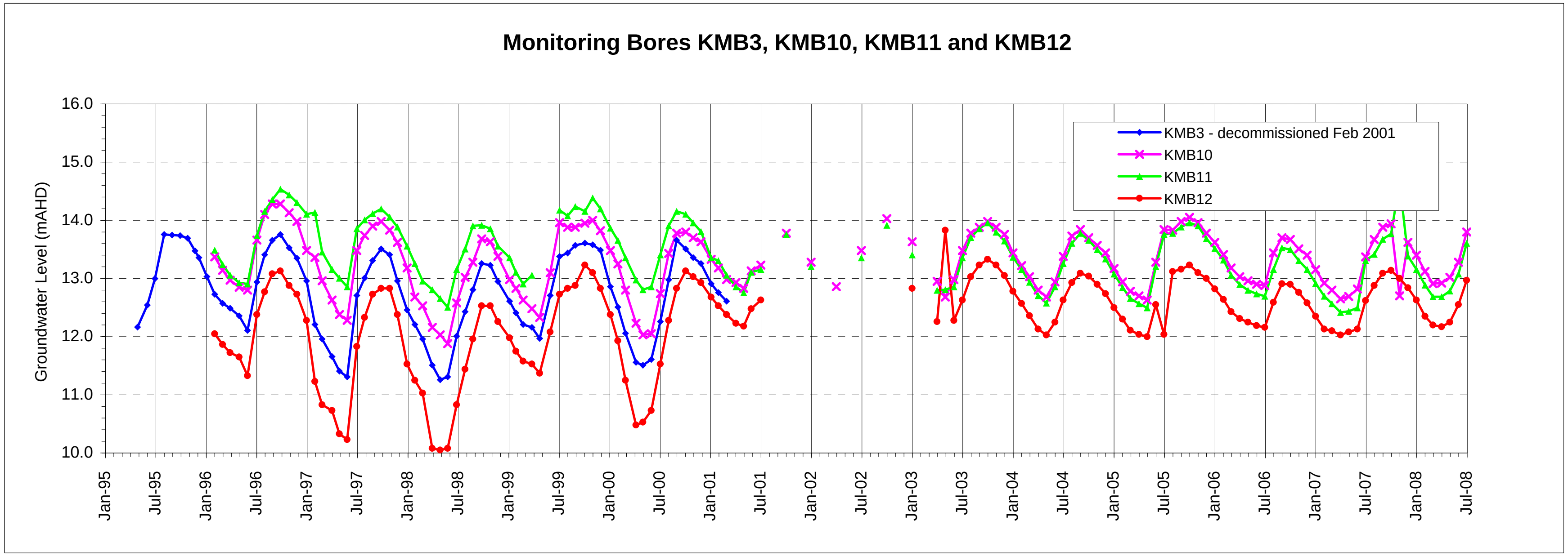
Hydrographs for Monitoring Bores KMB3, KMB10, KMB11, KMB12 and KMB13

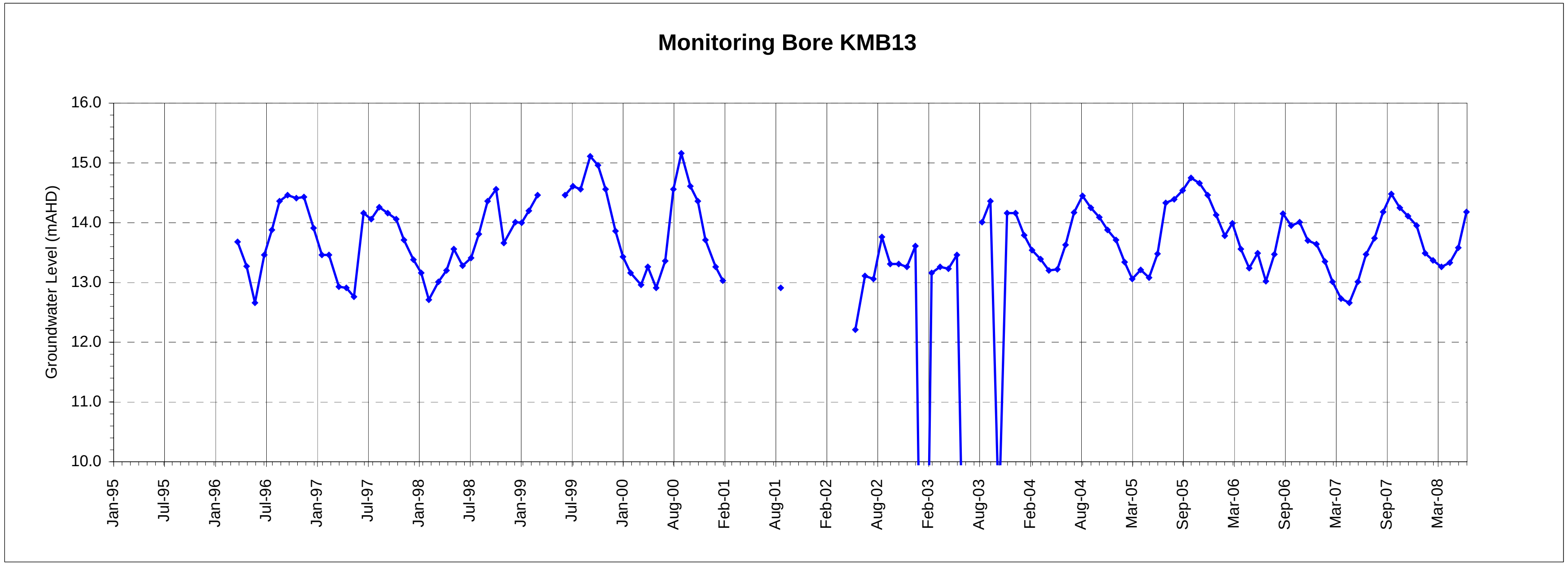
Rockwater Pty Ltd

Kemerton Silica Sand Pty Ltd

Groundwater Monitoring Review 2007/2008 GWL 60367(2&3)

Figure 7





Job number 258.0/08/01

Ref Monitoring Data2008.xls

By CK Sep-2008

Revision 0 Sep-2008

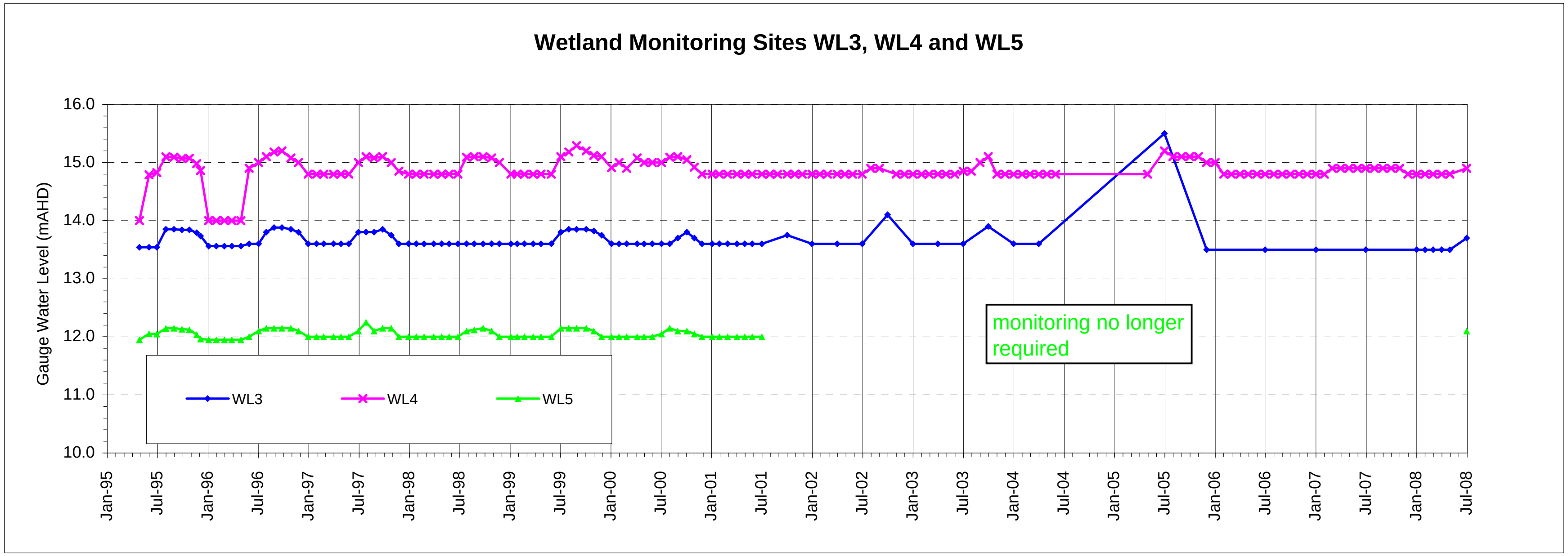
Hydrographs for Wetland Monitoring Sites WL3 to WL7

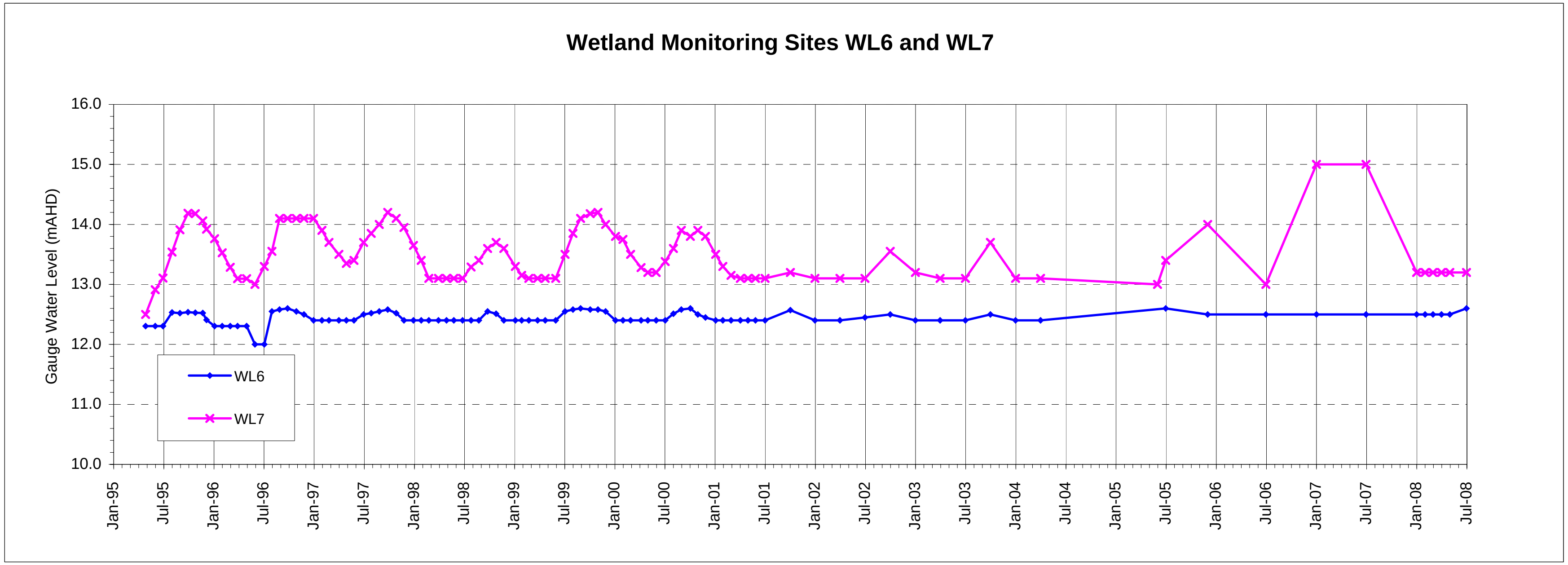
Rockwater Pty Ltd

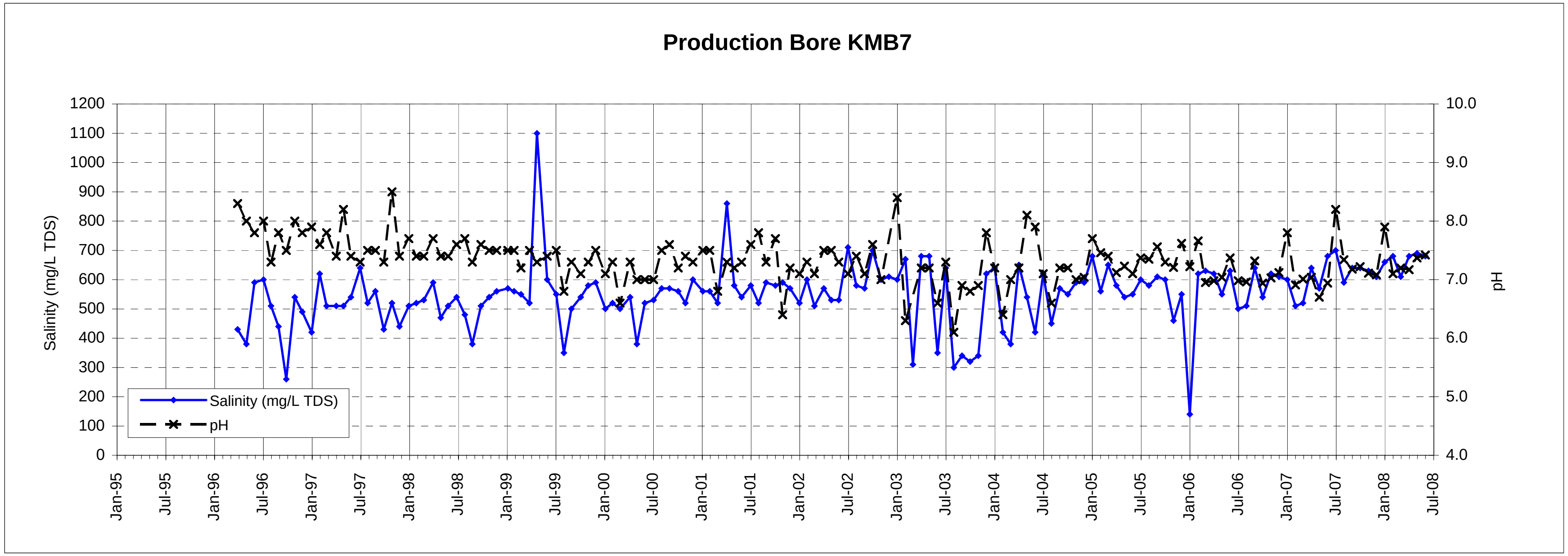
Kemerton Silica Sand Pty Ltd

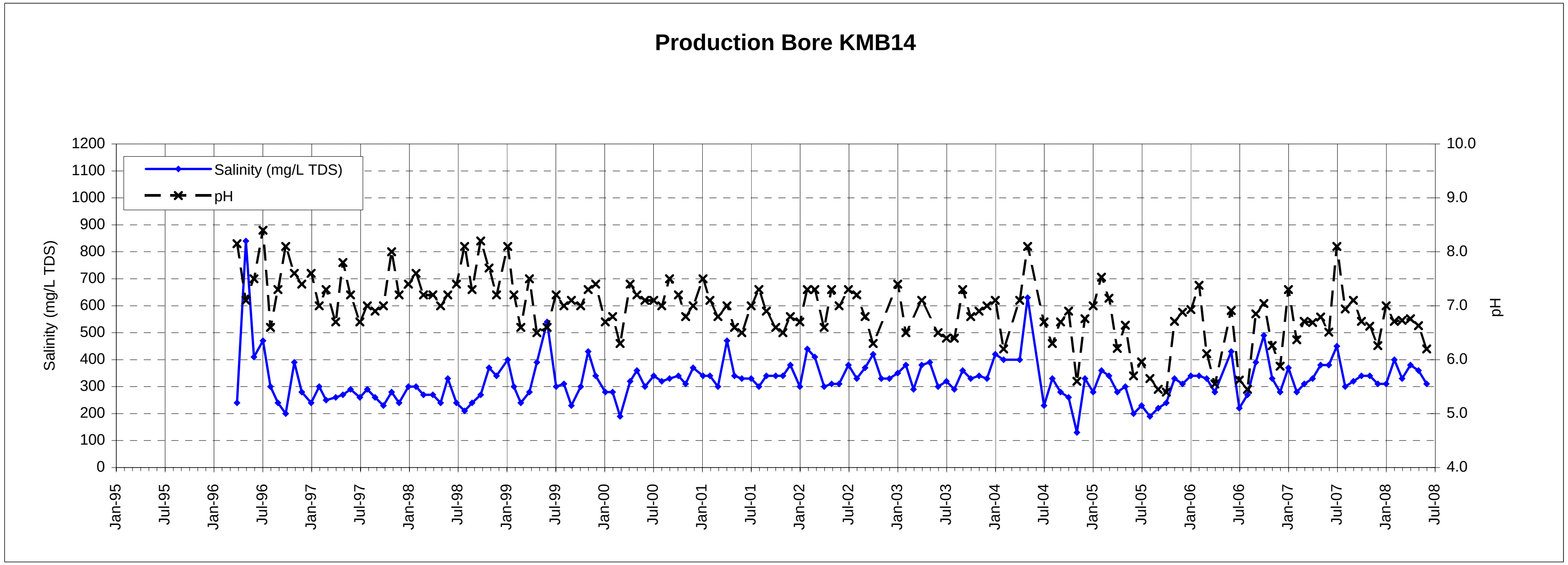
Groundwater Monitoring Review 2007/2008 GWL 60367(2&3)

Figure 8









Job number	258.0/08/01
Ref	Monitoring Data2008.xls
By CK	Sep-2008
Revision 0	Sep-2008

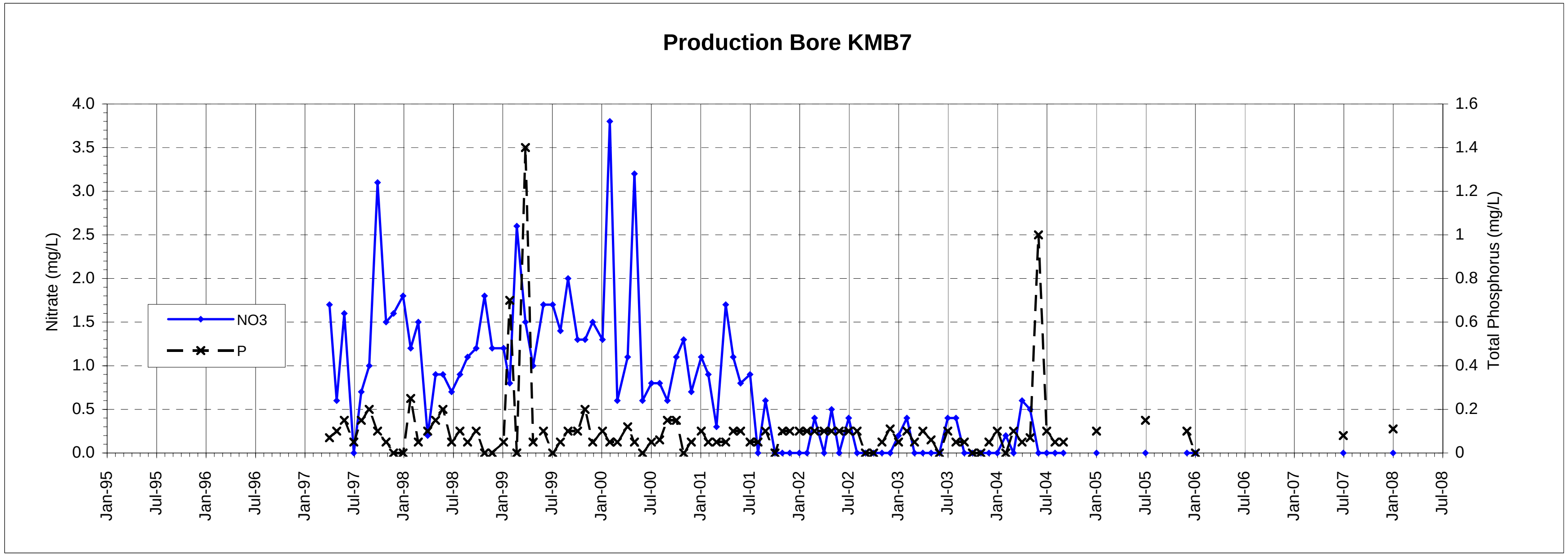
Salinity an pH in Production Bores

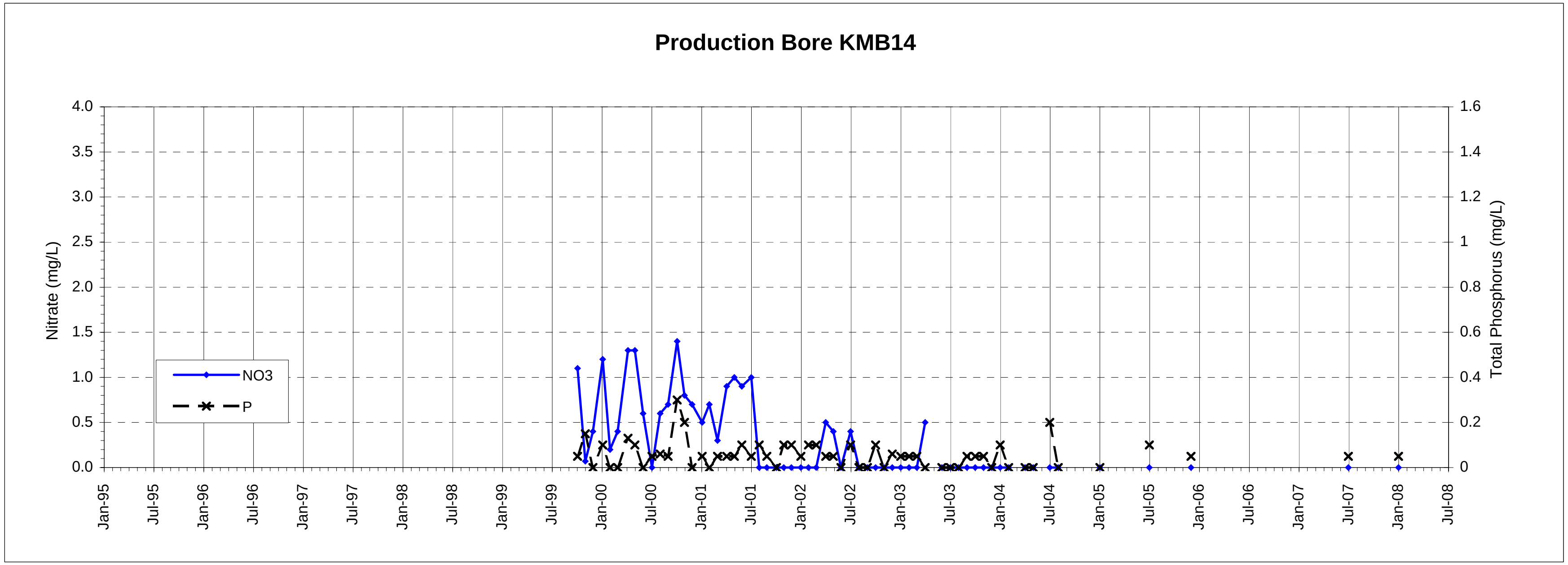
Rockwater Pty Ltd

Kemerton Silica Sand Pty Ltd

Groundwater Monitoring Review 2007/2008 GWL 60367(2&3)

Figure 9





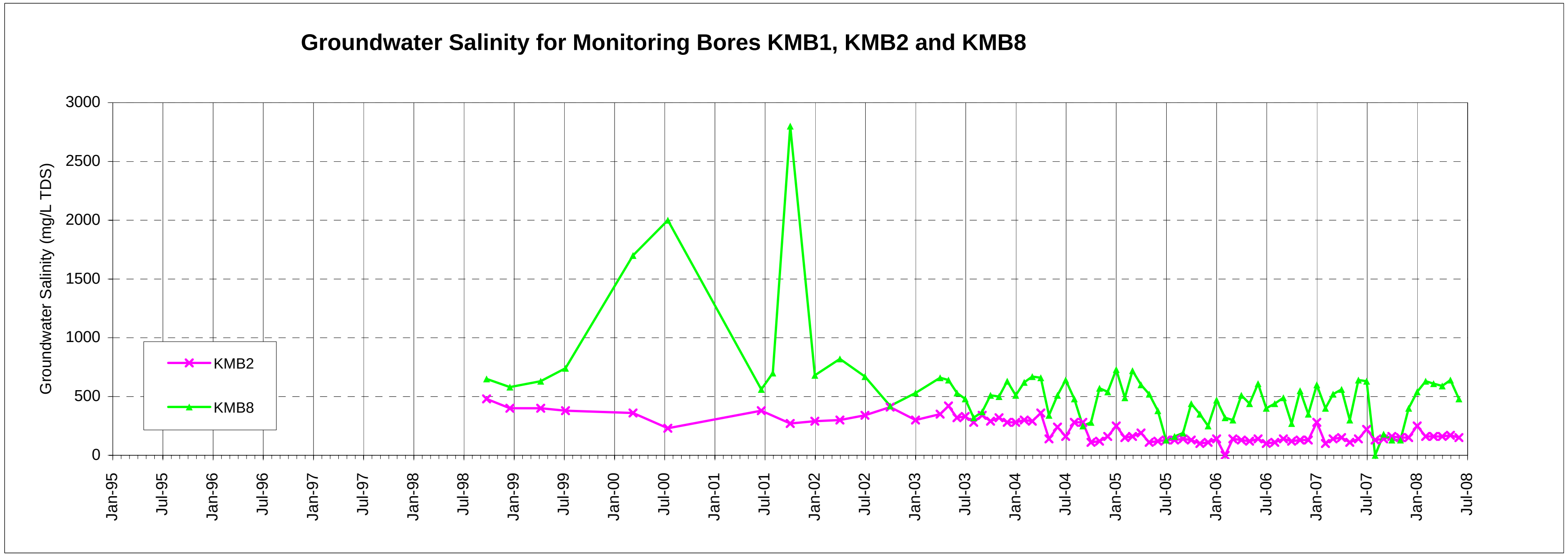
Job number	258.0/08/01	
Ref	Monitoring Data2008.xls	
By	CK	Sep-2008
Revision	0	Sep-2008

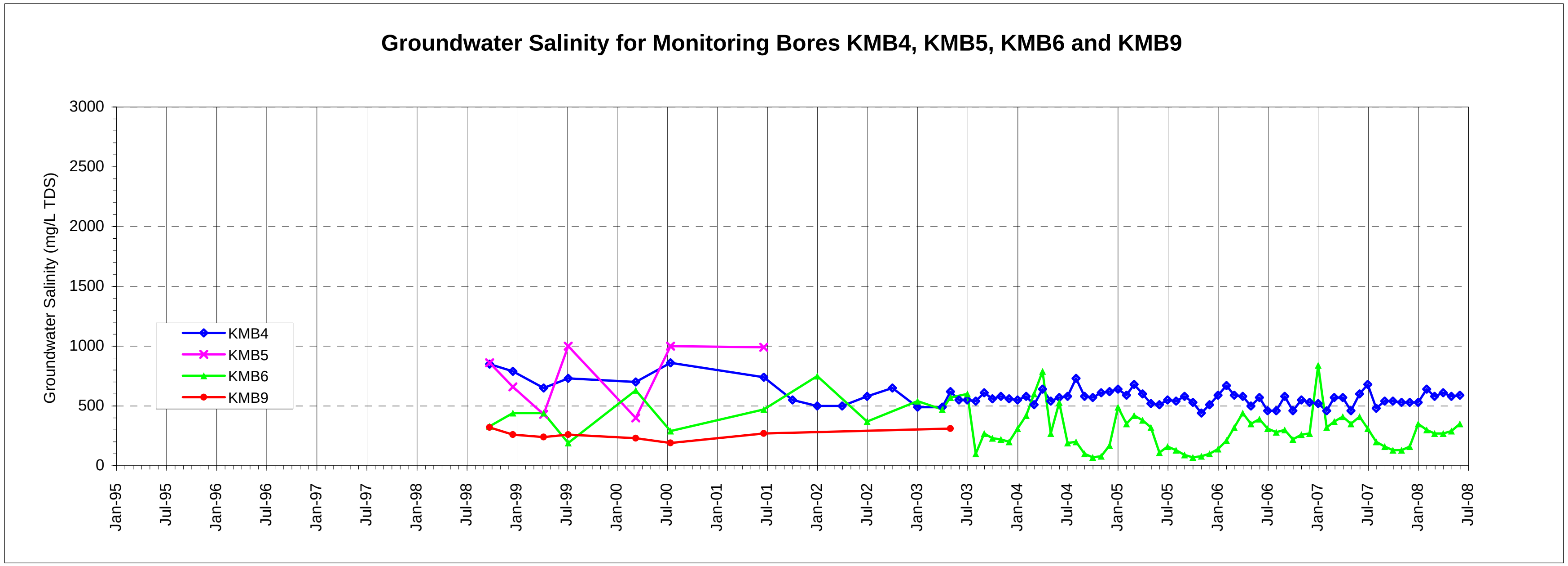
Nitrate and Phosphorus Concentrations in Production Bores

Rockwater Pty Ltd

Kemerton Silica Sand Pty Ltd
Groundwater Monitoring Review 2007/2008 GWL 60367(2&3)

Figure 10





Job number	258.0/08/01
Ref	Monitoring Data2008.xls
By	CK	Sep-2008
Revision	0	Sep-2008

Groundwater Salinity for Monitoring Bores KMB1, KMB2 and KMB8: KMB4, KMB5, KMB6 and KMB9

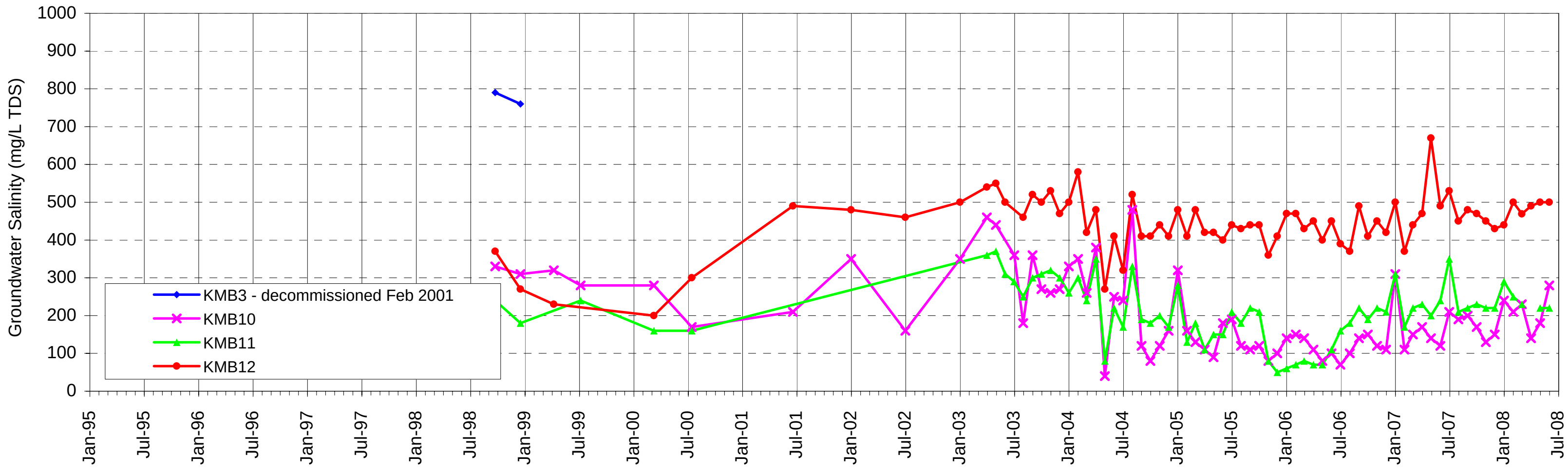
Rockwater Pty Ltd

Kemerton Silica Sand Pty Ltd

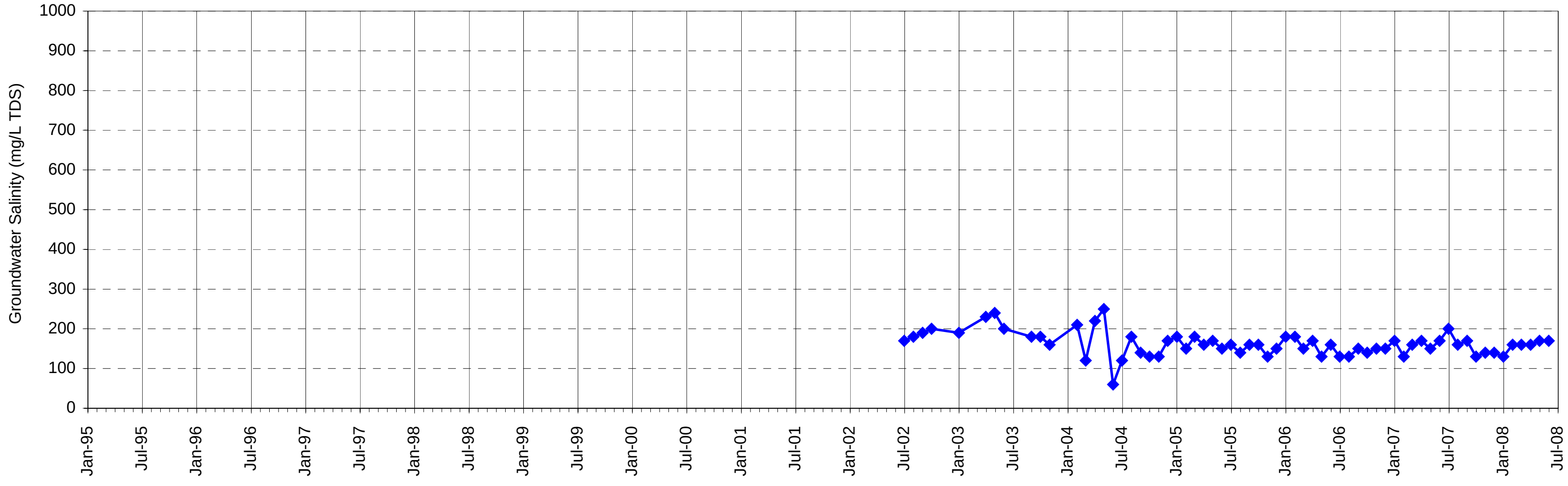
Groundwater Monitoring Review 2007/2008 GWL 60367(2&3)

Figure 11

Groundwater Salinity for Monitoring Bores KMB3, KMB10, KMB11 and KMB12



Groundwater Salinity for Monitoring Bore KMB13



Job number	258.0/08/01		
Ref	Monitoring Data2008.xls		
By	CK		Sep-2008
Revision	0		Sep-2008

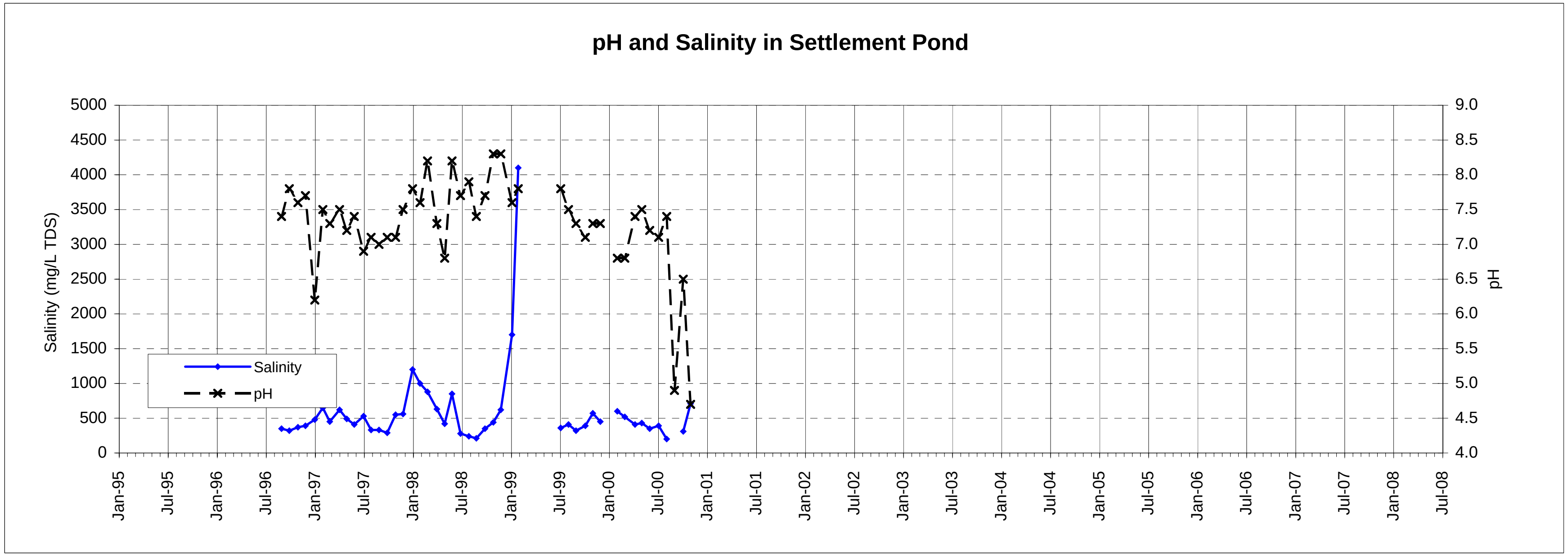
Groundwater Salinity for Monitoring Bores KMB3, KMB10, KMB11, KMB12 and KMB13

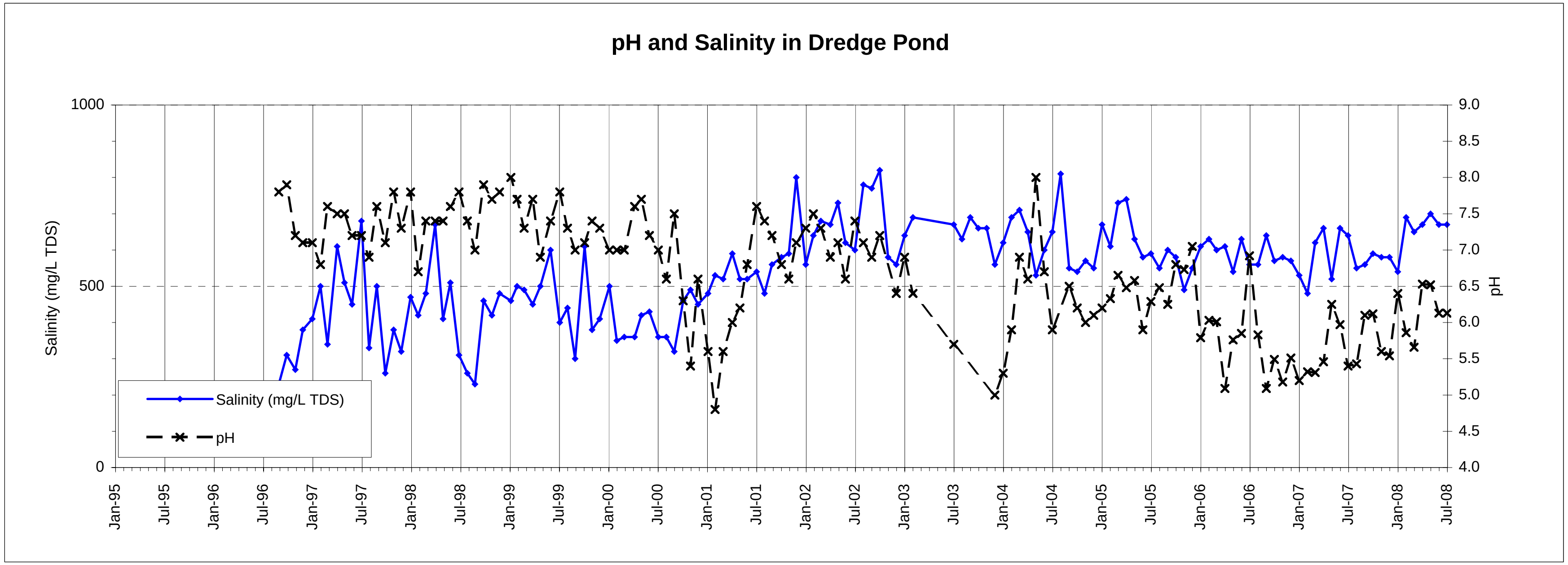
Rockwater Pty Ltd

Kemerton Silica Sand Pty Ltd

Groundwater Monitoring Review 2007/2008 GWL 60367(2&3)

Figure 12





Job number	258.0/08/01
Ref	Monitoring Data2008.xls
By CK	Sep-2008
Revision 0	Sep-2008

pH and Salinity in Settlement and Dredge Ponds

Rockwater Pty Ltd

Kemerton Silica Sand Pty Ltd

Groundwater Monitoring Review 2007/2008 GWL 60367(2&3)

Figure 13

APPENDICES

APPENDIX I

LICENCE TO TAKE WATER GWL 60367(2), GWL 60367(3) AND DEPARTMENT OF ENVIRONMENT LICENCE 6593/3

SW5331

Richard Watson

9726 4140

Mr Mark Gell
Resident Manager
Kemerton Silica Sand Pty Ltd
PO Box A283
AUSTRALIND WA 6233

Dear Mark

ISSUE OF A *LICENCE TO TAKE WATER* : GWL60367(3)
PROPERTY : Lot 32 On Diagram 63554 Rhodes Road, Wokalup

Please find enclosed your amended *Licence to Take Water*, issued under section 5C of the *Rights in Water and Irrigation Act 1914,* entitling you to take water from Superficial aquifer bores KMB7 and KMB14 for industrial purposes relating to silica sand mining on Lot 32 Rhodes Road Wokalup, subject to certain terms, conditions or restrictions.

The revised Annual Water Entitlement and conditions are consistent with those discussed previously and outlined in a letter dated 14 May 2007. However, please note that the chemistry conditions now include Total Titrateable Acidity which has recently be found to be a reliable indicator of Acid Sulphate Soil (ASS) environments at Myalup Swamp, 3.2km due west of KMB14.

It seems that KMB14 is equipped with a larger capacity pump than KMB7, which may be the cause of an apparent loss in efficiency as the higher yielding pump could be inducing excessive drawdown in the bore when switched on. This could draw the water level down to the slots/screen, and if there was no cut-off switch the bore would start sucking air. It is recommended that this bore be re-equipped with a smaller capacity pump and run more continuously at a lower rate.

There is also the risk of acid generation if Acid Sulphate Soils became exposed to air in the drawdown depression cone of the bore. A lower capacity pump would result in a shallower cone of depression and reduce the risk of exposing the ASS zones. There are benefits in spreading the draw around several bores in this aquifer and limiting individual drawpoints to 100,000kL/y if possible. The Department would need to be notified if additional bores were to be brought on-stream and each would need to be equipped with a meter.

It is important that you read the conditions of your licence carefully. If you do not understand your licence, please contact the Department as soon as possible, as there are penalties for failing to comply with all of your licence conditions. Under Section 26GG(2) of the *Rights in Water and Irrigation Act 1914*, you have a right to apply to the State Administrative Tribunal for a review of the decision to issue a *Licence to Take Water*. You have 28 days from the date you received this letter to request that the decision be reviewed.

For further information please contact the State Administrative Tribunal:

State Administrative Tribunal
12 St Georges Terrace
PERTH WA 6000

GPO Box U1991
PERTH WA 6845

Telephone: (08) 9219 3111
Toll-free: 1300 306 017
Facsimile: (08) 9202 1180

www.sat.justice.wa.gov.au

Under section 21 of the *State Administrative Tribunal Act 2004*, you have a right to request a written statement of reasons for the decision to issue a *Licence to Take Water*. This request must be made, in writing, to the Department of Water within 28 days after the day on which you received this letter.

If you wish to continue taking water after this *Licence to Take Water* expires, it is your responsibility to apply to the Department of Water for its renewal. Your past performance in complying with this licence will determine the terms, conditions or restrictions of any licence renewal. If this licence expires and you have not applied to renew it, then the taking of water must cease, or you will be in breach of the *Rights in Water and Irrigation Act 1914*. It is suggested that an application for renewal be made at least one month in advance of the *Licence to Take Water* expiry date.

Should legal access to the land cease, for example if the property is sold, before the *Licence to Take Water* expiry date, you are required to inform the Department using **Form I – Notice that Licence Holder is not or may not be Eligible to Hold a Licence** and return the enclosed licence within 30 days.

You may apply to amend or transfer the *Licence to Take Water* at any time. The Department may also amend, suspend or cancel this licence in certain circumstances.

Compliance with the terms, conditions or restrictions of this licence does not absolve the licensee from responsibility for compliance with the requirements of all Commonwealth and State legislation.

An extract of this licence has been placed in the public register and is available for viewing by appointment at Department of Water offices.

If you have any questions, please contact the South West regional office on 9726 4111.

Yours sincerely

R Watson

Richard Watson
Natural Resource Management Officer
South West Region

20 August 2007

Water and Rivers Commission
Government of Western Australia

Instrument No. GWL60367(3)

LICENCE TO TAKE WATER

Granted by the Commission under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Kemerton Silica Sand Pty Ltd		
Description of Water Resource	South West Coastal Perth - Superficial	**Annual Water Entitlement**	660000 kL
Location of Water Source	Lot 32 On Diagram 63554 - Volume/Folio 2128/998 - Lot 32 Rhodes Rd Wokalup Lot 100 On Plan 21567 - Volume/Folio 2167/550 - Lot 100 Wokalup		
Authorised Activities	**Taking of water for**	**Location of Activity**	
	Industrial purposes as detailed in application	Lot 32 On Diagram 63554 - Volume/Folio 2128/998 - Lot 32 Rhodes Rd Wokalup	
Duration of Licence	From 20 August 2007 to 30 June 2013		

This Licence is subject to the following terms, conditions and restrictions:

1 That the draw from the well/s be limited to the Superficial formation.

2 That should the licensee's draw adversely affect the aquifer or other users in the area, the Water and Rivers Commission may reduce the amount that may be drawn.

3 Approval by the Water and Rivers Commission is to be obtained prior to the construction of additional and replacement wells and the modification or refurbishment of existing wells.

4 The licensee is to comply with 'Schedule 1 of GWL60367(3) - Water Meters' and 'Schedule 2 of GWL60367(3) - Groundwater Monitoring Conditions' and any amendments made by or with the approval of the Commission.

End of terms, conditions and restrictions

This Licence is granted subject to the Rights in Water and Irrigation Regulations 2000

Department of Water
Government of Western Australia

Schedule 1 of GWL60367(3)
Water Meters

Licensee(s) : Kemerton Silica Sand Pty Ltd

Location of Water Source : Lots 32, 100 and 501 Rhodes Road, Wokalup

Metering Conditions:

1) The licensee shall install and maintain a cumulative water meter of a type authorised under the Rights in Water and Irrigation (Approved Meters) Order 2003 to each metering location listed below and the meters must be installed in accordance with the meter manufacturer's specifications.

2) The licensee shall record the volume of groundwater drawn **monthly** and forward the information to the Department of Water, PO Box 261 Bunbury 6231 by **31 July** each year.

Metering Locations :

Lot 32

- Superficial Aquifer Production Bores : **KMB 7 & KMB 14**

Locations of these bores are shown on the attached plan.

End of Terms, conditions and restrictions.

Department of Water
Government of Western Australia

Schedule 2 of GWL60367(3)
Groundwater Monitoring Program

Licensee(s) : Kemerton Silica Sand Pty Ltd

Location of Water Source : Lots 32, 100 and 501 Rhodes Road, Wokalup

Groundwater Monitoring Conditions :

1) The licensee shall measure the water levels in each of the nominated bores listed below **monthly.** Water levels in production bores are to be recorded whether the bore is in operation or not and a note made to that effect. Where applicable, data files are to be kept for both pump-on and pump-off data to allow separate trend analysis, but combined graph presentation.

2) The licensee shall have a water sample from each of the nominated bores listed below submitted for analysis **quarterly** according to the following schedule:

Sept or **Oct**	**Dec** or **Jan**	**March** or **April**	**June** or **July**
pH TDS	pH TDS	pH Total Dissolved Salts (TDS) Total Titrateable Acidity (TTA) Total Nitrogen (TN) Nitrite/Nitrate as N (NOx as N) Total Phosphorus (TP) Sulphate (SO_4^{2-}) Chloride (Cl^-)	pH TDS

3) All methods and equipment used in water quality sampling should be undertaken in accordance with the Australian Standard AS/NZS 5667 (1998) and wherever possible, a NATA registered laboratory should undertake the analyses, using NATA accredited analysis methods.

4) Water quality is to compared with the Australian Guidelines for Fresh and Marine Water Quality, October 2000 – Wetlands and Freshwater Lakes.

5) The Department of Water, at its discretion, may direct changes to be made to the monitoring program at any time.

6) The licensee is to provide an annual Groundwater Monitoring Summary prepared by a qualified professional in accordance with guidelines in the publication '*Hydrogeological reporting associated with a Groundwater Well Licence*'. The Summary will cover data recorded during the reporting year from 1 July to 30 June each year and is to include :

   - tabulated monthly production data for each production bore over the reporting year
   - histograms of historical monthly and annual production data for each production bore and combined borefield production
   - tabulated geochemical data for the reporting year
   - graphs of historical geochemical data

   The Summary is to be forwarded to the Department of Water, PO Box 261 Bunbury 6231 by **31 August** each year.

7) Every **three years** the licensee is to provide a Groundwater Monitoring Review prepared by a qualified professional in accordance with guidelines in the publication '*Hydrogeological reporting associated with a Groundwater Well Licence*'. The review will include a complete history of groundwater monitoring over the life of the borefield and a detailed analysis of the aquifer response to the groundwater production. The first Review is to be forwarded to the Department of Water, PO Box 261 Bunbury 6231 by **31 August 2008** and every three years thereafter.

Nominated Monitoring Bores :

The following bores are to be monitored in order to satisfy the groundwater water level and chemistry conditions.

Lot 32

- Superficial Aquifer Production Bores : **KMB 7 & 14**
- Superficial Aquifer Monitoring Bores : **KMB 2, 4, 5, 6, 8 & 13**

Lot 100

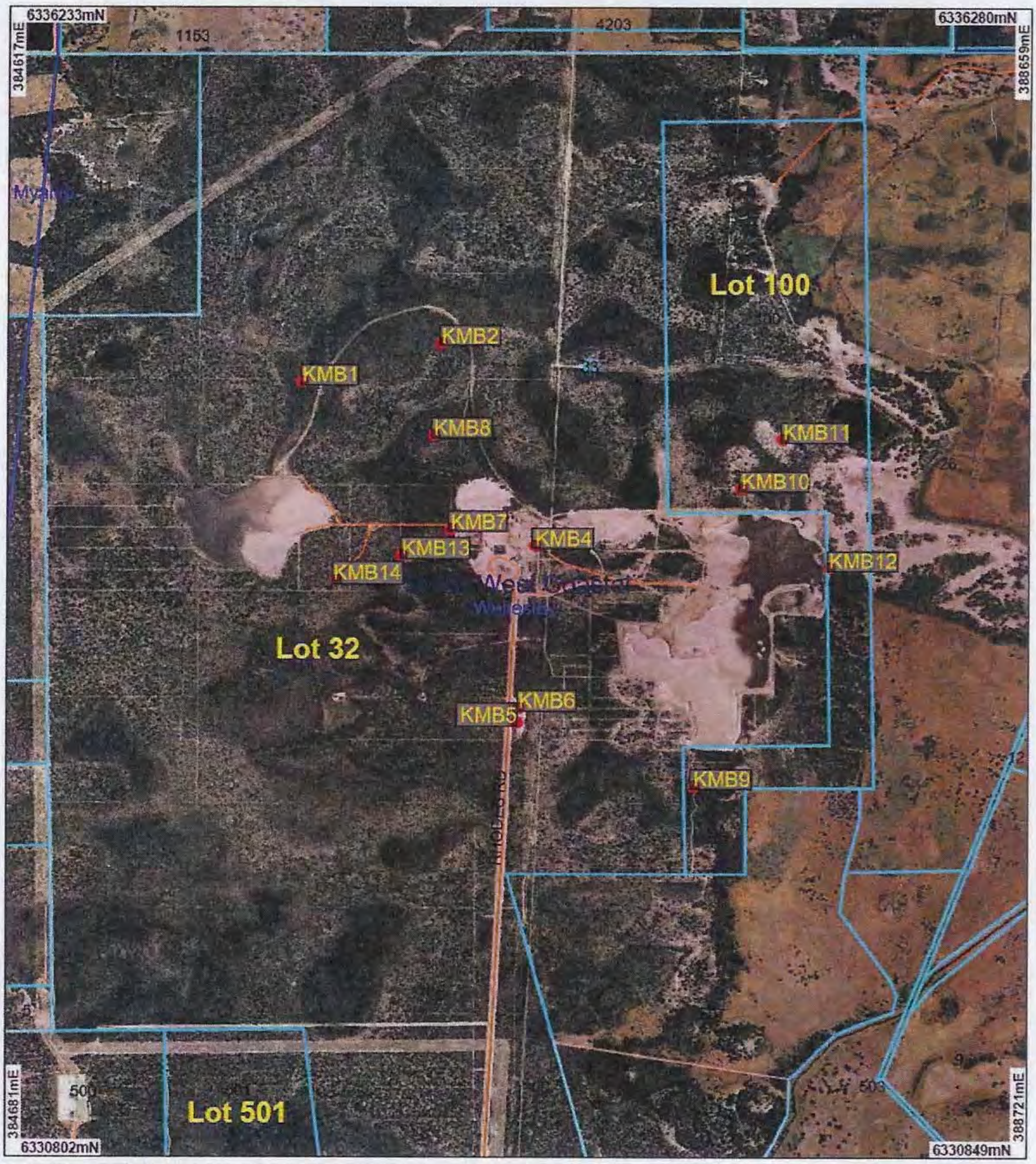
- Superficial Aquifer Monitoring Bores : **KMB 9, 10, 11 & 12**

Locations of these bores are shown on the attached plan.

End of Terms, conditions and restrictions.

Department of Water
Government of Western Australia

Kemerton Silica Sand Pty Ltd



LEGEND

WA Coastline - DoE
Road Centrelines - DLI 1/5/04
Declared Rare and Priority Flora List - CALM 01/07/05
- No Data
- Priority 1 - Poorly Known Taxa
- Priority 2 - Poorly Known Taxa
- Priority 3 - Poorly Known Taxa
- Priority 4 - Poorly Known Taxa
- Declared Rare Flora - Extant Taxa (cont)

Declared Rare Flora - Presumed Extinct Taxa
WIN Groundwater Sites, Monitoring - DoW
WRL DrawPoints
- INF;CND
- REC;DFT;INC;PRA;PRR;ACC
- SUR;TER;WTH;CAN;REF;REJ;EXP;-RIS

Cadastre - DLI
Localities - DLI
DWAID Groundwater Subareas - DOW
DWAID Groundwater Areas - DOW
Bunbury 50cm Orthomosaic - DLI04
Public Drinking Water Source Areas (PDWSAs) - DOW
- Policy Use - Not Assigned
- Policy Use - P1
- Policy Use - P2
- Policy Use - P3

N

0 ~750 m

Scale 1:25000
(Approximate when reproduced at A4)

Geocentric Datum Australia 1994

Note: the data in this map have not been projected. This may result in geometric distortion or measurement inaccuracies.

Prepared by: WatsonR
Prepared for:
Date: 17/07/2007 11:14:01 AM

Information derived from this map should be confirmed with the data custodian acknowleged by the agency acronym in the legend.

Department of Environment

Water and Rivers Commission
Government of Western Australia

Instrument No. GWL60367(2)

LICENCE TO TAKE WATER

Granted by the Commission under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Kemerton Silica Sands Pty Ltd		
Description of Water Resource	South West Coastal Perth - Superficial	**Annual Water Entitlement**	1000000 kL
Location of Water Source	Lot 501 on diagram 75018		
Authorised Activities	**Taking of water for**	**Location of Activity**	
	Industrial purposes as detailed in application	Lot 501 on diagram 75018 Lot 32 on diagram 63554	
Duration of Licence	From 14 October 2003 to 30 June 2013		

This Licence is subject to the following terms, conditions and restrictions:

1 That the licensee allows officers of the Water and Rivers Commission access to the bores or wells to measure water levels and obtain samples for monitoring purposes.

2 Monitoring of the aquifer performance shall be carried out by the licensee or his representative and the following information must be supplied:- a) a schedule of all production and monitoring wells is to be maintained giving details of well construction, pumping equipment and location. B) the total quantity of water pumped from the production well/s is to be measured and recorded monthly (1). C) water levels in all observation wells and production wells are to be measured and recorded monthly (1). Note should be taken as to whether the pumps are operating or not at the time of measurement. Measurements should be taken at the same phase of pumping i.E. Just before the pump is switched on or off. D) salinities in all production wells are to be measured and recorded every month.

3 The Water and Rivers Commission, at its discretion, may direct changes to be made to the monitoring programme at any time.

4 Should the monitoring at any time indicate a need for prompt action to prevent or reduce the effect of the licensee's draw on the underground resource, the licensee shall immediately report this to the Water and Rivers Commission and advise the corrective measures proposed.

5 Every one (1) year at the licensees own cost and commencing June 30, 1996, the licensee shall submit to the Water and Rivers Commission a report by a groundwater professional containing the following: A) the monitoring data compiled to the time of reporting. B) an assessment of the effects of the licensee's draw on the underground water resources of the area as determined from the monitoring data. C) an assessment of the monitoring programme and recommendations for any desirable changes to the programme.

6 The following shall apply to all groundwater abstraction authorized under this licence: (a) only that groundwater quantity necessary for the operation of the project shall be abstracted. (b) it is anticipated that the above quantity will be 1,000,000kl/yr. (c) all groundwater abstraction shall be metered.

7 That water drawn during dewatering operations shall be utilised where possible by the licensee in his mining and treatment operations.

This Licence is granted subject to the Rights in Water and Irrigation Regulations 2000

LICENCE TO TAKE WATER

Granted by the Commission under section 5C of the Rights in Water and Irrigation Act 1914

This Licence is subject to the following terms, conditions and restrictions:

8 That should the licensee's draw adversely affect other users, the licensee may be required to make good the supply to the affected users to the satisfaction of the Water and Rivers Commission.

9 Approval by the Water and Rivers Commission is to be obtained prior to the construction of additional and replacement wells and the modification or refurbishment of existing wells.

10 That should the licensee's draw adversely affect the aquifer or other users in the area, the Water and Rivers Commission may reduce the amount that may be drawn.

11 That the draw from the well/s be limited to the Superficial formation.

End of terms, conditions and restrictions

Department of Environment

Your ref:

Our ref:
L24/95 SWB1947-02
Enquiries:
Andrey Riedmann
Direct tel:
9726 4123

The Manager
Kemerton Silica Sand Pty Ltd
PO Box A283
Australind WA 6233

Dear Sir/Madam

ENVIRONMENTAL PROTECTION ACT 1986 - LICENCE
Kemerton Silica Sand Pty Ltd, cnr Wellesley and Treasure Roads
Kemerton WA 6230

You are advised that your application for a licence to operate the works prescribed under the *Environmental Protection Act 1986* at the above-mentioned location has been approved subject to the attached conditions. Enclosed is your licence together with receipt number, 01984 for the prescribed fee.

Recent amendments to the *Environmental Protection Act 1986* have provided for the issue of extended licences.

It is proposed to change the expiry date of your current licence from 20/03/06 to 20/03/2010. Implementation of this amendment will reduce the frequency of your licence renewal applications, although your monitoring reports and licence fees will still be required on an annual basis.

If any aspect of the conditions of licence aggrieves you, you may lodge an appeal, accompanied by the $50.00 fee, with the Minister for the Environment within 21 days from the date on which this licence is received. Members of the public may also appeal conditions. Please contact Margaret Johnston at the Appeal Convenor's Office on 9221 8711 after the closing date of appeals to check whether any appeals were received.

Under Section 58 of the *Environmental Protection Act 1986*, it is an offence to contravene a licence condition. This offence carries a penalty of up to $125,000, with a daily penalty of up to $25,000. The Department considers that a breach of this section, or any other section, of the *Environmental Protection Act 1986* to be extremely serious.

South West Region
35-39 McCombe Road
Bunbury Western Australia 6230
PO Box 261 Bunbury Western Australia 6231
Telephone (08) 9726 4111 Facsimile (08) 9726 4100
www.environ.wa.gov.au www.wrc.wa.gov.au

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT

Environmental Protection Act 1986

LICENCE

LICENCE NUMBER: 6593/4 **FILE NUMBER: L24/95**

NAME OF OCCUPIER:

Kemerton Silica Sand Pty Ltd

ADDRESS OF OCCUPIER:

PO Box A283
Australind WA 6233

NAME AND LOCATION OF PREMISES:

Kemerton Silica Sand Pty Ltd
cnr Wellesley and Treasure Roads
Kemerton WA 6230

Environmental Protection Regulations 1987
CLASSIFICATION(S) OF PREMISES:

Category 08 - Mineral Sands Mining or Processing

COMMENCEMENT DATE OF LICENCE: Monday, 21 March 2005

EXPIRY DATE OF LICENCE: Saturday, 20 March 2010

CONDITIONS OF LICENCE:
As described and attached:

DEFINITIONS
GENERAL CONDITION(S) (1)
AIR POLLUTION CONTROL CONDITION(S) (1)
WATER POLLUTION CONTROL CONDITION(S) (3)
SOLID WASTE CONTROL CONDITION(S) (1)
ATTACHMENTS (1)

W. Tg

....
Officer delegated under Section 20
of the *Environmental Protection Act 1986*

Date of Issue: Thursday, 10 March 2005

GENERAL CONDITION

ANNUAL MONITORING REPORT

G1 The licensee shall provide to the Director by **31 October each year**, a report containing the monitoring data and other collected data required by any condition of this licence. This report shall cover the previous 12 month period from 1 October to 30 September and shall contain:

(i) a brief background on the approval of the project and an overview of the project and its processes, and a current plan of the premises;

(ii) the monitoring data and other collected data required by any condition of this licence for the described period;

(iii) a discussion of the results of any monitoring programmes against background data and / or guidelines (data should be provided in tables and significant results should be presented in a graphical format);

(iv) a summary of incident reports and complaints received and discussion of any significant responses taken to minimise the likelihood of reoccurence; and

(v) a discussion of the operation of the project, compliance with conditions and the environmental performance to date.

AIR POLLUTION CONTROL CONDITION

DUST CONTROL

A1 The licensee shall not allow visible dust to cross the boundary of the premises.

WATER POLLUTION CONTROL CONDITIONS

LIQUID CHEMICAL STORAGE

W1(a) The licensee shall store and handle flammable and combustible liquids, such as hydrocarbons, where the total volume of each substance stored on the premises exceeds 250 litres, in accordance with Australian Standard 1940-2004: *The storage and handling of flammable and combustible liquids*.

W1(b) The licensee shall immediately remove and dispose of any liquid resulting from spills or leaks of liquids including fuel, oil or other hydrocarbons, whether inside or outside the containment compound(s) outlined in condition W1(a) to a licensed landfill site or bio-remediation area.

GROUNDWATER MONITORING

W2(a) The licensee shall maintain monitoring bores KMB1, KMB2, KMB4, KMB5, KMB6, KMB7, KMB8, KMB9, KMB10, KMB 11, KMB12, KMB13 and KMB14 at the approximate locations depicted in **Attachment 1** to enable the representative sampling of groundwater;

W2(b) The licensee shall determine, **monthly,** the standing water level (in metres Australian Height Datum) in each of the monitoring bores outlined in condition W2(a).

W2(c) The licensee shall determine, **monthly**, the in-situ levels of pH and total dissolved solids (in milligrams per litre) in each of the monitoring bores outlined in condition W2(a).

W2(d) The licensee shall provide the Director, with a groundwater monitoring report detailing the sampling results referred to in conditions W2(b) and W2(c) for the period 1 July to 30 June. This report shall form part of the Annual Monitoring Report specified in Condition G1.

W2(e) The licensee shall calibrate and maintain the on-site Conductivity-TDS-pH-temperature meter in accordance with the manufacturer's instructions.

SEWAGE DISPOSAL

W3 The licensee shall not place conventional septic systems and leach drains within 100 metres of any water body or watercourse.

SOLID WASTE DISPOSAL CONDITION

DISPOSAL OF SOLID WASTE

S1 The licensee shall dispose of all solid wastes to a licensed landfill site.

SEVERANCE

It is the intent of these licence conditions that they shall operate so that, if a condition or a part of a condition is beyond my power to impose, or is otherwise *ultra vires* or invalid, that condition or part of a condition shall be severed and the remainder of these conditions shall nevertheless be valid to the extent that they are within my power to impose and are not otherwise *ultra vires* or invalid.

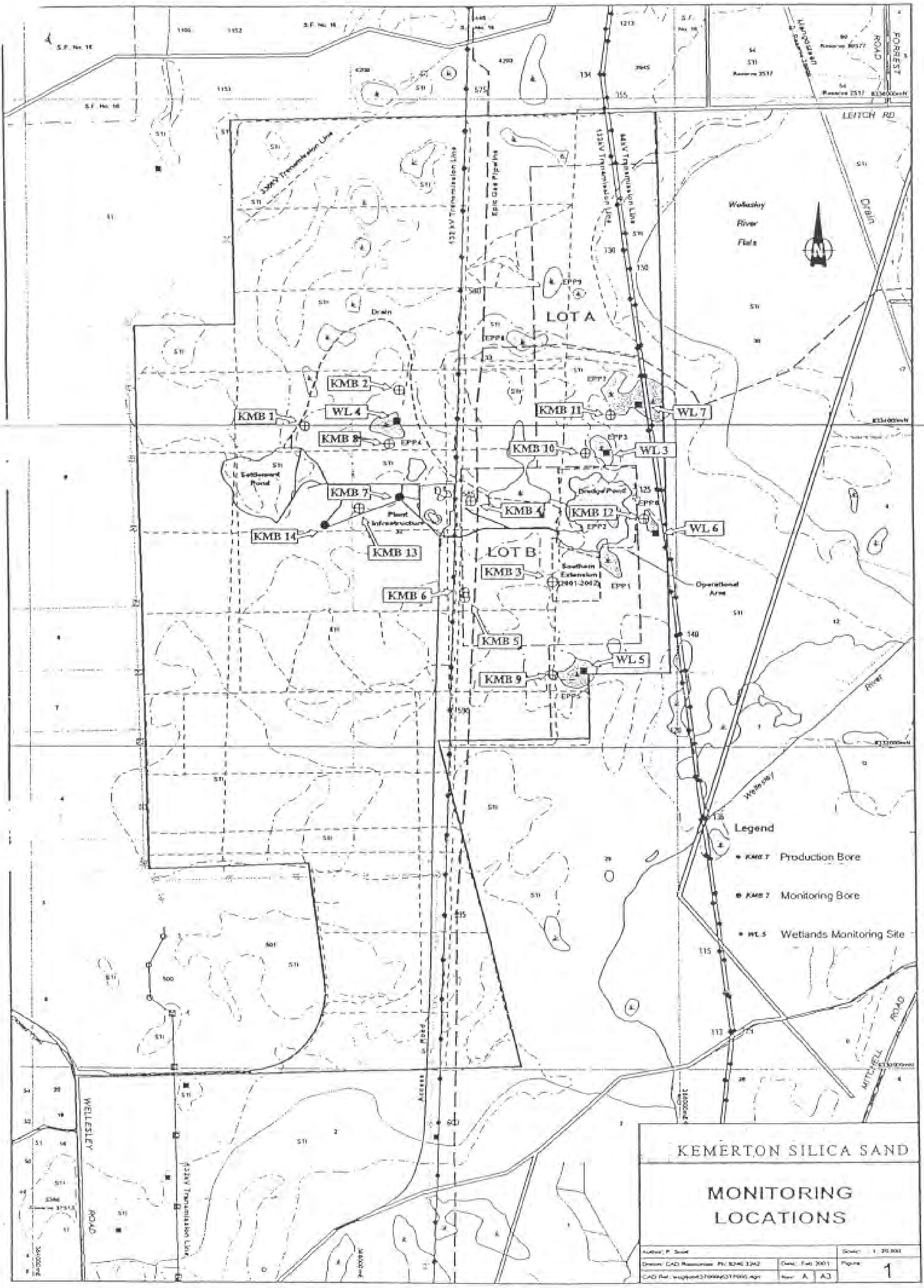
W.T.L.

....

Officer delegated under Section 20
of the *Environmental Protection Act 1986*

Date of issue: Thursday, 10 March 2005

ATTACHMENT 1 L24/95



APPENDIX II

MONITORING DATA

WATER BORE MONITORING
(m A.H.D. REDUCED LEVEL)

RAINFALL MONITORING
(mm)

WETLAND MONITORING
(m A.H.D. REDUCED LEVEL)

DATE	KMB1	KMB2	KMB3	KMB4	KMB5	KMB6	KMB7	KMB8	KMB9	KMB10	KMB11	KMB12	KMB13	KMB14	Month	Rainfall (July 1998+) Rain	KSS Annual Rain	KSS Average Rainfall	Wokalup Rainfall Rain	Wokalup Average Rainfall Mean	Wokalup Average Evaporation	Parkfield Rainfall Rain	Mean	WL3	WL4	WL5	WL6	WL7
13-Jan-93	10.650	10.950																		3.4								
19-Jan-93			9.490	10.530																3.4								
20-Jan-93					10.370										Jan-93				1.0	3.4	280.4	4.0						
20-Apr-93						12.970									Feb-93				1.4	47.1	242.3	0.2						
07-Apr-93							12.680								Mar-93				1.6	47.1	209.6	2.0						
28-Apr-95	13.717	13.634	12.163	13.123	12.939	12.966	13.385								Apr-95				28.5	47.1	129.9	27.8		13.540	14.000	11.950	12.305	12.500
02-Jun-95	13.947	13.994	12.543	13.513	13.324	13.346	13.770								May-95				159.0	187.1	83.9	160.8		13.540	14.790	12.054	12.305	12.911
30-Jun-95	14.287	14.414	12.998	13.918	13.734	13.781	14.170								Jun-95				127.8	187.1	63.9	133.3		13.540	14.826	12.049	12.305	13.105
02-Aug-95	15.227	15.234	13.758	14.768	14.534	14.556	14.935								Jul-95				282.4	133.5	64.0	264.2		13.850	15.098	12.148	12.533	13.539
31-Aug-95	15.267	15.244	13.748	14.748	14.564	14.586	14.930								Aug-95				106.8	133.5	76.3	72.8		13.850	15.090	12.150	12.520	13.910
29-Sep-95	15.317	15.244	13.738	14.728	14.544	14.566	14.914								Sep-95				103.8	90.7	96.2	81.8		13.840	15.070	12.131	12.538	14.185
26-Oct-95	15.252	15.234	13.693	14.723	14.534	14.556	14.904								Oct-95				81.2	55.4	137.5	74.0		13.840	15.075	12.121	12.528	14.180
22-Nov-95	15.117	15.099	13.474	14.548	14.344	14.366	14.759												30.0	31.4		9.8		13.790	14.980	12.038	12.523	14.060
06-Dec-95	15.027	14.964	13.358	14.448	14.219	14.241	14.634								Nov-95				6.6	9.6	179.0			13.735	14.862	11.963	12.407	13.920
04-Jan-96	14.787	14.684	13.033	14.183	13.949	13.966	14.414								Dec-95				9.4	3.4	246.7	11.4		13.560	14.000	11.950	12.305	13.763
01-Feb-96	14.537	14.414	12.728	13.918	13.704	13.716	14.179	14.307	12.441	13.370	13.486	12.049			Jan-96				0.0	6.5	280.4	1.1		13.560	14.000	11.950	12.305	13.526
01-Mar-96	14.222	14.074	12.573	13.533	13.404	13.446	3.184	13.667	12.186	13.140	13.241	11.864			Feb-96				7.7	13.0	242.3	0.0		13.560	14.000	11.950	12.305	13.284
28-Mar-96	14.047	13.939	12.488	13.498	13.284	13.301	13.629	13.782	12.016	12.970	13.056	11.724	13.680		Mar-96				19.6	13.0	209.6	4.5		13.560	14.000	11.950	12.305	13.096
30-Apr-96	13.857	13.814	12.358	13.518	13.174	13.246	13.484	13.707	11.916	12.850	12.926	11.649	13.270		Apr-96				69.4	47.1	129.9	10.2		13.560	14.000	11.950	12.305	13.096
30-May-96	13.967	13.894	12.108	13.798	13.234	13.196	13.684	13.567	11.906	12.800	12.906	11.329	12.660		May-96				245.4	133.5	83.9	53.0		13.600	14.900	12.000	12.000	13.000
03-Jul-96	14.347	14.584	12.938	14.198	13.804	13.906	7.734	14.467	12.636	13.660	13.736	12.379	13.460	13.375	Jun-96				220.0	173.4	63.9	197.8		13.600	15.000	12.100	12.000	13.300
31-Jul-96	14.897	15.114	13.408	14.608	14.304	14.446	4.884	15.067	13.156	14.100	14.156	12.769	13.880	5.415	Jul-96				203.0	173.4	64.0	184.1		13.800	15.100	12.150	12.550	13.550
28-Aug-96	15.397	15.364	13.658	14.828	14.584	14.746	6.454	15.167	13.456	14.280	14.356	13.079	14.360	7.175	Aug-96				184.0	133.5	76.3	166.7		13.880	15.180	12.150	12.580	14.100
26-Sep-96	15.697	15.414	13.758	14.878	14.734	14.796	5.064	15.187	13.456	14.280	14.536	13.129	14.460	6.325	Sep-96				48.0	90.7	96.2	159.2		13.880	15.200	12.150	12.600	14.100
28-Oct-96	15.497	15.174	13.528	14.708	14.584	14.646	5.004	15.067	13.356	14.130	14.436	12.879	14.410	7.275	Oct-96				71.0	55.4	137.5	47.0		13.850	15.080	12.150	12.550	14.100
25-Nov-96	15.497	15.114	13.348	14.578	14.454	14.526	4.934	14.767	13.206	13.980	14.306	12.729	14.430	14.475	Nov-96				24.2	31.4	179.0	53.0		13.800	15.000	12.100	12.500	14.100
30-Dec-96	15.147	14.814	12.958	14.278	14.134	14.196	5.464	14.367	12.956	13.480	14.106	12.279	13.910	7.475	Dec-96				2.6	9.6	246.7	29.0		13.600	14.800	12.000	12.400	14.100
29-Jan-97	14.897	14.494	12.208	13.978	13.734	13.846	4.134	14.017	12.506	13.360	14.136	11.229	13.460	5.475	Jan-97				26.2	3.4	280.4	1.6		13.600	14.800	12.000	12.400	13.900
24-Feb-97	14.667	14.414	11.958	13.678	13.434	13.596	5.334	13.917	12.306	12.960	13.456	10.829	13.460	8.125	Feb-97				23.4	6.5	242.3	36.0		13.600	14.800	12.000	12.400	13.700
01-Apr-97	14.447	14.214	11.658	13.428	13.214	13.316	4.684	13.597	12.106	12.630	13.156	10.729	12.930	6.075	Mar-97				22.6	47.1	209.6	19.3		13.600	14.800	12.000	12.400	13.500
28-Apr-97	14.397	14.114	11.408	13.328	13.034	13.196	3.784	13.517	11.956	12.380	13.006	10.329	12.910	6.025	Apr-97				135.8	47.1	129.9	23.4		13.600	14.800	12.000	12.400	13.350
26-May-97	14.597	14.364	11.308	13.328	12.934	13.096	4.084	13.567	11.956	12.280	12.856	10.229	12.760	5.775	May-97				196.4	133.5	83.9	107.2		13.600	14.800	12.000	12.400	13.400
30-Jun-97	14.797	15.014	12.708	14.228	13.934	13.996	6.334	14.617	12.906	13.480	13.856	11.829	14.160	7.875	Jun-97				170.5	187.1	63.9	200.4		13.800	15.000	12.100	12.500	13.700
28-Jul-97	15.147	15.164	13.008	14.478	14.234	14.376	4.184	14.697	13.106	13.740	14.006	12.329	14.060	6.175	Jul-97				134.0	185.6	64.0	116.0		13.800	15.100	12.250	12.520	13.850
26-Aug-97	15.217	15.154	13.308	14.528	14.534	14.496	4.584	14.897	13.256	13.900	14.116	12.729	14.260	6.675	Aug-97				88.2	135.6	76.3	83.2		13.800	15.080	12.100	12.550	14.000
26-Sep-97	15.397	15.214	13.508	14.578	14.384	14.596	5.084	14.867	13.306	13.980	14.196	12.829	14.160	6.775	Sep-97				33.0	92.7	96.2	123.1		13.850	15.100	12.150	12.580	14.200
27-Oct-97	15.047	15.014	13.408	14.528	14.234	14.316	5.284	14.727	13.056	13.830	14.056	12.829	14.060	7.275	Oct-97				18.6	62.4	137.5	20.2		13.750	15.000	12.150	12.520	14.100
24-Nov-97	14.917	14.714	12.958	14.178	14.034	14.116	5.184	14.567	12.856	13.620	13.886	12.379	13.710	7.475	Nov-97				0.2	36.0	179.0	19.8		13.600	14.850	12.000	12.400	13.950
29-Dec-97	14.647	14.514	12.458	13.928	13.684	13.796	3.804	14.267	12.506	13.180	13.556	11.529	13.380	6.395	Dec-97				9.2	14.7	246.7	0.0		13.600	14.800	12.000	12.400	13.650
26-Jan-98	14.397	14.364	12.208	13.728	13.434	13.446	3.934	14.167	12.256	12.680	13.256	11.249	13.160	6.275	Jan-98				0.2	13.9	280.4	5.7		13.600	14.800	12.000	12.400	13.400
23-Feb-98	14.097	14.014	11.958	13.528	13.184	13.296	3.284	14.067	11.976	12.530	12.956	11.029	12.710	5.775	Feb-98				75.2	15.8	242.3	0.0		13.600	14.800	12.000	12.400	13.100
30-Mar-98	14.097	13.914	11.508	13.378	12.984	13.096	4.784	13.667	11.806	12.160	12.806	10.079	13.010	6.875	Mar-98				22.9	21.2	209.6	98.4		13.600	14.800	12.000	12.400	13.100
28-Apr-98	14.277	13.964	11.258	13.228	12.884	12.996	4.104	13.817	11.756	12.030	12.656	10.049	13.200	6.245	Apr-98				75.2	53.4	129.9	25.4		13.600	14.800	12.000	12.400	13.100
25-May-98	14.137	13.984	11.308	13.178	12.884	12.896	13.704	13.967	11.656	11.880	12.506	10.079	13.560	13.595	May-98				187.6	139.6	83.9	82.0		13.600	14.800	12.000	12.400	13.100
26-Jun-98	14.297	14.464	12.008	13.828	13.384	13.546	4.384	14.067	12.306	12.580	13.156	10.829	13.280	6.275	Jun-98				122.8	194.2	63.9	148.0		13.600	14.800	12.000	12.400	13.100
27-Jul-98	14.557	14.714	12.428	14.028	13.584	13.776	4.584	14.227	12.566	13.020	13.506	11.439	13.410	6.475	Jul-98	102.5		154.5	175.8	185.6	64.0	79.2	161.2	13.600	15.090	12.100	12.400	13.290
24-Aug-98	14.597	14.914	12.808	14.298	13.984	14.046	5.684	14.367	12.856	13.280	13.906	11.959	13.810	7.745	Aug-98	169.5		151.8	140.4	135.6	76.3	172.1	114.9	13.600	15.100	12.120	12.400	13.400
25-Sep-98	14.937	15.064	13.258	14.528	14.434	14.546	5.384	14.657	13.156	13.680	13.916	12.529	14.360	7.265	Sep-98	149.0		103.1	40.6	92.7	96.2	87.7	80.3	13.600	15.100	12.150	12.550	13.600
26-Oct-98	14.967	14.954	13.228	14.558	14.234	14.316	14.004	14.867	13.076	13.630	13.856	12.529	14.560	14.075	Oct-98	54.0		56.3	16.6	62.4	137.5	23.0	48.8	13.600	15.080	12.100	12.510	13.700
23-Nov-98	14.617	14.714	12.948	14.228	13.974	14.096	4.434	14.267	12.856	13.380	13.556	12.259	13.660	6.225	Nov-98	13.5		26.7	17.8	36.0	179.0	9.5	26.5	13.600	15.000	12.000	12.400	13.600
04-Jan-99	14.347	14.314	12.608	13.978	13.614	13.746	13.534	14.217	12.406	12.980	13.356	11.979	14.010	13.575	Dec-98	11.0		11.5	8.4	14.7	246.7	4.0	13.0	13.600	14.800	12.000	12.400	13.300
27-Jan-99	14.047	13.994	12.408	13.648	13.394	13.446	3.024	13.467	12.206	12.830	13.106	11.749	14.000	5.375	Jan-99	4.0		15.4	0.0	13.9	280.4	4.0	12.2	13.600	14.800	12.000	12.400	13.150
22-Feb-99	13.827	13.614	12.208	13.558	13.324	13.246	2.784	13.267	11.906	12.630	12.906	11.579	14.200	5.275	Feb-99	-		8.2	18.9	15.8	242.3	0.0	12.4	13.600	14.800	12.000	12.400	13.100
26-Mar-99	13.747	13.714	12.158	13.358	13.034	13.176	1.884	13.087	11.916	12.480	13.056	11.529	14.460	4.475	Mar-99	11.5		12.0	22.8	21.2	209.6	13.0	20.5	13.600	14.800	12.000	12.400	13.100
23-Apr-99	13.517	13.414	11.968	13.248	12.934	12.976	1.854	12.867	11.656	12.330		11.369		4.475	Apr-99	27.5		49.2	207.6	53.4	129.9	31.0	40.3	13.600	14.800	12.000	12.400	13.100
31-May-99	13.977	14.244	12.708	13.908	13.404	13.646	13.284	13.967	12.316	13.100		12.079		13.575	May-99	260.3		126.2	232.5	139.6	83.9	209.0	117.0	13.600	14.800	12.000	12.400	13.100
04-Jul-99	14.897	15.044	13.378	14.728	14.384	14.576	3.684	14.867	13.206	13.960	14.176	12.729	14.460	14.460	Jun-99	256.0	1,058.8	149.8	146.6	194.2	63.9	215.0	169.3	13.800	15.100	12.150	12.550	13.500
02-Aug-99	15.297	15.164	13.438	14.728	14.444	14.596	14.284	14.907	13.296	13.880	14.076	12.829	14.610	5.675	Jul-99	166.5		154.5	96.6	185.6	64.0	84.0	161.2	13.850	15.180	12.150	12.580	13.850
30-Aug-99	15.317	15.134	13.568	14.678	14.514	14.566	4.684	14.777	13.206	13.880	14.236	12.879	14.560	7.135	Aug-99	114.0		151.8	124.0	135.6	76.3	96.0	114.9	13.850	15.290	12.150	12.600	14.100
04-Oct-99	15.347	15.134	13.608	14.798	14.534	14.666	5.384	14.797	13.306	13.950	14.156	13.229	15.110	7.135	Sep-99	115.0		103.1	109.8	92.7	96.2	83.0	80.3	13.850	15.200	12.150	12.580	14.180
01-Nov-99	15.377	15.234	13.578	14.808	14.534	14.646	14.184	15.167	13.306	14.000	14.386	13.099	14.960	14.575	Oct-99	119.0		56.3		62.4	137.5	0.4	48.8	13.820	15.120	12.100	12.580	14.200
29-Nov-99	15.297	15.064	13.488	14.598	14.344	14.336	5.034	14.567	13.096	13.820	14.196	12.829	14.560	7.025	Nov-99	-		26.7	2.0	36.0	179.0	11.0	26.5	13.750	15.100	12.000	12.550	14.000
04-Jan-00	14.797	14.614	12.858	14.108	13.834	13.946	4.234	14.217	12.656	13.480	13.866	12.379	13.860	6.075	Dec-99	7.5		11.5	49.3	14.7	246.7	25.0	13.0	13.600	14.910	12.000	12.400	13.800
31-Jan-00	14.697	14.514	12.508	13.978	13.654	13.746	3.784	13.987	12.456	13.250	13.656	11.929	13.430	5.655	Jan-00	31.5		15.4	2.9	13.9	280.4	2.0	12.2	13.600	15.000	12.000	12.400	13.750
28-Feb-00	14.597	14.364	12.058	13.728	13.374	13.466	2.924	13.787	12.156	12.800	13.356	11.249	13.160	4.775	Feb-00	2.5		8.2	27.5	15.8	242.3	20.0	12.4	13.600	14.900	12.000	12.400	13.500
06-Apr-00	14.547	14.494	11.558	13.478	13.084	13.196	3.684	13.767	11.906	12.230	12.976	10.479	12.960	5.475	Mar-00	17.5		12.0	53.4	21.2	209.6	41.0	20.5	13.600	15.080	12.000	12.400	13.280
01-May-00	14.347	14.264	11.508	13.328	12.934	13.076	13.134	13.817	11.856	12.030	12.806	10.529	13.260	13.225	Apr-00	54.0		49.2	32.0	53.4	129.9	33.9	40.3	13.600	15.000	12.000	12.400	13.200
31-May-00	14.197	14.114	11.608	13.178	12.984	13.016	5.684	13.517	11.856	12.050	12.856	10.729	12.910	7.425	May-00	48.0		126.2	154.8	139.6	83.9	145.2	117.0	13.600	15.000	12.000	12.400	13.200
03-Jul-00	14.497	14.514	12.258	13.678	13.484	13.616	6.484	14.017	12.516	12.740	13.406	11.529	13.360	8.025	Jun-00	154.5	830.0	149.8	294.2	194.2	63.9	225.3	169.3	13.600	15.000	12.050	12.400	13.380
02-Aug-00	14.947	14.994	12.978	14.248	14.114	14.246	13.734	14.617	13.126	13.430	13.906	12.279	14.560	14.125	Jul-00	253.5		154.5	209.5	185.6	64.0	137.1	161.2	13.600	15.090	12.150	12.510	13.600
31-Aug-00	15.147	15.164	13.658	14.568	14.484	14.596	14.734	14.767	13.406	13.780	14.156	12.829	15.160	8.125	Aug-00	179.0		151.8	69.0	135.6	76.3	59.1	114.9	13.700	15.100	12.100	12.580	13.900
03-Oct-00	15.097	14.964	13.508	14.428	14.434	14.496	6.264	14.617	13.256	13.800	14.106	13.129	14.610	8.025	Sep-00	88.5		103.1	11.9	92.7	96.2	5.8	80.3	13.800	15.050	12.100	12.600	13.800
30-Oct-00	14.897	14.764	13.358	14.278	14.134	14.256	6.334	14.317	13.056	13.700	13.956	13.029	14.360	8.225	Oct-00	13.5		56.3	42.6	62.4	137.5	25.4	48.8	13.700	14.920	12.050	12.500	13.900
27-Nov-00	14.697	14.614	13.258	14.178	13.984	14.096	5.184	14.067	12.856	13.630	13.806	12.929	13.710	6.975	Nov-00	36.5		26.7	n/a	36.0	179.0	0.0	26.5	13.600	14.800	12.000	12.450	13.800
03-Jan-01	14.297	14.164	12.908	13.828	13.684	13.696	3.884	13.667	12.506	13.330	13.356	12.679	13.260	6.075	Dec-00	1.0		11.5	0.0	14.7	246.7	2.0	13.0	13.600	14.800	12.000	12.400	13.500
29-Jan-01	14.057	13.964	12.758	13.588	13.354	13.446	5.584	13.417	12.256	13.180	13.306	12.529	13.030	7.625	Jan-01	-		15.4	0.0	13.9	280.4	0.0	12.2	13.600	14.800	12.000	12.400	13.300
28-Feb-01	13.847	13.714	12.608	13.328	13.134	13.256	2.584	13.217	12.006	12.980	13.056	12.379		4.865	Feb-01	-		8.2	1.2	15.8	242.3	1.4	12.4	13.600	14.800	12.000	12.400	13.150
03-Apr-01	13.647	13.514		13.128	12.884	12.996	3.334	12.947	11.806	12.930	12.856	12.229		5.475	Mar-01	3.0		12.0	0.4	21.2	209.6	2.8	20.5	13.600	14.800	12.000	12.400	13.100
01-May-01	13.447	13.364		12.938	12.734	12.876	2.684	12.817	11.726	12.830	12.756	12.179		4.875	Apr-01	7.0		49.2	131.4	53.4	129.9	142.4	40.3	13.600	14.800	12.000	12.400	13.100
28-May-01	13.497	13.484		13.178	12.984	13.096	4.184	12.967	12.056	13.130	13.106	12.479		6.175	May-01	157.0		126.2	34.3	139.6	83.9	63.8	117.0	13.600	14.800	12.000	12.400	13.100
02-Jul-01	13.467	13.464		13.228	12.984	13.146	2.184	12.917	12.206	13.230	13.156	12.629		4.275	Jun-01	44.0	783.0	149.8	93.4	194.2	63.9	n/a	169.3	13.600	14.800	12.000	12.400	13.100
31-Jul-01							1.884	13.067						3.825	Jul-01	84.5		154.5	131.4	185.6	64.0	62.8	161.2		14.80			
28-Aug-01							4.734	13.467					12.910	6.475	Aug-01	142.0		151.8	109.6	135.6	76.3	130.4	114.9		14.80			
02-Oct-01	13.947	14.164		13.928			2.684	13.617		13.780	13.756			6.475	Sep-01	112.5		103.1	26.6	92.7	96.2	98.3	80.3	13.75	14.80		12.57	13.20
29-Oct-01							4.434	13.517						6.325	Oct-01	25.0		56.3	40.2	62.4	137.5	15.4	48.8		14.80			
26-Nov-01							12.654	13.537						12.775	Nov-01	34.5		26.7	37.3	36.0	179.0	31.2	26.5		14.80			
31-Dec-01	13.697	13.694		13.478		13.346	1.884	13.267		13.280	13.206			3.975	Dec-01	22.5		11.5	0.0	14.7	246.7	43.4	13.0	13.600	14.80		12.40	13.10
28-Jan-02							13.234	13.367						13.175	Jan-02	8.0		15.4	0.0	13.9	280.4	2.4	12.2		14.80			
25-Feb-02							12.784	13.117						12.875	Feb-02	2.5		8.2	9.9	15.8	242.3	1.8	12.4		14.80			
01-Apr-02	13.367	13.314		13.108			4.484	12.817		12.860				6.155	Mar-02	18.5		12.0	92.2	21.2	209.6	10.7	20.5	13.60	14.80		12.40	13.10
29-Apr-02							0.734	12.567						2.675	Apr-02	43.5		49.2	69.9	53.4	129.9	50.3	40.3		14.80			
27-May-02							3.884	12.667					12.210	5.475	May-02	82.0		126.2	175.2	139.6	83.9	60.3	117.0		14.80			
01-Jul-02	14.197	13.814		13.678		13.546	12.934	13.417		13.480	13.356		13.110	11.875	Jun-02	199.0	774.5	149.8	162.4	194.2	63.9	191.6	169.3	13.60	14.80		12.45	13.10
01-Aug-02							2.934	13.667					13.060	4.375	Jul-02	205.5		154.5	119.6	187.7	64.0	145.1	161.2		14.90			
01-Sep-02							13.634	14.117					13.760	13.675	Aug-02	136.5		151.8	95.4	135.8	76.3	59.2	114.9		14.90			
01-Oct-02	14.397	13.364		14.368			2.934	13.567		14.03	13.916		13.310	6.425	Sep-02	92.5		103.1	64.8	92.6	96.2	45.6	80.3	14.10			12.5	13.55
01-Nov-02							1.684	14.167					13.310	3.575	Oct-02	65.5		56.3	17.0	61.8	137.5	22.2	48.8		14.80			
01-Dec-02							4.784	13.867					13.260	6.175	Nov-02	21.5		26.7	2.4	36.7	179.0	3.8	26.5		14.80			
01-Jan-03	13.947	14.014		13.928		13.796	8.834	13.867		13.63	13.406	12.829	13.610	13.725	Dec-02	7.5		11.5	4.8	3.4	246.7	2.3	13.0	13.6	14.80		12.4	13.2
01-Feb-03							3.684	13.567					3.230	4.975	Jan-03	5.0		15.4	41.0	6.5	280.4	13.6	12.2		14.80			
01-Mar-03							13.604	13.547					13.160	2.275	Feb-03	38.5		8.2	25.7	13.0	242.3	12.0	12.4		14.80			
01-Apr-03	13.527	13.644		13.598	12.984	13.176	13.664	13.477	11.886	12.95	12.796	12.259	13.260	10.115	Mar-03	27.0		12.0	47.1	47.1	209.6	68.8	20.5	13.6	14.80		12.4	13.1
01-May-03	13.607	13.614		13.628			13.224	13.427	12.106	12.68	12.806	13.829	13.230	10.075	Apr-03	77.0		49.2	90.6	133.5	129.9	83.4	40.3		14.80			
01-Jun-03	13.597	13.714		13.678		13.396	13.804	13.617	12.156	12.98	12.856	12.279	13.460	10.325	May-03	90.5		126.2	152.4	187.1	83.9	85.2	117.0		14.80			
02-Jul-03	13.847	14.114		14.028		13.796	1.584	13.867	12.656	13.48	13.356	12.629	6.060	0.875	Jun-03	177.0	944.0	149.8	198.4	173.4	63.9	85.2	169.3	13.600	14.9		12.4	13.1
01-Aug-03	14.337	14.654		14.498		14.196	14.484	14.467	12.996	13.78	13.706	13.029		0.675	Jul-03	168.0		154.5	122.0	185.6	64.0	118.4	161.2		14.9			
01-Sep-03	14.597	14.814		14.578		14.346	14.584	14.567	13.156	13.88	13.856	13.229	14.010	0.875	Aug-03	129.0		151.8	119.6	135.6	76.3	116.7	114.9		15.0			
01-Oct-03	14.697	15.014		14.728		14.446	14.834	14.917	13.256	13.98	13.956	13.329	14.360	1.675	Sep-03	128.0		103.1	31.0	92.7	96.2	99.7	80.3	13.9	15.1		12.5	13.7
01-Nov-03	14.637	14.834		14.568		14.326	1.304	14.757		13.88	13.796	13.229	9.060	15.565	Oct-03	50.5		56.3	47.2	62.4	137.5	44.0	48.8		14.8			
01-Dec-03	14.487	14.634		14.428		14.186	14.484	14.437		13.76	13.646	13.049	14.160	0.525	Nov-03	46.5		26.7	2.4	36.0	179.0	24.3	26.5		14.8			
01-Jan-04	14.247	14.404		14.238		13.886	12.284	14.157	14.456	13.44	13.366	12.779	14.160	13.855	Dec-03	6.5		11.5	26.0	14.7	246.7	11.0	13.0	13.6	14.8		12.4	13.1
01-Feb-04	14.077	14.174		14.038		13.696	12.084	13.867	12.596	13.22	13.156	12.569	13.790	13.695	Jan-04	46.5		15.4	6.6	13.9	280.4	45.0	12.2		14.8			
01-Mar-04	13.887	13.904		13.778		13.486	11.874	13.757	12.326	13.03	12.936	12.359	13.540	6.245	Feb-04	10.5		8.2	0.0	15.8	242.3	6.4	12.4		14.8			
01-Apr-04	13.707	13.724		13.548		13.256	11.584	13.557	12.326	12.8	12.706	12.129	13.390	13.275	Mar-04	1.0		12.0	25.1	21.2	209.6	1.3	20.5	13.6	14.8		12.4	13.1
01-May-04	13.557	13.564		13.408		13.116	11.314	13.397	12.326	12.68	12.576	12.029	13.200	5.704	Apr-04	27.5		49.2	111.6	53.4	129.9	16.9	40.3		14.8			
01-Jun-04	13.647	13.784		13.668		13.356	11.524	13.577	12.326	12.94	12.856	12.249	13.220	3.515	May-04	127.5		126.2	186.3	139.6	83.9	114.6	117.0		14.8			
01-Jul-04	13.827	14.314		14.228		13.946	12.084	13.867	12.326	13.38	13.256	12.629	13.630	0.175	Jun-04	167.5	909.0	149.8	130.8	194.2	63.9	169.9	169.3					
01-Aug-04	14.330	14.664		14.480		14.246	12.394	14.567	13.076	13.730	13.606	12.929	14.170	9.275	Jul-04	130.0		154.5	163.3	185.6	64.0	133.4	161.2					
01-Sep-04	14.607	14.824		14.648		14.376	12.584	14.767	13.226	13.840	13.776	13.089	14.450	10.375	Aug-04	177.5		151.8	30.5	135.6	76.3	139.6	114.9					
01-Oct-04	14.577	14.674		14.408		14.196	12.414	14.607	13.076	13.700	13.656	13.039	14.250	4.605	Sep-04	35.0		103.1	44.8	92.7	96.2	23.3	80.3					
01-Nov-04	14.407	14.554		14.238		14.046	12.054	14.367	12.926	13.570	13.496	12.899	14.090	6.745	Oct-04	48.5		56.3	35.6	62.4	137.5	43.5	48.8					
01-Dec-04	14.277	14.364		14.158		13.906	11.864	14.237	12.926	13.440	13.336	12.739	13.880	3.815	Nov-04	56.5		26.7	30.0	36.0	179.0	48.4	26.5					
01-Jan-05	14.057	14.134		13.998		13.606	14.144	13.997	12.516	13.170	13.076	12.499	13.710	0.535	Dec-04	3.5		11.5	0.0	14.7	246.7	8.8	13.0					
01-Feb-05	13.807	13.764		13.638		13.356	12.684	13.557	12.276	12.940	12.846	12.300	13.340	4.245	Jan-05	-		15.4	4.0	13.9	280.4	1.0	12.2					
01-Mar-05	12.607	13.574		13.468		13.106	2.974	12.187	12.066	12.780	12.656	12.109	13.060	10.775	Feb-05	5.5		8.2	27.9	15.8	242.3	9.0	12.4					
01-Apr-05	13.477	13.494		13.298		12.996	13.374	13.337	11.956	12.700	12.566	12.039	13.210	13.235	Mar-05	13.5		12.0	39.6	21.2	209.6	24.0	20.5					
01-May-05	13.397	13.364		13.178		12.906	1.474	13.127	11.886	12.630	12.496	11.999	13.080	13.135	Apr-05	34.5		49.2	249.4	53.4	129.9	63.6	40.3		14.8			
01-Jun-05	13.947	14.144		13.868		13.646	1.644	13.737	12.676	13.280	13.206	12.549	13.480	13.725	May-05	275.0		126.2	188.6	139.6	83.9	252.7	117.0					13.0
01-Jul-05	14.617	14.884		14.498		14.306	2.544	14.627	13.236	13.840	13.756	12.039	14.330	14.475	Jun-05	201.5	981.0	149.8	81.5	194.2	63.9	197.2	169.3	15.5	15.2		12.6	13.4
01-Aug-05	14.737	15.334		14.488		14.256	2.614	14.697	13.176	13.830	13.776	13.119	14.390	14.585	Jul-05	75.0		154.5	140.2	185.6	77.5	52.0	161.2		15.1			
01-Sep-05	14.977	15.134		14.618		14.466	2.364	14.827	13.306	13.98	13.886	13.159	14.54	14.785	Aug-05	143.5		151.8	154.8	135.6	96.0	110.8	114.9		15.1			
01-Oct-05	15.177	15.264		14.748		14.586	2.654	15.077	13.336	14.05	13.956	13.229	14.75	14.945	Sep-05	142.0		103.1	92.9	92.7	136.4	85.4	80.3		15.1			
01-Nov-05	15.127	15.224		14.638		14.506	2.074	14.967	13.256	13.96	13.906	13.099	14.66	14.865	Oct-05	81.5		56.3	38.4	62.4	180.0	58.6	48.8		15.1			
01-Dec-05	14.887	14.974		14.478		14.196	6.234	13.747	13.056	13.78	13.686	12.999	14.46	14.555	Nov-05	26.0		26.7	27.4	36.0	241.8	44.9	26.5	13.5	15.0		12.5	14
01-Jan-06	14.707	14.704		14.188		13.976	5.624	14.417	12.856	13.62	13.516	12.819	14.13	7.105	Dec-05	27.5		11.5	30.6	14.7	282.1	18.2	13.0		15.0			
01-Feb-06	14.487			14.018		13.776	2.524	14.097	12.676	13.41	13.316	12.639	13.78	8.185	Jan-06	36.0		15.4	30.6	13.9	240.8	36.6	12.2		14.8			
01-Mar-06	14.257	14.184		13.878		13.536	14.074	14.037	12.456	13.18	13.056	12.429	13.99	13.735	Feb-06	1.5		8.2	1.2	15.8	210.8	-	12.4		14.8			
01-Apr-06	14.027	13.974		13.568		13.326	13.434	13.707	12.276	13.03	12.896	12.309	13.56	13.655	Mar-06	7.5		12.0	4.2	21.2	129.0	12.0	20.5		14.8			
01-May-06	13.867	13.794		13.568		13.196	0.684	13.417	12.196	12.96	12.796	12.249	13.24	13.455	Apr-06	33.5		49.2	22.0	53.4	83.7	38.9	40.3		14.8			
01-Jun-06	13.767	13.724		13.338		13.116	13.534	13.577	12.156	12.9	12.736	12.189	13.49	13.495	May-06	28.0		126.2	29.5	139.6	63.0	16.4	117.0		14.8			
01-Jul-06	13.657	13.584		13.208		13.026	0.134	13.177	12.126	12.88	12.696	12.159	13.02	13.345	Jun-06	26.5		149.8	14.2	194.2	65.1	22.8	169.3	13.5	14.8		12.5	13
01-Aug-06	13.897	14.064		13.628		13.546	0.784	13.717	12.616	13.44	13.156	12.589	13.47	13.645	Jul-06	169.5		154.5	139.7	185.6	77.5	122.8	161.2		14.8			
01-Sep-06	14.327	14.494		14.108		13.936	4.964	14.307	12.976	13.7	13.526	12.909	14.15	14.165	Aug-06	180.0	978.0	151.8	168.2	135.6	96.0	137.8	114.9		14.8			
01-Oct-06	14.357	14.474		13.998		13.896	4.734	14.107	12.916	13.67	13.496	12.899	13.95	14.165	Sep-06	63.0		103.1	60.0	92.7	136.4	43.8	80.3		14.8			
01-Nov-06	14.247	14.354		13.978		13.776	5.134	14.167	12.746	13.51	13.306	12.759	14.01	13.955	Oct-06	45.0		56.3	23.9	62.4	180.0	19.2	48.8		14.8			
01-Dec-06	14.117	14.194		13.848		13.676	4.124	13.867	12.636	13.4	13.156	12.579	13.7	13.875	Nov-06	28.5		26.7	21.9	36.0	241.8	24.7	26.5		14.8			
01-Jan-07	13.947	14.004		13.648		13.446	4.164	13.787	12.386	13.15	12.916	12.349	13.64	13.705	Dec-06	-		11.5	0.0	14.7	282.1	0.0	13.0	13.5	14.8		12.5	15
01-Feb-07	13.757	13.764		13.438		13.216	3.984	13.527	12.156	12.92	12.696	12.129	13.35	13.425	Jan-07	22.5		15.4	19.0	13.9	240.8	21.0	12.2		14.8			
01-Mar-07	13.617	13.614		13.278		13.026	4.284	13.357	12.016	12.8	12.566	12.099	13.01	4.185	Feb-07	8.5		8.2	13.0	15.8	210.8	3.0	12.4		14.9			
01-Apr-07	13.417	13.424		12.998		12.736	0.574	13.067	11.786	12.65	12.416	12.029	12.73	5.935	Mar-07	19.0		12.0	24.4	21.2	129.0	11.6	20.5		14.9			
01-May-07	13.347	13.314		12.928		12.646	0.684	12.417	11.746	12.69	12.436	12.079	12.66	12.745	Apr-07	49.0		49.2	48.6	53.4	83.7	31.8	40.3		14.9			
01-Jun-07	13.327	13.344		12.918		12.606	13.054	13.147	11.786	12.82	12.496	12.129	13.01	13.035	May-07	80.0		126.2	85.6	139.6	63.0	52.7	117.0		14.9			
01-Jul-07	13.727	13.954		13.498		13.266	13.694	13.687	12.456	13.37	13.306	12.619	13.47	13.105	Jun-07	121.0		149.8	107.8	194.2	65.1	173.1	169.3	13.5	14.9		12.5	15
01-Aug-07	14.057	14.304		13.898		13.616	14.134	13.927	12.786	13.67	13.416	12.879	13.74	2.005	Jul-07	189.5		154.5	181.9	185.6	65.1	110.3	161.2		14.9			
01-Sep-07	14.387	14.654		14.248		13.966	14.474	14.507	13.016	13.88	13.676	13.089	14.18	5.255	Aug-07	146.5		151.8	178.8	135.6	77.5		114.9		14.9			
01-Oct-07	14.657	14.794		14.268		14.086	14.594	14.647	13.066	13.94	13.766	13.139	14.48	14.425	Sep-07	105.5		103.1	128.5	92.7	96.0		80.3		14.9			
01-Nov-07	14.507	14.594		14.178		13.916	14.464	14.427	12.826	12.7	14.656	12.999	14.25	14.255	Oct-07	60.0		56.3	61.0	62.4	136.4	33.9	48.8		14.9			
01-Dec-07	14.377	14.434		14.008		13.756	14.234	14.267	12.686	13.62	13.386	12.839	14.11	14.125	Nov-07	3.0		26.7	3.2	36.0	180.0	2.4	26.5		14.8			
01-Jan-08	14.197	14.224		13.798		13.546	14.014	14.077	12.476	13.4	13.156	12.629	13.95	13.925	Dec-07	28.0		11.5	21.2	14.7	241.8	32.0	13.0	13.5	14.8		12.5	13.2
01-Feb-08	13.937	13.934		13.518		13.286	0.364	13.697	12.206	13.12	12.886	12.349	13.49	13.495	Jan-08	-		15.4	0.0	13.9	282.1	0.0	12.2	13.5	14.8		12.5	13.2
01-Mar-08	13.747	13.744		13.348		13.006	2.434	13.537	11.996	12.91	12.686	12.199	13.37	13.135	Feb-08	12.0		8.2	15.4	15.8	240.8	7.0	12.4	13.5	14.8		12.5	13.2
01-Apr-08	13.617	13.684		13.218		12.916	1.744	13.437	11.916	12.92	12.686	12.169	13.26	13.315	Mar-08	1.0		12.0	2.8	21.2	210.8	3.6	20.5	13.5	14.8		12.5	13.2
01-May-08	13.617	13.724		13.238		12.976	1.634	13.477	12.006	13.02	12.786	12.249	13.33	13.425	Apr-08	138.0		49.2	173.4	53.4	129.0	101.1	40.3	13.5	14.8		12.5	13.2
01-Jun-08	13.787	13.984		13.498		13.196	13.584	13.757	12.276	13.28	13.076	12.549	13.58	13.585	May-08	114.0		126.2	129.6	139.6	83.7	134.9	117.0					
01-Jul-08	14.387	14.604		14.118		13.776	5.104	14.427	12.826	13.8	13.606	12.969	14.18	14.245	Jun-08	150.5	948.0	149.8	147.4	194.2	63.0	144.3	169.3	13.7	14.9	12.100	12.6	13.2

KMB7 PRODUCTION BORE MONITORING | KMB14 PRODUCTION BORE MONITORING | PRODUCTION BORES | SETTLEMENT AND DREDGE POND MONITORING

	KMB7							KMB14							Total Monthly Flow (m^3)	Total Annual Flow (m^3)	Dredge pond							Settlement Pond	
DATE	pH	Salinity (mg/L TDS)	Meter	Flow (m3)	Annual Flow	NO_3	P	pH	Salinity (mg/L TDS)	Meter	Flow (m3)	Annual Flow	NO_3	P			pH	Salinity (mg/L TDS)	SO_4 (mg/L)	Water Level	Meter	Use (m3)	Annual Use	pH	Salinity
13-Jan-93																									
19-Jan-93																									
20-Jan-93																									
20-Apr-93																									
07-Apr-93																									
28-Apr-95																									
02-Jun-95																									
30-Jun-95																									
02-Aug-95																									
31-Aug-95																									
29-Sep-95																									
26-Oct-95																									
22-Nov-95																									
06-Dec-95																									
04-Jan-96																									
01-Feb-96																									
01-Mar-96				20,412							20,000				40,412										
28-Mar-96	8.3	430		22,596				8.15	240		22,000				44,596										
30-Apr-96	8.0	380		43,925				7.10	840		57,874				101,799										
30-May-96	7.8	590		43,925				7.50	410		57,874				101,799										
03-Jul-96	8.0	600		33,670	164,528			8.40	470		42,331	200,079			76,001	364,607									
31-Jul-96	7.3	510		32,808				6.60	300		42,060				74,868										
28-Aug-96	7.8	440		43,617				7.30	240		34,023				77,640		8	230						7.40	350
26-Sep-96	7.5	260		55,403				8.10	200		38,550				93,953		8	310						7.80	320
28-Oct-96	8.0	540		40,205				7.60	390		28,734				68,939		7	270						7.60	370
25-Nov-96	7.8	490		43,018				7.40	280		31,933				74,951		7	380						7.70	390
30-Dec-96	7.9	420		47,459				7.60	240		31,865				79,324		7	410						6.20	480
29-Jan-97	7.6	620		40,970				7.00	300		27,898				68,868		7	500						7.50	650
24-Feb-97	7.8	510		44,394				7.30	250		32,716				77,110		8	340						7.30	450
01-Apr-97	7.4	510		55,531		1.7	0.07	6.70	260		39,543				95,074		8	610						7.50	620
28-Apr-97	8.2	510		43,289		0.6	0.1	7.80	270		30,675				73,964		8	510						7.20	490
26-May-97	7.4	540		34,708		1.6	0.15	7.20	290		25,822				60,530		7	450						7.40	410
30-Jun-97	7.3	640		51,788	533,190	0	0.05	6.70	260		29,928	393,747			81,716	926,937	7	680						6.90	530
28-Jul-97	7.5	520		42,765		0.7	0.15	7.00	290		29,334				72,099		7	330						7.10	330
26-Aug-97	7.5	560		45,010		1	0.2	6.90	260		32,596				77,606		8	500						7.00	330
26-Sep-97	7.3	430		47,317		3.1	0.1	7.00	230		33,420				80,737		7	260						7.10	290
27-Oct-97	8.5	520		47,956		1.5	0.05	8.00	280		31,957				79,913		8	380						7.10	550
24-Nov-97	7.4	440		41,737		1.6	<0.05	7.20	240		29,806				71,543		7	320						7.50	560
29-Dec-97	7.7	510		53,326		1.8	<0.05	7.40	300		37,009				90,335		8	470						7.80	1,200
26-Jan-98	7.4	520		42,601		1.2	0.25	7.60	300		31,181				73,782		7	420						7.60	1,000
23-Feb-98	7.4	530		43,282		1.5	0.05	7.20	270		30,744				74,026		7	480						8.20	880
30-Mar-98	7.7	590		51,247		0.2	0.1	7.20	270		37,307				88,554		7	670						7.30	630
28-Apr-98	7.4	470		26,501		0.9	0.15	7.00	240		19,852				46,353		7	410						6.80	420
25-May-98	7.4	510		19,902		0.9	0.2	7.20	330		14,372				34,274		8	510						8.20	850
26-Jun-98	7.6	540		42,344	503,988	0.7	0.05	7.40	240		32,624	360,202			74,968	864,190	8	310						7.70	280
27-Jul-98	7.7	480		35,839		0.9	0.1	8.10	210		27,742				63,581		7	260						7.90	240
24-Aug-98	7.3	380		41,739		1.1	0.05	7.30	240		31,961				73,700		7	230						7.40	210
25-Sep-98	7.6	510		30,410		1.2	0.1	8.20	270		23,629				54,039		8	460						7.70	350
26-Oct-98	7.5	540		35,743		1.8	<0.05	7.70	370		27,073				62,816		8	420						8.30	440
23-Nov-98	7.5	560		41,078		1.2	<0.05	7.20	340		31,464				72,542		8	480						8.30	620
04-Jan-99	7.5	570		38,137		1.2	0.05	8.10	400		28,604				66,741		8	460						7.60	1,700
27-Jan-99	7.5	560		35,637		0.8	0.7	7.20	300		27,026				62,663		8	500						7.80	4,100
22-Feb-99	7.2	550		39,827		2.6	<0.05	6.60	240		27,206				67,033		7	490							
26-Mar-99	7.5	520		50,723		1.5	1.4	7.50	280		38,695				89,418		8	450							
23-Apr-99	7.3	1100		46,500		1	0.05	6.50	390		35,812				82,312		7	500							
31-May-99	7.4	600		18,394		1.7	0.1	6.60	540		12,050				30,444		7	600							
04-Jul-99	7.5	550		47,904	461,931	1.7	<0.05	7.20	300		37,226	348,488			85,130	810,419	8	400						7.80	360
02-Aug-99	6.8	350		28,996		1.4	0.05	7.00	310		21,422				50,418		7	440						7.50	410
30-Aug-99	7.3	500		41,602		2	0.1	7.10	230		33,631				75,233		7	300						7.30	320
04-Oct-99	7.1	540		51,815		1.3	0.1	7.00	300		36,895		1.1	0.05	88,710		7	610						7.10	390
01-Nov-99	7.3	580		21,313		1.3	0.2	7.30	430		14,870		0.07	0.15	36,183		7	380						7.30	570
29-Nov-99	7.5	590	775,676	19,154		1.5	0.05	7.40	340	334,310	13,644		0.4	<0.05	32,798		7	410						7.30	450
04-Jan-00	7.1	500	812,307	36,631		1.3	0.1	6.70	280	359,176	24,866		1.2	0.1	61,497		7	500							
31-Jan-00	7.3	520	846,590	34,283		3.8	0.05	6.80	280	385,295	26,119		0.2	<0.05	60,402		7	350			780759			6.80	600
28-Feb-00	6.6	500	888,210	41,620		0.6	0.05	6.30	190	417,064	31,769		0.4	<0.05	73,389		7	360			850511	69752		6.80	520
06-Apr-00	7.3	540	947,659	59,449		1.1	0.12	7.40	320	462,340	45,276		1.3	0.13	104,725		8	360			949792	99281		7.40	410
01-May-00	7.0	380	980,570	32,911		3.2	0.05	7.20	360	486,319	23,979		1.3	0.1	56,890		8	420			1003743	53951		7.50	430
31-May-00	7.0	520	19,741	39,171		0.6	<0.05	7.10	300	513,828	27,509		0.6	<0.05	66,680		7	430			1066911	63168		7.20	350
03-Jul-00	7.0	530	60,203	40,462	447,407	0.8	0.05	7.10	340	542,042	28,214	328,194	<0.1	0.05	68,676	775,601	7	360			1131956	65045	351,197	7.10	390
02-Aug-00	7.5	570	98,907	38,704		0.8	0.06	7.00	320	559,543	17,501		0.6	0.06	56,205		7	360			1185679	53723		7.40	200
31-Aug-00	7.6	570	137,898	38,991		0.6	0.15	7.50	330	577,915	18,372		0.7	0.05	57,363		8	320			1240455	54776		4.90	
03-Oct-00	7.2	560	177,248	39,350		1.1	0.15	7.20	340	604,890	26,975		1.4	0.3	66,325		6	460			1303055	62600		6.50	310
30-Oct-00	7.4	520	211,277	34,029		1.3	<0.05	6.80	310	629,673	24,783		0.8	0.2	58,812		5	490			1358396	55341		4.70	710
27-Nov-00	7.3	600	244,455	33,178		0.7	0.05	7.00	370	651,681	22,008		0.7	<0.05	55,186		7	450			1410444	52048			
03-Jan-01	7.5	560	291,070	46,615		1.1	0.1	7.50	340	686,259	34,578		0.5	0.05	81,193		6	480			1486531	76087			
29-Jan-01	7.5	560	326,597	35,527		0.9	0.05	7.10	340	710,833	24,574		0.7	<0.05	60,101		5	530			1540129	53598			
28-Feb-01	6.8	520	366,938	40,361		0.3	0.05	6.80	300	734,561	23,728		0.3	0.05	64,089		6	520			1600422	60293			
03-Apr-01	7.3	860	415,483	48,545		1.7	0.05	7.00	470	771,739	37,178		0.9	0.05	85,723		6	590			1678883	78461			
01-May-01	7.2	580	454,505	39,022		1.1	0.10	6.60	340	802,188	30,449		1	0.05	69,471		6	520			1739514	60631			
28-May-01	7.3	540	492,511	38,006		0.8	0.10	6.50	330	830,674	28,486		0.9	0.10	66,492		7	520			1794566	55052			
02-Jul-01	7.6	580	540,396	47,885	480,213	0.9	0.05	7.00	330	866,628	35,954	324,586	1	0.05	83,839	804,799	8	540		13	1864957	70391	733,001		
31-Jul-01	7.8	520	579,283	38,887		<0.2	0.05	7.3	300	897,113	30,485		0	0.10	69,372		7	480	220	13	1923595	58638			
28-Aug-01	7.3	590	616,230	36,947		0.6	0.10	6.9	340	922,982	25,869		0	0.05	62,816		7	560	190	14	1970719	47124			
02-Oct-01	7.7	580	661,761	45,531		0	0.00	6.6	340	956,110	33,128		0	0.00	78,659		7	580	200	14	2040309	69590			
29-Oct-01	6.4	590	698,895	37,134		0	0.10	6.5	340	982,705	26,595		0	0.05	63,729		7	590	190	14	2099042	58733			
26-Nov-01	7.2	570	736,768	37,873		0	0.10	6.8	380	10,653	27,948		0	0.10	65,821		7	800	190	14	2159535	60493			
31-Dec-01	7.1	520	765,009	28,241		0	0.10	6.7	300	30,856	20,203		0	0.05	48,444		7	560	190	13	2204144	44609			
28-Jan-02	7.3	600	783,954	18,945		0	0.10	7.3	440	45,970	15,114		0	0.10	34,059		8	640	190	13	2235415	31271			
25-Feb-02	7.1	510	803,286	19,332		0.4	0.10	7.3	410	60,318	14,348		0	0.10	33,680		7	680	170	13	2266456	31041			
01-Apr-02	7.5	570	845,994	42,708		0	0.10	6.6	300	90,780	30,462		0.5	0.05	73,170		7	670	170	13	2333882	67426			
29-Apr-02	7.5	530	886,650	40,656		0.5	0.10	7.3	310	123,080	32,300		0.4	0.05	72,956		7	730	190	13	2400536	66654			
27-May-02	7.3	530	911,598	24,948		0	0.10	7.0	310	142,591	19,511		0	0.00	44,459		7	620	190	13	2441233	40697			
01-Jul-02	7.1	710	950,992	39,394	410,596	0.4	0.10	7.3	380	172,670	30,079	306,042	0.4	0.10	69,473	716,638	7	600	190	13	2505062	63829	640,105		
01-Aug-02	7.4	580	990,235	39,243		0	0.10	7.2	330	203,251	30,581		0	0.00	69,824		7	780	190	14	2568852	63790			
01-Sep-02	7.1	570	27,523	37,288		0	0.00	6.8	370	230,614	27,363		0	0.00	64,651		7	770	190	14	2627871	59019			
01-Oct-02	7.6	700	74,750	47,227		0	0.00	6.3	420	264,880	34,266		0	0.10	81,493		7	820	180	14	2701937	74066			
01-Nov-02	7.0	600	111,790	37,040		0	0.05		330	292,510	27,630		0	0.00	64,670			580		14	2760565	58628			
01-Dec-02		610	158,462	46,672		0	0.11		330	325,950	33,440		0	0.06	80,112		6	560	220	14	2833052	72487			
01-Jan-03	8.4	600	185,572	27,110		0.2	0.05	7.4	350	340,551	14,601		0	0.05	41,711		7	640	250	13	2871121	38069			
01-Feb-03	6.3	670	202,049	16,477		0.4	0.10	6.5	380	347,007	6,456		0	0.05	22,933		6	690	240	13	2892570	21449			
01-Mar-03		310	224,724	22,675		0	0.05		290	368,172	21,165		0	0.05	43,840					13	2932279	39709			
01-Apr-03	7.2	680	232,530	7,806		0	0.10	7.1	380	379,659	11,487		0.5	0.00	19,293					13	2949257	16978			
01-May-03	7.2	680	239,293	6,763		0	0.06		390	388,572	8,913				15,676					13	2962992	13735			
01-Jun-03	6.6	350	242,872	3,579		0	0.00	6.5	300	399,064	10,492		0	0.00	14,071					13	2974823	11831			
02-Jul-03	7.3	640	260,846	17,974	309,854	0.4	0.10	6.4	320	406,553	7,489	233,883	0	0.00	25,463	543,737	6	670		13	2998002	23179	492,940		
01-Aug-03	6.1	300	293,715	32,869		0.4	0.05	6.4	290	427,438	20,885		0	0.00	53,754			630		13	3046483	48481			
01-Sep-03	6.9	340	301,658	7,943		0	0.05	7.3	360	469,224	41,786		0	0.05	49,729			690		14	3088286	41803			
01-Oct-03	6.8	320	301,823	165		0	0.00	6.8	330	509,422	40,198		0	0.05	40,363			660		14	3121353	28125			
01-Nov-03	6.9	340	306,117	4,294		0	0.00	6.9	340	551,170	41,748		0	0.05	46,042			660		14	3159501	32418			
01-Dec-03	7.8	620	306,377	260		0	0.05	7.0	330	590,983	39,813		0	0.00	40,073		5	560		13	3192005	38504			
01-Jan-04	7.2	640	309,909	3,532		0	0.10	7.1	420	612,514	21,531		0	0.10	25,063		5	620		13	3209627	17622			
01-Feb-04	6.4	420	318,063	8,154		0.2	0.00	6.2	400	615,728	3,214		0	0.00	11,368		6	690		13	3212299	2672			
01-Mar-04	7.0	380	325,603	7,540		0	0.10			623,362	7,634				15,174		7	710		13	3218948	6649			
01-Apr-04	7.2	650	334,225	8,622		0.6	0.05	7.1	400	629,828	6,466		0	0.00	15,088		7	650		13	3224184	5236			
01-May-04	8.1	540	343,199	8,974		0.5	0.07	8.1	630	635,949	6,121		0	0.00	15,095		8	530		13	3229348	5164			
01-Jun-04	7.9	420	350,795	7,596		0	1.00			652,893	16,944				24,540		7	600		13	3243650	14302			
01-Jul-04	7.1	620	357,387	6,592	96,541	0	0.10	6.7	230	672,599	19,706	266,046	0	0.20	26,298	362,587	6	650		13	3259995	16345	257,321		
01-Aug-04	6.6	450	363,474	6,087		0	0.05	6.3	330	687,025	14,426		0	0.00	20,513			810		13	3271976	11981			
01-Sep-04	7.2	570	368,430	4,956		0	0.05	6.7	280	694,713	7,688				12,644		7	550		13	3278327	6351			
01-Oct-04	7.2	550	371,957	3,527				6.9	260	700,608	5,895				9,422		6	540		13	3283177	4850			
01-Nov-04	7.0	590	375,924	3,967				5.6	130	713,115	12,507				16,474		6	570		13	3293493	10316			
01-Dec-04	7.0	590	384,025	8,101				6.8	330	732,549	19,434				27,535		6	550		13		0			
01-Jan-05	7.7	680	389,285	5,260		0	0.10	7.0	280	750,128	17,579		0	0.00	22,839		6	670	1	13		0			
01-Feb-05	7.5	560	405,971	16,686				7.5	360	764,499	14,371				31,057		6	610		13		0			
01-Mar-05	7.4	650	429,011	23,040				7.1	340	767,865	3,366				26,406		7	730		13		0			
01-Apr-05	7.1	580	458,068	29,057				6.2	280	769,490	1,625				30,682		6	740		13		0			
01-May-05	7.2	540	485,399	27,331				6.6	300	770,094	604				27,935		7	630		13	3333717	40224			
01-Jun-05	7.1	510	514,926	29,527				5.7	200	770,218	124				29,651		6	580		13	3333766	49			
01-Jul-05	7.4	600	546,761	31,835	189,374	<0.05	0.15	6.0	230	770,606	388	98,007	<0.05	0.1	32,223	287,381	6	590		13	3334045	279	74,050		
01-Aug-05	7.4	580	576,025	29,264				5.7	190	770,625	19				29,283		6	550		13	3334045	?			
01-Sep-05	7.6	610	607,066	31,041				5.5	220	770,643	18				31,059		6	600		13					
01-Oct-05	7.3	600	638,656	31,590				5.4	240	770,657	14				31,604		7	580		14					
01-Nov-05	7.21	460	662,091	23,435				6.71	330	771,979	1,322				24,757		7	490		14					
01-Dec-05	7.62	550	685,423	23,332		<0.05	0.1	6.88	310	775,215	3,236		<0.05	0.05	26,568		7	550		13					
01-Jan-06	7.22	140	700,402	14,979				6.93	340	780,437	5,222				20,201		6	610		13					
01-Feb-06	7.66	620	719,965	19,563				7.38	340	789,104	8,667				28,230		6	630		13					
01-Mar-06	6.95	630	731,380	11,417				6.11	330	800,130	11,026				22,443		6	600		13	no reading				
01-Apr-06	6.98	620	748,508	17,128				5.55	280	806,569	6,439				23,567		5	610		13	no reading				
01-May-06	7.04	550	770,687	22,179						810,432	3,863				26,042		6	540		13	no reading				
01-Jun-06	7.37	630	788,439	17,752				6.91	430	810,454	22				17,774		6	630		13					
01-Jul-06	6.98	500	816,862	28,423	270,103			5.62	220	810,883	429	40,277			28,852	310,290	7	560		13					
01-Aug-06	6.96	510	840,731	23,869				5.45	270	810,895	12				23,881		6	560		13					
01-Sep-06	7.32	640	870,160	29,429				6.85	390	813,452	2,530				31,959		5	640		13					
01-Oct-06	6.94	540	891,726	21,566				7.04	490	814,925	1,473				23,039		5	570		13					
01-Nov-06	7.03	620	910,612	18,886				6.26	330	826,901	11,976				30,862		5	580		13					
01-Dec-06	7.12	610	928,592	17,980				5.88	280	831,184	4,283				22,263		6	570		13					
01-Jan-07	7.80	600	942,224	13,632				7.30	370	838,230	7,046				20,678		5	530		13					
01-Feb-07	6.91	510	963,696	21,472				6.37	280	843,268	5,038				26,510		5	480		13					
01-Mar-07	7.01	520	977,411	13,715				6.71	310	853,436	10,168				23,883		5	620		12					
01-Apr-07	7.04	640	456	23,045				6.69	330	881,654	28,218				51,263		5	660		12					
01-May-07	6.70	570	31,266	30,810				6.79	380	888,138	6,484				37,294		6	520		12					
01-Jun-07	6.94	680	45,932	14,666				6.51	380	892,749	4,611				19,277		6	660		12					
01-Jul-07	8.20	700	76,700	30,768	259,838	<0.2	0.08	8.10	450	899,397	6,648	88,487	<0.2	0.05	37,416	348,325	5	640		13					
01-Aug-07	7.34	590	98,055	21,355				6.94	300	904,363	4,966				26,321		5	550		13					
01-Sep-07	7.18	640	116,566	18,511				7.10	320	907,312	2,949				21,460		6	560		13					
01-Oct-07	7.22	640	147,270	30,704				6.71	340	916,917	9,605				40,309		6	590		13					
01-Nov-07	7.11	630	161,892	14,622				6.62	340	922,359	5,442				20,064		6	580		13					
01-Dec-07	7.08	610	174,704	12,812				6.26	310	925,922	3,563				16,375		6	580		13					
01-Jan-08	7.90	660	176,344	1,640		<0.2	0.11	7.00	310	933,909	7,987		<0.2	0.05	9,627		6	540		13					
01-Feb-08	7.10	680	178,282	1,938				6.71	400	942,935	9,026				10,964		6	690		no survey					
01-Mar-08	7.20	610	193,412	15,130				6.73	330	943,487	552				15,682		6	650		12					
01-Apr-08	7.17	680	198,432	5,020				6.76	380	952,608	9,121				14,141		7	670		no survey					
01-May-08	7.37	690	201,636	3,204				6.63	360	952,718	110				3,314		7	700		13					
01-Jun-08	7.42	680	210,256	8,620				6.20	310	953,157	439				9,059		6	670							
01-Jul-08			246,997	36,741	170,297					953,324	167	53,927			36,908	224,224	6	670							

APPENDIX III

WATER CHEMISTRY DATA

KMB1												
Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	5.2		200									
17-Dec-98	5.4	210	190	45.0	4.0	<0.1	0.02	<0.005	0.3	<0.05	<0.005	<0.05
8-Apr-99	5.4		180	55.0	10.0	<0.2	0.05	<0.05	0.2	<0.05	<0.05	<0.05
7-Jul-99	6.1	250	180	65.0	20.0	<0.2	<0.05	<0.005	0.3	<0.05	<0.005	<0.05
9-Mar-00	6.2	430	250	90.0	45.0	0.3	<0.05	<0.005	0.6	<0.05	<0.005	<0.05
14-Jul-00	5.2	460	300	84.0	90.0	<0.01	<0.01	<0.01	0.48	0.01	<0.01	<0.01
19-Jun-01	5.5	320	220	70.0	30.0	<0.2	<0.05	<0.05	0.3	<0.05	<0.05	0.05
31-Dec-01	4.9		230	65.0					0.3			
1-Jul-02	4.6		260	69.0					0.35			
1-Jan-03			320	78.0					0.6			
1-Apr-03			320									
1-May-03			340									
2-Jul-03			420									
1-Aug-03			360									
1-Sep-03			480									
1-Oct-03			430									
1-Nov-03			500									
1-Dec-03			490									
1-Jan-04	4.8		590	73.0					1.8			
1-Feb-04			490									
1-Mar-04			580									
1-Apr-04			590									
1-May-04			500									
1-Jun-04			620									
1-Jul-04	5.4		600	73.0					2			
1-Aug-04			710									
1-Sep-04	4.6		510									
1-Oct-04	4.6		470									
1-Nov-04	4.6		490									
1-Dec-04	4.8		500									
1-Jan-05	4.6		370	95.0	300.0				2.1			
1-Feb-05	5.0		440									
1-Mar-05	4.9		920									
1-Apr-05	4.9		450									
1-May-05	4.7		300									
1-Jun-05	4.8		260									
1-Jul-05	4.9		330	88.0	150.0				1			
1-Aug-05	4.8		340									
1-Sep-05	4.3		430									
1-Oct-05	4.5		410									
1-Nov-05	4.7		360									
1-Dec-05	5.2		410	86.0	250.0				0.9			
1-Jan-06	4.6		400									
1-Feb-06	5.2		320									
1-Mar-06	4.6		270									
1-Apr-06	4.5		270									
1-May-06	4.6		210									
1-Jun-06	5.1		250									
1-Jul-06	4.7		190	100.0	71.0				0.57			
1-Aug-06	4.7		210									
1-Sep-06	4.8		270									
1-Oct-06	4.6		230									
1-Nov-06	4.5		280									
1-Dec-06	4.7		280									
1-Jan-07	3.7		300	82.0	130.0				0.73			
1-Feb-07	4.8		290									
1-Mar-07	4.6		280									
1-Apr-07	4.8		210									
1-May-07	5.2		140									
1-Jun-07	4.8		210									
1-Jul-07	4.7		320.0	130.0	83.0				0.5			
1-Aug-07	n/a		n/a	Pump failure no sample collected								
1-Sep-07	4.6		220									
1-Oct-07	4.8		270									
1-Nov-07	4.9		270									
1-Dec-07	5.1		260									
1-Jan-08	5.8		250	120.0	160.0				0.85			
1-Feb-08	5.1		270									
1-Mar-08	5.1		240									
1-Apr-08	4.9		210									
1-May-08	5.7		170									
1-Jun-08	4.8		210									
Monitoring no longer required under conditions of GWL60367(3)												

KMB3

Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	7.1		790									
17-Dec-98	7.2	1200	760	240.0	4.0	<0.1	<0.01	<0.005	0.1	<0.05	<0.005	0.10
8-Apr-99	7.2		720	230.0	10.0	<0.2	0.05	<0.05	0.1	<0.05	<0.05	0.10
7-Jul-99	7.5	1300	700	210.0	10.0	<0.2	<0.05	<0.005	0.1	<0.05	0.01	0.10
9-Mar-00	7.1	1200	640	210.0	10.0	<0.2	<0.05	<0.005	0.85	<0.05	0.065	0.10
14-Jul-00	7.1	1200	760	250.0	<1	<0.01	<0.01	<0.01	0.18	0.04	<0.01	<0.01
19-Jun-01	na	na	na	na	na	na	na	na	na	na	na	na
na = no analysis (KMB3 was decomissioned in February 2001)												
Monitoring no longer required under GWL condtions												

KMB5

Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	7.0		860									
17-Dec-98	7.0	1200	660	190.0	6.0	<0.1	<0.01	<0.005	0.1	<0.05	<0.005	0.05
8-Apr-99	7.6		430	120.0	<10	<0.2	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
7-Jul-99	7.4	1700	1000	350.0	30.0	<0.2	<0.05	0.005	0.15	<0.05	0.015	0.10
9-Mar-00	7.2	760	400	55.0	<10	<0.2	<0.05	<0.005	<0.05	<0.05	<0.005	0.10
14-Jul-00	7.2	1600	1000	370.0	24.0	<0.01	<0.01	<0.01	0.1	0.03	<0.01	<0.01
19-Jun-01	7.3	1600	990	340.0	15.0	<0.2	<0.05	<0.05	0.2	<0.05	<0.05	0.10
Monitoring to Recommence - Condition of GWL												

KMB9

Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	4.2		320									
17-Dec-98	4.7	320	260	74.0	5.0	<0.1	<0.01	<0.005	0.35	<0.05	<0.005	<0.05
8-Apr-99	5.1		240	65.0	10.0	<2	<0.05	<0.05	0.35	<0.05	<0.05	<0.05
7-Jul-99	4.4	350	260	80.0	30.0	<0.2	<0.05	<0.005	0.35	<0.05	<0.005	<0.05
9-Mar-00	5.6	280	230	40.0	10.0	0.6	<0.05	<0.005	0.45	<0.05	<0.005	<0.05
14-Jul-00	4.6	290	190	66.0	32.0	<0.01	<0.01	<0.01	0.31	<0.01	<0.01	<0.01
19-Jun-01	5.5	290	270	75.0	15.0	<0.2	<0.05	<0.05	0.45	<0.05	<0.05	<0.05
1-May-03			310									
Monitoring to Recommence - Condition of GWL												

KMB4												
Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	7.3		850									
17-Dec-98	7.4	1300	790	240.0	<5	<0.1	0.01	<0.005	0.1	<0.05	<0.005	0.05
8-Apr-99	7.4		650	180.0	20.0	<0.2	0.05	<0.05	0.05	<0.05	<0.05	<0.05
7-Jul-99	7.8	1300	730	230.0	<10	<0.2	<0.05	<0.005	0.05	<0.05	0.015	0.10
9-Mar-00	7.0	1200	700	220.0	10.0	<0.2	<0.05	<0.005	0.1	<0.05	<0.005	0.10
14-Jul-00	7.1	1300	860	250.0	<1	<0.01	<0.01	<0.01	0.22	0.03	<0.01	<0.01
19-Jun-01	7.8	1200	740	200.0	<10	<0.2	<0.05	<0.05	0.1	<0.05	<0.05	0.10
2-Oct-01	9.0	820	550	210.0	10.0	<0.2			0.1			<0.05
31-Dec-01	9.7	770	500	210.0	9.0	<0.2			<0.05			<0.05
1-Apr-02	9.2	780	500	220.0	7.0	0.4			<0.05			<0.05
1-Jul-02	8.9	820	580	220.0	9.0	0.4			<0.05			<0.05
1-Oct-02	9.1	850	650	210.0	10.0	<0.2			<0.05			0.05
1-Jan-03	6.4	750	490	240.0	9.0	0.4			<0.05			<0.05
1-Apr-03	6.9	860	490	220.0	8.0	0.4			<0.05			<0.05
1-May-03			620									
1-Jun-03			550									
1-Jul-03	8.9	850	550	220.0	11.0	<0.2			<0.05			<0.05
1-Aug-03			540									
1-Sep-03			610									
1-Oct-03	8.7		560	230.0	11.0				<0.05			<0.05
1-Nov-03			580									
1-Dec-03			560									
1-Jan-04	8.9		550	230.0	11.0	<0.2			<0.05			<0.05
1-Feb-04			580									
1-Mar-04			510									
1-Apr-04	6.8		640	240.0	11.0	0.5			0.05			0.10
1-May-04			540									
1-Jun-04			570									
1-Jul-04	7.0	1100	580	220.0	12.0	0.2			0.05			1.40
1-Aug-04	6.5		730									
1-Sep-04	7.1	1170	580									
1-Oct-04	7.0	1230	570									
1-Nov-04	6.9	1280	610									
1-Dec-04	6.9	1300	620									
1-Jan-05	7.6	1200	640	240.0	21.0							
1-Feb-05	7.1	1210	590									
1-Mar-05	7.1	1300	680									
1-Apr-05	6.9	1070	600									
1-May-05	6.9	1080	520									
1-Jun-05	7.0	1100	510									
1-Jul-05	7.0	1060	550									
1-Aug-05	7.1	1040	540									
1-Sep-05	7.6	1080	580									
1-Oct-05	8.6	1050	530									
1-Nov-05	8.0	950	440									
1-Dec-05	7.3	1000	510	210.0	<10				<0.05			0.05
1-Jan-06	7.4	1180	590									
1-Feb-06	7.5	1370	670									
1-Mar-06	6.9	1120	590									
1-Apr-06	7.0	1160	580									
1-May-06	6.8	1020	500									
1-Jun-06	7.2	1090	570									
1-Jul-06	7.2	1010	460	180.0	29.0	2.1			0.11			<0.05
1-Aug-06	6.9	930	460									
1-Sep-06	7.3	1100	580									
1-Oct-06	6.9	1020	460									
1-Nov-06	7.3	760	550									
1-Dec-06	7.3	1060	530									
1-Jan-07	7.6	1000	520	190.0	45.0				0.13			
1-Feb-07	6.9	920	460									
1-Mar-07	7.0	1180	570									
1-Apr-07	7.1	1220	570									
1-May-07	7.1	920	460									
1-Jun-07	7.8	1090	600									
1-Jul-07	8.3	970	680	180.0	47.0				0.0			0.0
1-Aug-07	8.0	1090	480									
1-Sep-07	7.2	1020	540									
1-Oct-07	7.5	1060	540									
1-Nov-07	7.4	1180	530									
1-Dec-07	7.1	1100	530									
1-Jan-08	7.9	1000	530	180.0	61.0				0.1			<.0.01
1-Feb-08	6.9	1250	640									
1-Mar-08	6.8	1100	580									
1-Apr-08	6.8	1120	610									
1-May-08	7.1	1070	580									
1-Jun-08	7.4	1050	590									

KMB6

Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	4.6		330									
17-Dec-98	4.9	320	440	68.0	13.0	0.3	0.02	<0.005	1.4	<0.05	<0.005	0.10
8-Apr-99	7.3		440	90.0	<10	<2	0.05	<0.05	3.6	0.05	<0.05	<0.05
7-Jul-99	4.4	170	190	20.0	20.0	0.3	<0.05	0.005	0.15	<0.05	0.005	0.05
9-Mar-00	5.0	420	630	70.0	60.0	0.6	<0.05	<0.005	1.8	<0.05	0.02	0.05
14-Jul-00	3.5	460	290	81.0	55.0	<0.01	<0.01	<0.01	0.22	0.01	<0.01	<0.01
19-Jun-01	4.5	590	470	160.0	35.0	0.6	<0.05	<0.05		<0.05	<0.05	
31-Dec-01	3.7	640	750									
1-Jul-02	3.8	340	370									
1-Jan-03	3.8	370	540									
1-Apr-03			470									
1-May-03			570									
2-Jul-03			600									
1-Aug-03			100									
1-Sep-03			270									
1-Oct-03			230									
1-Nov-03			220									
1-Dec-03			200									
1-Jan-04	4.2	280	310									
1-Feb-04			420									
1-Mar-04			600									
1-Apr-04			790									
1-May-04			270									
1-Jun-04			530									
1-Jul-04	3.9		190									
1-Aug-04			200									
1-Sep-04	4.3	230	100									
1-Oct-04	4.8	160	70									
1-Nov-04	4.6	200	80									
1-Dec-04	4.2	340	170									
1-Jan-05	3.6	500	490									
1-Feb-05	3.8	750	350									
1-Mar-05	4.3	860	420									
1-Apr-05	4.4	720	380									
1-May-05	4.5	700	320									
1-Jun-05	3.8	230	110									
1-Jul-05	4.5	310	160									
1-Aug-05	3.9	300	130									
1-Sep-05	4.3	180	90									
1-Oct-05	4.7	160	70									
1-Nov-05	4.5	170	80									
1-Dec-05	4.8	230	100									
1-Jan-06	4.1	310	140									
1-Feb-06	4.3	460	210									
1-Mar-06	3.7	620	320									
1-Apr-06	3.6	880	440									
1-May-06	4.1	680	350									
1-Jun-06	4.8	760	390									
1-Jul-06	4.9	630	310									
1-Aug-06	3.5	530	280									
1-Sep-06	3.8	590	300									
1-Oct-06	3.8	420	220									
1-Nov-06	3.6	550	260									
1-Dec-06	3.7	590	270									
1-Jan-07	3.1	740	840						0.67			
1-Feb-07	3.6	770	320									
1-Mar-07	4.1	790	370									
1-Apr-07	4.3	850	410									
1-May-07	4.7	630	350									
1-Jun-07	5.2	770	410									
1-Jul-07	3.9	380.0	310.0									
1-Aug-07	3.6	480.0	200.0									
1-Sep-07	3.9	310.0	160.0									
1-Oct-07	4..46	290.0	130.0									
1-Nov-07	4.1	300.0	130.0									
1-Dec-07	3.2	360	160									
1-Jan-08	3.8	410	350									
1-Feb-08	3.9	620	300									
1-Mar-08	4.6	500	270									
1-Apr-08	5.2	510	270									
1-May-08	5.4	550	290									
1-Jun-08	3.9	630	350									

KMB7												
Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
31-Jul-01	7.8		520			<0.2						0.05
28-Aug-01	7.3		590			0.6						0.10
2-Oct-01	7.7		580			<0.2						<0.05
29-Oct-01	6.4		590			<0.2						0.10
26-Nov-01	7.2		570			<0.2						0.10
31-Dec-01	7.1		520			<0.2						0.10
28-Jan-02	7.3		600			<0.2						0.10
25-Feb-02	7.1		510			0.4						0.10
1-Apr-02	7.5		570			<0.2						0.10
29-Apr-02	7.5		530			0.5						0.10
27-May-02	7.3		530			<0.2						0.10
1-Jul-02	7.1	1000	710	120.0	58.0	0.4	<0.05	<0.05	0.8	<0.05	<0.05	0.10
1-Aug-02	7.4		580			<0.2						0.10
1-Sep-02	7.1		570			<0.2						<0.05
1-Oct-02	7.6		700			<0.2						<0.05
1-Nov-02	7.0	990	600		50.0	<0.2						0.05
1-Dec-02		1000	610			<0.2						0.11
1-Jan-03	8.4	900	600	140.0	53.0	0.2						0.05
1-Feb-03	6.3		670			0.4						0.10
1-Mar-03		590	310			<0.02						0.05
1-Apr-03	7.2		680			<0.2						0.10
1-May-03	7.2		680			<0.2						0.06
1-Jun-03	6.6		350			<0.2						<0.05
1-Jul-03	7.3		640			0.4						0.10
1-Aug-03	6.1		300			0.4						0.05
1-Sep-03	6.9		340			<0.2						0.05
1-Oct-03	6.8		320			<0.2						<0.05
1-Nov-03	6.9		340			<0.2						<0.05
1-Dec-03	7.8	1000	620			<0.2						0.05
1-Jan-04	7.2	1000	640	120.0	85.0	<0.2						0.10
1-Feb-04	6.4	620	420			0.2						<0.05
1-Mar-04	7.0	660	380			<0.2						0.10
1-Apr-04	7.2	1000	650			0.6						0.05
1-May-04	8.1	1000	540			0.5						0.07
1-Jun-04	7.9	740	420			<0.2						1.00
1-Jul-04	7.1	1000	620			<0.2						0.10
1-Aug-04	6.6	760	450									
1-Sep-04	7.2	1130	570									
1-Oct-04	7.2	1180	550									
1-Nov-04	7.0	1220	590									
1-Dec-04	7.0	1240	590									
1-Jan-05	7.7	1100	680	140.0	83.0	<0.2						0.10
1-Feb-05	7.5	1160	560									
1-Mar-05	7.4	1260	650									
1-Apr-05	7.1	590	580									
1-May-05	7.2	1110	540									
1-Jun-05	7.1	1180	550									
1-Jul-05	7.4	1170	600									
1-Aug-05	7.4	1110	580									
1-Sep-05	7.6	1130	610									
1-Oct-05	7.3	1170	600									
1-Nov-05	7.2	980	460									
1-Dec-05	7.6	1060	550	160.0	83.0	<0.05						0.10
1-Jan-06	7.2	290	140									
1-Feb-06	7.7	1420	620									
1-Mar-06	7.0	1180	630									
1-Apr-06	7.0	1260	620									
1-May-06	7.0	1130	550									
1-Jun-06	7.4	1200	630									
1-Jul-06	7.0	1090	500									
1-Aug-06	7.0	1030	510									
1-Sep-06	7.3	1220	640									
1-Oct-06	6.9	1130	540									
1-Nov-06	7.0	1200	620									
1-Dec-06	7.1	1220	610									
1-Jan-07	7.8	1100	600	150.0	110.0	<0.2						0.05
1-Feb-07	6.9	1070	510									
1-Mar-07	7.0	1090	520									
1-Apr-07	7.0	1360	640									
1-May-07	6.7	1050	570									
1-Jun-07	6.9	1270	680									
1-Jul-07	8.2	1100.0	700.0			<0.2						0.1
1-Aug-07	7.3	1360.0	590.0									
1-Sep-07	7.2	1220	640									
1-Oct-07	7.2	1270	640									
1-Nov-07	7.1	1360	630									
1-Dec-07	7.1	1280	610									
1-Jan-08	7.9	1200	660	150.0	110.0	<0.2						0.1
1-Feb-08	7.1	1300	680									
1-Mar-08	7.2	1200	610									
1-Apr-08	7.2	1260	680									
1-May-08	7.4	1270	690									
1-Jun-08	7.4	1200	680									

KMB8												
Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	6.8		650									
17-Dec-98	7.2	890	580	110.0	62.0	<0.1	0.02	<0.005	0.75	<0.05	<0.005	<0.05
8-Apr-99	7.1		630	140.0	50.0	<0.2	0.05	<0.05	0.15	<0.05	<0.05	<0.05
7-Jul-99	6.8	1200	740	180.0	160.0	<0.2	<0.05	<0.005	0.6	<0.05	0.015	0.05
9-Mar-00	6.2	2800	1700	660.0	310.0	0.4	<0.05	<0.005	11	0.1	<0.005	0.05
14-Jul-00	6.6	3100	2000	830.0	480.0	<0.01	<0.01	<0.01	8.2	0.08	<0.01	<0.01
19-Jun-01	7.1	880	560	170.0	15.0	<0.2	<0.05	<0.05	0.35	<0.05	<0.05	0.05
31-Jul-01			700									0.05
2-Oct-01	3.2	3800	2800	730.0	1100.0	0.05			130			<0.05
31-Dec-01	6.8	1000	680	190.0	55.0	<0.2			1.6			<0.05
1-Apr-02	5.2	1200	820	270.0	170.0	0.4			14			<0.05
1-Jul-02	7.1	1000	670	150.0	3.0	0.5			1.3			<0.05
1-Oct-02	4.2	520	420	81.0	140.0	2.9			2.5			<0.05
1-Jan-03	6.8	710	530	180.0	36.0	0.5			1			<0.05
1-Apr-03	7.0	960	660	150.0	8.0	<0.2			8.4			<0.05
1-May-03			640									
1-Jun-03			530									
1-Jul-03	6.1	610	480	110.0	100.0	5.4			6.2			<0.05
1-Aug-03			320									
1-Sep-03			370									
1-Oct-03	6.6	880	510	140.0	120.0	1.1			0.45			<0.05
1-Nov-03			500									
1-Dec-03			630									
1-Jan-04	6.1	800	510	130.0	92.0	<0.2			23			<0.05
1-Feb-04			620									
1-Mar-04			670									
1-Apr-04	7.0	1000	660	150.0	39.0	0.5			5.4			<0.05
1-May-04			340									
1-Jun-04			510									
1-Jul-04	6.6	1000	640	190.0	200.0	0.2			1.2			0.30
1-Aug-04			480									
1-Sep-04	6.4	540	250									
1-Oct-04	6.0	610	280									
1-Nov-04	6.0	1200	570									
1-Dec-04	6.1	1120	540									
1-Jan-05	7.1	1300	730	200.0	180.0	<0.2			12			<0.05
1-Feb-05	6.3	1040	490									
1-Mar-05	6.6	1410	720									
1-Apr-05	6.6	1150	600									
1-May-05	6.6	1120	520									
1-Jun-05	6.0	800	380									
1-Jul-05	7.0	270	130									
1-Aug-05	6.1	310	160									
1-Sep-05	6.6	390	190									
1-Oct-05	6.2	900	440									
1-Nov-05	6.5	670	350									
1-Dec-05	7.2	500	250	100.0	19.0				9.4			<0.05
1-Jan-06	6.0	920	470									
1-Feb-06	6.0	660	320									
1-Mar-06	6.0	600	300									
1-Apr-06	6.0	1030	510									
1-May-06	6.5	880	440									
1-Jun-06	7.0	1200	610									
1-Jul-06	6.3	810	400	230.0	9.0				2.1			<0.05
1-Aug-06	6.0	780	440									
1-Sep-06	6.2	950	490									
1-Oct-06	6.2	550	270									
1-Nov-06	6.3	1070	550									
1-Dec-06	6.1	740	350									
1-Jan-07	7.2	1000	600	180.0	76.0	<0.05						
1-Feb-07	6.4	980	400									
1-Mar-07	6.4	1090	520									
1-Apr-07	6.2	1140	560									
1-May-07	5.4	630	300									
1-Jun-07	6.7	1180	640						3.9			
1-Jul-07	7.2	980	630	200.0	150.0							
1-Aug-07	n/a	n/a	n/a	Pump failure no sample collected								
1-Sep-07	6.6	370	180									
1-Oct-07	6.4	280	130									
1-Nov-07	6.5	290	130									
1-Dec-07	6.3	860	400						3.6			
1-Jan-08	7.1	1000	540	210.0	53.0							
1-Feb-08	6.9	1250	630									<0.01
1-Mar-08	7.0	1200	610									
1-Apr-08	7.2	1080	590									
1-May-08	7.2	1130	640									
1-Jun-08	6.9	880	480									

KMB10												
Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	3.8		330									
17-Dec-98	3.8	260	310	53.0	12.0	<0.1	0.01	<0.005	0.55	<0.05	<0.005	<0.05
8-Apr-99	3.9		320	50.0	30.0	<2	0.05	<0.05	0.8	<0.05	<0.05	<0.05
7-Jul-99	3.4	290	280	80.0	40.0	<0.2	<0.05	<0.005	0.3	<0.05	<0.005	<0.05
9-Mar-00	3.9	210	280	40.0	25.0	0.4	<0.05	<0.005	0.7	<0.05	<0.005	0.05
14-Jul-00	3.7	270	170	49.0	48.0	<0.01	<0.01	<0.01	0.56	<0.01	<0.01	<0.01
19-Jun-01	5.4	180	210	40.0	15.0	<0.2	<0.05	<0.05	0.3	<0.05	<0.05	<0.05
31-Dec-01	4.4		350		4.0	<0.2						<0.05
1-Jul-02	5.2		160		4.0	<0.2						<0.05
1-Jan-03	4.4		350			0.3			0.65			<0.05
1-Apr-03			460									
1-May-03			440									
2-Jul-03			360									
1-Aug-03			180									
1-Sep-03			360									
1-Oct-03			270									
1-Nov-03			260									
1-Dec-03			270									
1-Jan-04	3.7	430	330		70.0	<0.2						<0.5
1-Feb-04			350									
1-Mar-04			260									
1-Apr-04			380									
1-May-04			40									
1-Jun-04			250									
1-Jul-04	3.8		240		30.0	<0.2						0.20
1-Aug-04			480									
1-Sep-04	3.7	270	120									
1-Oct-04	4.1	200	80									
1-Nov-04	3.7	270	120									
1-Dec-04	3.9	340	160									
1-Jan-05	3.7	410	320		13.0	0.2						<0.05
1-Feb-05	4.0	340	160									
1-Mar-05	4.9	270	130									
1-Apr-05	5.0	180	110									
1-May-05	4.9	210	90									
1-Jun-05	3.7	460	180									
1-Jul-05	4.2	390	190									
1-Aug-05	3.6	250	120									
1-Sep-05	3.6	250	110									
1-Oct-05	3.7	260	120									
1-Nov-05	3.8	190	80									
1-Dec-05	4.4	220	100		<10							<0.05
1-Jan-06	3.7	290	140									
1-Feb-06	4.4	340	150									
1-Mar-06	3.9	270	140									
1-Apr-06	4.3	240	110									
1-May-06	5.0	180	80									
1-Jun-06	5.3	210	100									
1-Jul-06	5.1	190	70		9.0				0.19			<0.05
1-Aug-06	4.7	220	100									
1-Sep-06	4.2	300	140									
1-Oct-06	3.7	360	150									
1-Nov-06	3.8	270	120									
1-Dec-06	3.9	260	110									
1-Jan-07	3.4	450	310		<10	<0.2						<0.05
1-Feb-07	4.0	250	110									
1-Mar-07	3.9	320	150									
1-Apr-07	3.8	380	170									
1-May-07	4.5	270	140									
1-Jun-07	4.6	210	120									
1-Jul-07	4.3		210.0		52.0				0.5			0.0
1-Aug-07	3.6	430	190									
1-Sep-07	3.6	410	200									
1-Oct-07	3.8	350	170									
1-Nov-07	3.8	290	130									
1-Dec-07	3.8	350	150									
1-Jan-08	3.8	360	240		66.0							0.0
1-Feb-08	3.8	440	210									
1-Mar-08	4.0	470	230									
1-Apr-08	4.2	270	140									
1-May-08	4.1	370	180									
1-Jun-08	3.7	530	280									

KMB11												
Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	4.8		240									
17-Dec-98	5.4	160	180	38.0	3.0	<0.1	0.01	<0.005	0.7	<0.05	<0.005	<0.05
7-Jul-99	4.8	280	240	95.0	20.0	<0.2	<0.05	<0.005	0.7	<0.05	<0.005	0.05
9-Mar-00	4.2	180	160	30.0	10.0	0.3	<0.05	<0.005	0.65	<0.05	<0.005	0.10
14-Jul-00	4.6	250	160	64.0	9.0	<0.01	<0.02	<0.03	0.9	<0.01	<0.01	<0.01
1-Apr-03			360									
1-May-03			370									
1-Jun-03			310									
1-Jul-03			290									
1-Aug-03			250									
1-Sep-03			300									
1-Oct-03			310									
1-Nov-03			320									
1-Dec-03			300									
1-Jan-04			260									
1-Feb-04			300									
1-Mar-04			240									
1-Apr-04			350									
1-May-04			80									
1-Jun-04			220									
1-Jul-04			170									
1-Aug-04			330									
1-Sep-04			190									
1-Oct-04			180									
1-Nov-04	5.5		200									
1-Dec-04	5.5	370	170									
1-Jan-05			280									
1-Feb-05	5.4	340	130									
1-Mar-05	5.6	370	180									
1-Apr-05	5.5	380	110									
1-May-05	5.3	350	150									
1-Jun-05	5.6	310	150									
1-Jul-05	6.0	420	210									
1-Aug-05	5.5	390	180									
1-Sep-05	5.6	430	220									
1-Oct-05	5.6	430	210									
1-Nov-05	5.4	170	80									
1-Dec-05	5.8	110	50									
1-Jan-06	5.2	140	60									
1-Feb-06	5.8	170	70									
1-Mar-06	5.2	160	80									
1-Apr-06	5.4	160	70									
1-May-06	5.5	150	70									
1-Jun-06	5.9	240	110									
1-Jul-06	5.9	340	160									
1-Aug-06	5.6	360	180									
1-Sep-06	5.8	450	220									
1-Oct-06	5.6	390	190									
1-Nov-06	5.5	450	220									
1-Dec-06	5.5	460	210									
1-Jan-07	5.5	450	310									
1-Feb-07	5.5	400	170									
1-Mar-07	5.5	470	220									
1-Apr-07	5.4	510	230									
1-May-07	5.4	380	200									
1-Jun-07	5.5	470	240									
1-Jul-07	6.7	430	350									
1-Aug-07	5.7	500	210									
1-Sep-07	5.7	430	220									
1-Oct-07	5.7	460	230									
1-Nov-07	5.8	510	220									
1-Dec-07	5.7	480	220									
1-Jan-08	6.1	430	290									
1-Feb-08	5.6	500	250									
1-Mar-08	5.6	470	230									
1-Apr-08	bore damaged											
1-May-08	5.8	430	220									
1-Jun-08	5.9	400	220									

KMB12												
Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Sep-98	6.3		370									
17-Dec-98	6.8	320	270	51.0	9.0	<0.1	0.02	<0.005	0.4	<0.05	<0.005	<0.05
8-Apr-99	6.2		230	30.0	<10	<0.2	<0.05	<0.05	0.3	<0.05	<0.05	<0.05
9-Mar-00	5.8	260	200	30.0	15.0	0.2	<0.05		0.5	<0.05	<0.005	
14-Jul-00	6.1	470	300	81.0	91.0	<0.01	<0.01	<0.01	0.35	0.01	<0.01	<0.01
19-Jun-01	7.6	770	490	90.0	10.0	<0.2	<0.05	<0.05	0.1	<0.05	<0.05	0.10
31-Dec-01	6.7	740	480	95.0	3.0	0.4						0.05
1-Jul-02	7.3	820	460	110.0	3.0	0.4						0.10
1-Jan-03	7.9	750	500	120.0	3.0	1.1						0.05
1-Apr-03			540									
1-May-03			550									
1-Jun-03			500									
1-Aug-03			460									
1-Sep-03			520									
1-Oct-03			500									
1-Nov-03			530									
1-Dec-03			470									
1-Jan-04	6.6	790	500	99.0	4.0	<0.2						0.05
1-Feb-04			580									
1-Mar-04			420									
1-Apr-04			480									
1-May-04			270									
1-Jun-04			410									
1-Jul-04	7.1	760	320	100.0	8.0	<0.2						0.25
1-Aug-04			520									
1-Sep-04	7.1	850	410									
1-Oct-04	7.4	900	410									
1-Nov-04	7.3	910	440									
1-Dec-04	7.2	870	410									
1-Jan-05	8.0	830	480	110.0	2.0	<0.2						0.10
1-Feb-05	7.4	860	410									
1-Mar-05	7.5	960	480									
1-Apr-05	7..21	810	420									
1-May-05	7.3	870	420									
1-Jun-05	7.3	860	400									
1-Jul-05	7.5	870	440									
1-Aug-05	7.2	840	430									
1-Sep-05	7.5	850	440									
1-Oct-05	7.2	880	440									
1-Nov-05	7.4	760	360									
1-Dec-05	7.6	810	410	120.0	<10							0.10
1-Jan-06	7.3	930	470									
1-Feb-06	7.7	1000	470									
1-Mar-06	7.1	840	430									
1-Apr-06	7.2	920	450									
1-May-06	7.2	830	400									
1-Jun-06	7.6	880	450									
1-Jul-06	7.3	850	390	100.0	8.0							0.05
1-Aug-06	7.3	780	370									
1-Sep-06	7.4	930	490									
1-Oct-06	7.0	880	410									
1-Nov-06	7.2	870	450									
1-Dec-06	7.2	870	420									
1-Jan-07	7.8	840	500	120.0	5.0	2.6						0.05
1-Feb-07	6.8	820	370									
1-Mar-07	7.2	950	440									
1-Apr-07	7.1	1010	470									
1-May-07	7.2	1270	670									
1-Jun-07	7.2	920	490									
1-Jul-07	8.4	850	530	110.0	4.0							0.07
1-Aug-07	7.5	960	450									
1-Sep-07	7.6	880	480									
1-Oct-07	7.7	940	470									
1-Nov-07	7.4	980	450									
1-Dec-07	7.4	940	430									
1-Jan-08	7.9	820	440	120.0	5.0							0.09
1-Feb-08	7.4	970	500									
1-Mar-08	7.2	900	469									
1-Apr-08	7.5	900	490									
1-May-08	7.3	930	500									
1-Jun-08	7.5	880	500									

KMB13													
Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1-Jul-02	5.8	270	170	68.0	6.0	0.4						<0.05
1-Aug-02			180									
1-Sep-02			190									
1-Oct-02			200									
1-Jan-03	6.4	270	190	80.0	9.0	<0.2						<0.05
1-Apr-03			230									
1-May-03			240									
1-Jun-03			200									
1-Sep-03			180									
1-Oct-03			180									
1-Nov-03			160									
1-Dec-03												
1-Jan-04												
1-Feb-04			210									
1-Mar-04			120									
1-Apr-04			220									
1-May-04			250									
1-Jun-04			60									
1-Jul-04	6.2	280	120	68.0	12.0	0.4						0.25
1-Aug-04			180									
1-Sep-04	5.7	330	140									
1-Oct-04	5.7	300	130									
1-Nov-04	5.6	310	130									
1-Dec-04	5.6	350	170									
1-Jan-05	6.1	310	180									
1-Feb-05	5.7	350	150									
1-Mar-05	5.8	370	180									
1-Apr-05	5.6	310	160									
1-May-05	5.6	350	170									
1-Jun-05	5.8	330	150									
1-Jul-05	5.9	330	160									
1-Aug-05	5.4	310	140									
1-Sep-05	5.7	340	160									
1-Oct-05	5.6	340	160									
1-Nov-05	5.6	270	130									
1-Dec-05	6.1	330	150	72.0	<10							<0.05
1-Jan-06	5.6	370	180									
1-Feb-06	6.1	380	180									
1-Mar-06	5.4	320	150									
1-Apr-06	5.5	360	170									
1-May-06	5.8	260	130									
1-Jun-06	5.9	320	160									
1-Jul-06	6.0	300	130									
1-Aug-06	5.7	270	130									
1-Sep-06	5.8	320	150									
1-Oct-06	5.8	310	140									
1-Nov-06	5.4	320	150									
1-Dec-06	5.6	340	150									
1-Jan-07	5.9	330	170	82.0	9.0	<0.2						0.05
1-Feb-07	5.9	320	130									
1-Mar-07	5.6	390	160									
1-Apr-07	5.5	380	170									
1-May-07	5.7	320	150									
1-Jun-07	5.5	340	170									
1-Jul-07	7.1	310	200	81.0	6.0							<0.01
1-Aug-07	5.8	380	160									
1-Sep-07	5.7	340	170									
1-Oct-07	5.8	300	130									
1-Nov-07	5.8	330	140									
1-Dec-07	5.9	320	140									
1-Jan-08	6.4	280	130	66.0	6.0							<0.01
1-Feb-08	5.9	340	160									
1-Mar-08	5.9	310	160									
1-Apr-08	5.9	330	160									
1-May-08	5.8	320	170									
1-Jun-08	6.0	310	170									

KMB14												
Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
19-Jun-01	7.2	550	330	85.0	45.0	<0.2	<0.05	<0.05	0.8	<0..05	<0.05	0.10
31-Jul-01	7.3		300			<0.2						0.10
28-Aug-01	6.9		340			<0.2						<0.05
2-Oct-01	6.6		340			<0.2						<0.05
29-Oct-01	6.5		340			<0.2						0.10
26-Nov-01	6.8		380			<0.2						0.10
31-Dec-01	6.7		300			0.4						0.05
28-Jan-02	7.3		440			<0.1						-0.90
25-Feb-02	7.3		410			<0.2						0.10
1-Apr-02	6.6		300			0.5						0.05
29-Apr-02	7.3		310			0.4						0.05
27-May-02	7.0		310			<0.2						<0.05
1-Jul-02	7.3	700	380	88.0	30.0	0.4	<0.05	<0.05	1.2	<0.05	<0.05	0.10
1-Aug-02	7.2		330			<0.2						<0.05
1-Sep-02	6.8		370			<0.2						<0.05
1-Oct-02	6.3		420			<0.2						0.10
1-Nov-02		550	330			<0.2						<0.05
1-Dec-02		540	330			<0.2						0.06
1-Jan-03	7.4	520	350	91.0	53.0	<0.2						0.05
1-Feb-03	6.5		380			<0.2						0.05
1-Mar-03		510	290			<0.2						0.05
1-Apr-03	7.1		380			0.5						<0.05
1-May-03			390									
1-Jun-03	6.5		300			<0.2						<0.05
1-Jul-03	6.4		320			<0.2						<.05
1-Aug-03	6.4		290			<0.2						<0.05
1-Sep-03	7.3		360			<0.2						0.05
1-Oct-03	6.8		330			<0.2						0.05
1-Nov-03	6.9		340			<0.2						0.05
1-Dec-03	7.0	530	330			<0.2						<0.05
1-Jan-04	7.1	690	420	86.0	32.0	<0.2						0.10
1-Feb-04	6.2	550	400			<0.2						<0.05
1-Mar-04												
1-Apr-04	7.1	660	400			<0.2						<0.05
1-May-04	8.1	920	630			<0.2						<0.05
1-Jun-04												
1-Jul-04	6.7	540	230			<0.2						0.20
1-Aug-04	6.3	530	330									
1-Sep-04	6.7	570	280									
1-Oct-04	6.9	580	260									
1-Nov-04	5.6	310	130									
1-Dec-04	6.8	600	330									
1-Jan-05	7.0	570	280	85.0	63.0	<0.2						<0.05
1-Feb-05	7.5	740	360									
1-Mar-05	7.1	690	340									
1-Apr-05	6.2	590	280									
1-May-05	6.6	640	300									
1-Jun-05	5.7	460	200									
1-Jul-05	6.0	480	230									
1-Aug-05	5.7	400	190									
1-Sep-05	5.5	460	220									
1-Oct-05	5.4	480	240									
1-Nov-05	6.7	690	330									
1-Dec-05	6.9	640	310	100.0	70.0	<0.05						0.05
1-Jan-06	6.9	690	340									
1-Feb-06	7.4	720	340									
1-Mar-06	6.1	630	330									
1-Apr-06	5.6	590	280									
1-May-06	n/a	n/a	n/a									
1-Jun-06	6.9	830	430									
1-Jul-06	5.6	500	220									
1-Aug-06	5.5	540	270									
1-Sep-06	6.9	750	390									
1-Oct-06	7.0	1040	490									
1-Nov-06	6.3	650	330									
1-Dec-06	5.9	570	280									
1-Jan-07	7.3	690	370	91.0	55.0	<0.2						0.10
1-Feb-07	6.4	570	280									
1-Mar-07	6.7	650	310									
1-Apr-07	6.7	720	330									
1-May-07	6.8	710	380									
1-Jun-07	6.5	720	380									
1-Jul-07	8.1	710	450			<0.2						0.05
1-Aug-07	6.9	690	300									
1-Sep-07	7.1	620	320									
1-Oct-07	6.7	680	340									
1-Nov-07	6.6	740	340									
1-Dec-07	6.3	660	310									
1-Jan-08	7.0	630	310	89.0	64.0	<0.2						0.05
1-Feb-08	6.7	790	400									
1-Mar-08	6.7	640	330									
1-Apr-08	6.8	700	380									
1-May-08	6.6	670	360									
1-Jun-08	6.2	580	310									

WETLANDS													
	Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
	Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
WL3	1-Jul-02	5.8		40									
	30-Dec-02	dry											
	1-Jul-03	5.4		190									
	1-Jul-05	5.4		220									
	1-Dec-05	5.1		360									
	1-Jul-07	dry		dry									
	1-Jan-08	dry		dry									
WL4	31-Dec-01	dry	dry	dry	dry	dry							
	1-Jul-02	dry	dry	dry	dry	dry							
	1-Aug-02	7.3		130									
	1-Sep-02	6.6		210									
	1-Oct-02	6.2		470									
	1-Nov-02	dry	dry	dry									
	1-Dec-02	dry	dry	dry									
	1-Jan-03	dry	dry	dry	dry	dry							dry
	1-Jul-03	6.1	220	160	42.0	26.0	dry						<0.05
	1-Jan-04	dry	dry	dry	dry	dry	0.3						dry
	2-Sep-04	5.9	380	170	93.0	41.0	dry						<0.05
	1-Jan-05	dry	dry	dry	dry	dry	<0.2						dry
	1-Jul-05	5.7	510	260	100.0	64.0	dry						0.10
	1-Dec-05	6.2	740	350	140.0	100.0	0.05						0.05
	1-Jul-07	dry	dry	dry	dry	dry	dry						dry
	1-Jan-08	dry	dry	dry	dry	dry	dry						dry
WL6	1-Jul-02	4.9		270			dry						
	1-Jul-03	4.9		400									
	1-Jan-04	6.5		1600									
	2-Sep-04	6.4		590	290.0	47.0	<0.2						0.15
	1-Jan-05	7.6		3800									
	1-Jul-05	4.4		550									
	1-Dec-05	6.8		300									
	1-Jul-06	dry		dry									
	1-Jan-08	dry		dry									
WL7	1-Jul-02	6.4		2900									
	1-Jan-03	7.3		2600									
	1-Jul-03	6.4		1500									
	1-Jan-04	6.2		1500									
	2-Sep-04	5.8		920	500.0	58.0	<0.2						<0.05
	1-Jan-05	6.4		3200									
	1-Jul-05	6.6		800									
	1-Dec-05	7.0		650									
	1-Jul-06	7.1		-									
	1-Dec-06	dry		dry									
	1-Jul-07	dry		dry									
	1-Jan-08	7.6		2900									

Dredge Pond

Analyte	pH	Electrical Conductivity @ 25ºC	Total Dissolved Solids – by evaporation	Chloride	Sulphate	Nitrate	Cobalt	Copper	Soluble Iron	Manganese	Nickel	Total Phosphorus
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
31-Jul-01	7.4		480		220.0							
28-Aug-01	7.2		560		190.0							
2-Oct-01	6.8		580		200.0							
29-Oct-01	6.6		590		190.0							
26-Nov-01	7.1		800		190.0							
31-Dec-01	7.3		560		190.0							
28-Jan-02	7.5		640		190.0							
25-Feb-02	7.3		680		170.0							
1-Apr-02	6.9		670		170.0							
29-Apr-02	7.1		730		190.0							
27-May-02	6.6		620		190.0							
1-Jul-02	7.4		600		190.0							
1-Aug-02	7.1	630	780		190.0							
1-Sep-02	6.9	620	770		190.0							
1-Oct-02	7.2	640	820		180.0							
1-Nov-02			580									
1-Dec-02	6.4		560		220.0							
1-Jan-03	6.9		640		250.0							
1-Feb-03	6.4		690		240.0							
1-Mar-03												
1-Apr-03												
1-May-03												
1-Jun-03												
2-Jul-03	5.7		670			1.3						<0.05
1-Aug-03			630									
1-Sep-03			690									
1-Oct-03			660									
1-Nov-03			660									
1-Dec-03	5.0		560									
1-Jan-04	5.3		620									
1-Feb-04	5.9		690									
1-Mar-04	6.9		710									
1-Apr-04	6.6		650									
1-May-04	8.0		530									
1-Jun-04	6.7		600									
1-Jul-04	5.9		650									
1-Aug-04			810									
1-Sep-04	6.5		550									
1-Oct-04	6.2		540									
1-Nov-04	6.0		570									
1-Dec-04	6.1		550									
1-Jan-05	6.2	1200	670		1.0	1.2						0.20
1-Feb-05	6.3	1280	610									
1-Mar-05	6.7	1380	730									
1-Apr-05	6.5	1340	740									
1-May-05	6.6	1290	630									
1-Jun-05	2.9	1220	580									
1-Jul-05	6.3	1120	590									
1-Aug-05	6.5	1100	550									
1-Sep-05	6.3	1130	600									
1-Oct-05	6.8	1140	580									
1-Nov-05	6.7	960	490									
1-Dec-05	7.1	1070	550									
1-Jan-06	5.8	1230	610									
1-Feb-06	6.0	1300	630									
1-Mar-06	6.0	1140	600									
1-Apr-06	5.1	1240	610									
1-May-06	5.8	1120	540									
1-Jun-06	5.9	1210	630									
1-Jul-06	6.9	1180	560									
1-Aug-06	5.8	1030	560									
1-Sep-06	5.1	1220	640									
1-Oct-06	5.5	1110	570									
1-Nov-06	5.2	1160	580									
1-Dec-06	5.5	1180	570									
1-Jan-07	5.2	1100	530									
1-Feb-07	5.3	1100	480									
1-Mar-07	5.3	1250	620									
1-Apr-07	5.5	1380	660									
1-May-07	6.3	1030	520									
1-Jun-07	6.0	1240	660									
1-Jul-07	5.4	1100	640									
1-Aug-07	5.4	1280	550									
1-Sep-07	6.1	1090	560									
1-Oct-07	6.1	1190	590									
1-Nov-07	5.6	1250	580									
1-Dec-07	5.5	1240	580									
1-Jan-08	6.4	1100	540									
1-Feb-08	5.9	1340	690									
1-Mar-08	5.7	1250	650									
1-Apr-08	6.5	1220	670									
1-May-08	6.5	1250	700									
1-Jun-08	6.1	1180	670									

APPENDIX 4:
REVIEW OF FLORA, VEGETATION AND CONSERVATION VALUES ON KEMERTON PROJECT AREA
MAY 2003
MATTISKE CONSULTING PTY LTD

KEMERTON SILICA SANDS

REVIEW OF FLORA, VEGETATION AND CONSERVATION VALUES

ON

KEMERTON PROJECT AREA

Prepared for:

Kemerton Silica Sands

Prepared by:

Mattiske Consulting Pty Ltd

May 2003

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1. SUMMARY

This report provides an updated summary of previous botanical studies within the Kemerton project area, previously collated for Gwalia Consolidated Ltd by Mattiske Consulting Pty Ltd's (1999). The minesite is located at Kemerton, approximately 3km north of the Kemerton Industrial Park, 27km northeast of Bunbury and west of Benger Swamp.

The initial operation was assessed and approved by the Environmental Protection Authority in July 1994, subject to conditions stated in the *Kemerton Silica Sand Mining Proposal Gwalia Consolidated Ltd. Report and Recommendations, Bulletin 471* (Environmental Protection Authority 1994).

The project area occurs within the Drummond Sub-District of the Darling Botanical District (Diels 1906; Gardner 1942) in the South-western Botanical Province, as defined by Beard (1980). Previous authors have stressed the significance of landforms, soils and climate in determining the distribution of plant communities in this area (Diels 1906; Havel 1968; Smith 1974; Heddle *et al.* 1980).

Eight botanical studies were undertaken in the project area between 1993 and the 1999 by Mattiske & Associates (1993 a,b,c,d), Ecos Consulting Pty Ltd (1998), Arbortech Pty Ltd (1997) and Muir Environmental (1999). A total of 65 families, 174 genera, and 365 plant taxon (including varieties and subspecies) were recorded. Species representation was greatest in the Papilionaceae (34 taxon), Myrtaceae (39 taxon), Proteaceae (18 taxon) and Cyperaceae (21 taxon) families. This flora composition is typical of the Bassendean (Central and South) Complex, as described by Heddle *et al.*, 1980. 58 introduced taxon were recorded, occurring predominantly in the Asteraceae (11 taxon), Poaceae (10 taxon) and Papilionaceae (7 taxon) families. Weed encroachment was low, with the exception of pasture and cleared areas within the project area.

As a result of the merging of the findings on the flora and also subsequent taxonomic changes, there is a need to update the information on the flora through some targeted survey work to search for a few species and subspecies (namely – *Adenanthos cygnorum* subsp. *chamaephyton* (P3), *Eucalyptus rudis* subsp. *cratyantha* (P4) and *Pimelea ciliata* subsp. *longituba* (P3); which have been recorded previously at the species level but not the subspecies level). All of the latter subspecies have been recorded previously in the general area and therefore need to be re-checked. In addition, *Stylidium scandens*, has been recorded previously but not allocated to a particular assessments. This needs clarification in any future reporting.

Following a search of the databases managed by the Department of Conservation and Land Management (2003), a total of four Declared Rare, no Priority 1, three Priority 2, ten Priority 3 and five Priority 4 species are potentially found on the Swan Coastal Plain near the Kemerton project area.

In the specific project area, one Declared Rare Flora species, *Conostylis micrantha* (R), pursuant to subsection (2) of section 23F of the Wildlife Conservation Act (1950), was located by Ecos Consulting Pty Ltd (1998) and Arbortech Pty Ltd (1997). The collection needs verification as it has not been recorded on other surveys in the area. The latter species is listed as Endangered under the Environmental Protection and Biodiversity Conservation Act (1999).

Six Priority flora species were located within the project area over an extended period. These included *Boronia juncea* subsp. *juncea* (P1), *Boronia gracilis* subsp. *gracilis* (P2), *Acacia semitrullata* (P3), *Goodenia filiformis* (P3), *Caladenia speciosa* (P4) and *Acacia flagelliformis* (P4).

Further investigations are required to address the distribution of the rare and priority species on the project area, as defined above (E.M. Mattiske and Associates 1993a, 1993b, 1993c, 1993d; Ecos Consulting Pty Ltd 1998 and Arbortech Pty Ltd 1997). In addition surveys are required to search for the species as defined above, which may occur in the area (as defined by Keighery 1998 and Muir Environmental 1999).

A total of 24 vegetation communities and 27 vegetation mapping units were defined and mapped for the Kemerton Sands project area, with three of the mapping units comprising disturbed stages of vegetation communities in the area. The representation of the different vascular plant species in the respective vegetation communities at the proposed Kemerton Silica Sands survey area and transport corridor are summarized in Appendix B.

In summary the key issues related to the flora and vegetation values on the Kemerton area:

- The area is recognized as supporting regionally significant vegetation as large sections of the Swan Coastal Plain have been cleared and modified for agricultural and urbanization activities.
- The southern section of the Kemerton survey area has been part of a previous negotiation to protect some of the values in a conservation area (see conservation zones in Bunbury regional planning reports).
- There are a series of EPP wetlands within the Kemerton survey area.
- There are a significant number of conservation category wetlands (including sumplands and damplands) in the Kemerton survey area.
- There are a range of rare and priority species that have been either recorded in the Kemerton survey area or in adjacent areas (and consequently may potentially occur within the specific project area).
- The vegetation communities provide an east-west corridor in an area where few corridors of native vegetation remain. The latter is significant for native fauna movement through the area.
- The vegetation communities, as a result of their very structure and composition provide habitats for vertebrate fauna.
- The structure of the vegetation in some areas has been modified by historical logging as sections of the area were logged in preparation for clearing and pine plantations, which did not eventuate.
- There are several pockets of *Phytophthora cinnamomi* on the survey area and this has significant implications for operational activities as the area is low lying and seasonally wet.

As a result of the timing of the previous studies there is a need to undertake targeted research on selected rare and priority species, updating the map legends with recent taxonomic changes (e.g. *Agonis linearifolia* to *Taxandria linearifolia*) and review the specific values on the proposed development areas as compared with the wider Kemerton area as compared with regional flora and vegetation values. The latter work cannot be undertaken until more specific project specifications and location details are supplied.

2. INTRODUCTION

Mattiske Consulting Pty Ltd. was commissioned in October 1999 by Sons of Gwalia Ltd to review past botanical studies, and determine vegetation and conservation values and rehabilitation requirements within Gwalia Consolidated Ltd's Kemerton Silica Sand project area. This report has been reviewed and updated for Kemerton Silica Sands in February 2003.

2.1 Location

The project area is located 3km north of the Kemerton Industrial Estate and 27km north-north-east of Bunbury and west of Benger Swamp. A transport route runs south through the project area and through the Kemerton Industrial Estate to Marriott road.

2.2 Project and Operation

The initial operation at Kemerton was assessed and approved by the Environmental Protection Authority in July 1994, subject to conditions stated in the ***Kemerton Silica Sand Mining Proposal Gwalia Consolidated Ltd. Report and Recommendations, Bulletin 471*** (Gwalia Consolidated Ltd, 1993; Environmental Protection Authority, 1994).

Kemerton Silica Sands proposes to extend operations within the wider Kemerton survey area. This report summarized values on the wider Kemerton area and does not address the specific values affected by any proposed proposal at this juncture as these details were not supplied by the Kemerton Silica Sands.

2.3 Flora and Vegetation

The Project Area is located in the South Western Botanical Province of Western Australia, in the Darling Botanical District (Diels, 1906) and the Swan Coastal Plain (Coastal Belt) Subregion of the Drummond Botanical Subdistrict (Diels, 1906; Beard, 1990). The distinctive biological values of the Darling System were recognised by Diels (1906) and developed by Gardner (1942). Previous authors have stressed the significance of landforms, soils and climate in determining the distribution of vegetation communities in this area (Diels, 1906; Havel, 1968; Smith, 1974; Heddle ***et al.,*** 1980).

The flora and vegetation of this area has been defined by Beard (1981), Smith (1974) and Heddle ***et al.*** (1980) at a regional scale utilising the structure and floristics of the native vegetation. Heddle ***et al.*** (1980) produced a vegetation map at 1:250 000 scale, which defined vegetation complexes in relation to the landform-soil units, determined by Churchward and McArthur (1980). This regional mapping work defines the Study Area as occurring within the Swan Coastal Plain, predominantly in the Bassendean (Central and South) Complex. Vegetation ranges from a woodland of ***Eucalyptus marginata*** subsp. ***marginata*** (jarrah) **-** ***Allocasuarina fraseriana*** (sheoak) **-** ***Banksia*** spp. to low woodlands of ***Melaleuca*** spp. and sedgelands on the moister sites. ***Banksia menziesii*** is replaced in dominance on the upper slopes by ***Banksia attenuata*** and ***Banksia grandis*** in these southern areas of the complex. The tree species ***Banksia ilicifolia, Banksia littoralis*** and ***Melaleuca preissiana*** are common on the lower lying moister sites.

The survey area also includes some representation of the Serpentine River and Cannington Complexes to the east, the Karrakatta Complex (Central and South)(Heddle *et al.,* 1980) and Southern River Complex to the west (Mattiske, *pers. comm.*). The Southern River Complex consists of an open woodland of marri-jarrah-*Banksia* on elevated areas and a fringing woodland of *Eucalyptus rudis-Melaleuca rhaphiophylla* along streams. This community occurs on soils derived from Aeolian Deposits (Heddle *et al.,* 1980).

2.4 Past Flora and Vegetation Studies

Information has been extracted from the eight botanical studies, which have been undertaken in the project area between 1993 and the 1999, specifically:

- "Gwalia Consolidated Limited - Kemerton Sand Project. Flora and Vegetation Studies by E.M. Mattiske & Associates". February 1993 report details December 1992 reconnaissance botanical studies undertaken throughout entire project area;
- "Gwalia Consolidated Limited - Kemerton Sand Project. Flora and Vegetation by E.M. Mattiske & Associates". June 1993 report details April 1993 vegetation mapping in project area;
- "Gwalia Consolidated Limited - Kemerton Sand Project. Updated Flora and Vegetation Report by E.M. Mattiske & Associates". November 1993 report reviews and supplements flora and vegetation within operational areas undertaken in October 1993;
- "Gwalia Consolidated Limited - Kemerton Sand Project. Vegetation Mapping of Proposed Transport Corridor by E.M. Mattiske & Associates". November 1993 report details vegetation and flora studies and mapping undertaken in a 50m wide strip along the proposed transport route during October 1993;
- "Kemerton Silica Sand Environmental Monitoring Report 1998 by Ecos Consulting Pty Ltd". Annual report outlining quarterly flora monitoring conducted within the project area during 1998;
- "Kemerton Silica Sand Environmental Monitoring Report 1997 by Arbortech Pty Ltd". Annual report outlining quarterly flora monitoring conducted within the project area during 1997;
- "Report of Biological Survey - Phase 1: Kemerton Industrial Estate. Report and Appendices by Muir Environmental". 1999 Report detailing October to November 1998 Biological Surveys of the Kemerton Industrial Estate; and
- "Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area by B.Keighery". 1998 report for the Department of Environmental Protection.

2.5 Rare and Priority Flora

Species of flora and fauna are defined as rare or priority conservation status where their populations are restricted geographically or threatened by local processes. The Department of Conservation and Land Management recognises these threats of extinction and consequently applies regulations towards population and species protection.

Rare Flora species are gazetted under subsection 2 of section 23F of the Wildlife Conservation Act (1950) and therefore it is an offence to "take" or damage rare flora without Ministerial approval. Section 23F of the Wildlife Conservation Act (1950-1980) defines "to take" as "… to gather, pick, cut, pull up, destroy, dig up, remove or injure the flora or to cause or permit the same to be done by any means.

Table 1: Definition of Rare and Priority Flora Species (Department of Conservation and Land Management, 2003)

Note: In other sections of the report these codes are referred to as the SCC – State Conservation Code

Conservation Code	Category
R	Declared Rare Flora – Extant Taxa "Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection and have been gazetted as such."
P1	Priority One – Poorly Known Taxa "Taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey."
P2	Priority Two – Poorly Known Taxa "Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but urgently need further survey."
P3	Priority Three – Poorly Known Taxa "Taxa which are known from several populations, and the taxa are not believed to be under immediate threat (i.e. not currently endangered), either due to the number of known populations (generally >5), or known populations being large, and either widespread or protected. Such taxa are under consideration for declaration as 'rare flora' but need further survey."
P4	Priority Four – Rare Taxa "Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5-10 years."

Priority Flora are under consideration for declaration as 'rare flora', but are in urgent need of further survey (Priority One to Three) or require monitoring every 5-10 years (Priority Four). Table 1 presents the definitions of Declared Rare and the four Priority ratings under the Wildlife Conservation Act (1950) as extracted from Department of Conservation and Land Management (2003). Table 2 presents the definitions of the categories of threatened species under the Environmental Protection and Biodiversity Conservation Act, 1999.

Table 2: Categories of Threatened Flora Species (Environmental Protection and Biodiversity Conservation Act, 1999)

Note: In other sections of the report these codes are referred to as the FCC – Federal Conservation Code

Category Code	Category
Ex	Extinct Taxa which at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
ExW	Extinct in the Wild Taxa which is known only to survive in cultivation, in captivity or as a naturalized population well outside its past range; or it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
CE	Critically Endangered Taxa which at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
E	Endangered Taxa which is not critically endangered and it is facing a very high risk of extinction in the wild in the immediate or near future, as determined in accordance with the prescribed criteria.
V	Vulnerable Taxa which is not critically endangered or endangered and is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.
CD	Conservation Dependent Taxa which at a particular time if, at that time, the species is the focus of a specific conservation program, the cessation of which would result in the species becoming vulnerable, endangered or critically endangered within a period of 5 years.

2.6 Declared Rare or Priority Species Expected to Occur in Project Area.

Following a search of the databases managed by the Department of Conservation and Land Management (2002) a total of:

- four Declared Rare *Flora (Caladenia huegelii, Diuris purdiei, Drakaea elastica, Drakaea micrantha*),
- no Priority 1 species,
- three Priority 2 species (*Oligochaetochilus* sp. Yalgorup (G.Brockman GBB463) (pn), *Boronia capitata* subsp*. capitata, Haloragis aculeolata*),
- ten Priority 3 species (*Schoenus* sp. Waroona (G.J. Keighery 12235) (pn*), Chamaescilla gibsonii, Acacia semitrullata, Lasiopetalum membranaceum, Hibbertia spicata* subsp. *leptotheca, Verticordia attenuata, Haloragis tenuifolia, Myriophyllum echinatum, Hemigenia microphylla, Rhodanthe pyrethrum*) and
- five Priority 4 species (*Conostylis pauciflora* subsp*. pauciflora, Caladenia speciosa, Jacksonia sparsa, Pultenaea skinneri, Anthotium junciforme*).

Only those species that occur on the western sand dune systems near Kemerton were extracted. Those rare and priority species located on the eastern part of the Swan Coastal Plain on the fluviatile soils were not included in the potential species for the Kemerton area. Therefore all of the species listed above may potentially occur near the Kemerton area (Figure 8).

Of these species, *Caladenia huegelii*, *Diuris purdiei* and *Drakaea elastica* are listed as Endangered under the EPBC Act (1999) and *Drakaea micrantha* is listed as Vulnerable under the EPBC Act (1999).

C*aladenia huegelii* (DRF) has been recorded largely within *Banksia*-Jarrah Sheoak woodland and low open forest on sandy soils from Perth to Busselton, with several scattered populations south of the Brockman Highway between Nannup and Augusta and also near Albany. The majority of the populations occur on the sandier soils of the Swan Coastal Plain.

Diuris purdiei (DRF) has been recorded in seasonally moist to wet swamps with sandy soils from Cannington. This species fluctuates in numbers in response to fire. As such it is only known from a restricted number of populations on the Swan Coastal Plain.

Drakaea elastica (DRF) was recorded in *Banksia*-Sheoak woodland with Jarrah and/or Marri on sandy soils from several locations between Gingin and Busselton, and also at Lake Guraga. The flowering period is October to November (CALM, 1998) Populations were located by Muir (1999) on the southeast side of the Kemerton Industrial Estate (Muir study site 348) in deep sandy soils associated with lowland Jarrah-*Banksia* woodland. This species may also occur in the "Lower slope Open Woodland of *Eucalyptus marginata - Banksia* spp. and *Kunzea ericifolia* over *Melaleuca thymoides, Calytrix fraseri* and mixed shrubs" (A-3) vegetation community in the south of the project area.

Drakaea micrantha (DRF) characteristically occurs in *Banksia*-Jarrah-Sheoak woodlands adjacent to winter wet swamps and on hillsides in white-grey sand along the coastal strip between Perth and Albany. The flowering period is between September to October (CALM, 1998) Muir (1999) recorded populations approximately one kilometre from the project area's south western point in deep sandy soil associated with Jarrah-*Banksia* Woodland (Muir study site 183). While not located by Muir (1999), Mattiske (1997,1993a,b,d) or Keighery (1998), it may also be present in the following communities in the project area:

- A-1. Upper slope Open Woodland dominated by *Eucalyptus marginata - Banksia* spp. and *Kunzea ericifolia* over *Stirlingia latifolia* and mixed shrubs over *Dasypogon bromeliifolius,* and
- A-3. Lower slope Open Woodland of *Eucalyptus marginata - Banksia* spp. and *Kunzea ericifolia* over *Melaleuca thymoides, Calytrix fraseri* and mixed shrubs.

Keighery (1998) stated that *Hydatella dioica* (DRF), *Centrolepis caespitosa* (DRF) and *Schoenus capillifolius* (P2) are likely to be present in the project area. *Hydatella dioica* is an annual herb that occurs in muddy claypans in Midland, Ellenbrook, near Bunbury and near Margaret River. *Centrolepis caespitosa* is a tufted annual that flowers from October to December. It occurs in white sand or clay in salt flats. *Schoenus capillifolius* is a semi-aquatic tufted annual that inhabits winter wet clay pans in habitats including *Melaleuca viminea* shrublands, open herb fields. It has also been previously recorded with *Hydatella dioica* (DRF), *Trithuria* sp. and *Triglochin* sp. surrounded by low sedges, low *Verticordia* sp. heath over *Melaleuca lateritia* heath. These three small annual aquatic species can only be located through detailed survey in late spring (CALM, 1998).

The species that may also potentially occur in the area (based on the regional database search, Figure 8) need to also be investigated further to eliminate the likelihood of their occurrence in any potential disturbance areas.

2.7 Other Significant Flora

Keighery (1998) found the following taxa to be uncommon and restricted on the Plain, and these have been extracted and summarized in Figure 2:

- An unusual form of *Melaleuca systena* growing to two metres;
- *Melaleuca* sp. *(brachyphylla*-B.Keighery), an uncommon species on the Plain;
- *Hakea trifurcata* – a small-flowered form previously only known from the Peel-Harvey region, previously located by Mattiske in communities D2 and E2; and
- *Hibbertia perfoliata* – an uncommon poorly-collected species on the Plain (Muir, 1999). Found in communities C3 and D2.

Keighery (1998) noted that *Verticordia nitens* and *Banksia menziesii* are at the southern limits of their range. *Verticordia nitens* is common to the sandplains north of Perth, but is known to occur in only two areas to the south of Perth. It was located by Mattiske in community A3. This is the most southern *Banksia menziesii* recording, with the closest known population being from Peel area. It has previously been recorded by Mattiske in communities A3 and G1.

Evandra pauciflora is noted in Keighery's 1998 study to be a distinctive sedge that inhabits damplands on the Swan Coastal Plain from Forrestdale to the Capel Nature Reserve. This sedge is a distinguishing aspect of wetlands with mixed shrubs.

2.8 Threatened Ecological Communities and Significance of Vegetation

A range of communities has been defined as threatened ecological communities (English and Blyth 1997) for Western Australia. This includes a significant number of communities on the Swan Coastal Plain. Although a range of communities have been recognized by the threatened ecological section of the Department of Conservation and Land Management, these communities currently do not have the same level of legal protection at the State level.

The latter situation will be changed when the Wildlife Conservation Act (1950) is updated to the Biodiversity Act (in preparation).

Selected threatened ecological communities are listed under the Environmental Protection and Biodiversity Conservation Act (EPBC Act, 1999) at the Federal level. Consequently those communities listed under the Federal legislation are a trigger under the EPBC Act (1999).

The significance of vegetation on the Swan Coastal Plain has increased in recent decades primarily as large sections have been cleared for agricultural activities and urbanization. In addition, there has been an increasing awareness of the values of remnant vegetation in terms of protecting biodiversity and the ecological functions of catchments.

3. OBJECTIVES

The specific objectives of this study are:

- to review flora and vegetation data collected for the proposed mine area and transport corridor collect between December 1992 and October 2003;
- to review the conservation status of all flora species, with reference to listings on the Declared Rare and Priority Flora species, as defined by the Department of Conservation and Land Management (2003);
- to review the conservation status of the vegetation in relation to conservation category wetlands and threatened ecological communities (as defined by the Environmental Protection and Biodiversity Conservation Act 1999 and English and Blyth 1997).
- to assess potential dieback locations, issues and management; and
- to prepare a series of maps and a report summarizing information collated to date.

4. METHODS

Detailed recordings of the vascular plant species were recorded during eight field studies by Mattiske & Associates (1993a,b.c.d), Ecos Consulting Pty Ltd (1998), Arbortech Pty Ltd (1997), Keighery (1998) and Muir Environmental (1999).

The most comprehensive field studies for the Kemerton survey area were undertaken by E.M. Mattiske & Associates between December 1992 and October 1993. The initial study in December 1992 concentrated on the wetlands on the north-eastern section of the proposed mining operations. April 1993 studies encompassed the entire Project Area, which was supplemented by additional opportunistic annual and other species collections in October 1993. In the same period, detailed flora and vegetation studies were undertaken over the 50m wide transport corridor.

4.1 Flora

Methods for work undertaken by E.M. Mattiske and Associates can be found in the respective reports (E.M. Mattiske and Associates 1993a, 1993b, 1993c, 1993d). The methods for the work undertaken by other consultants are summarized in the respective reports by Ecos Consulting Pty Ltd (1998), Arbortech Pty Ltd (1997), Keighery (1998) and Muir Environmental (1999).

E.M. Mattiske and Associates systematically recorded flora at each survey site and collections made where further identification was required. Selective opportunistic collecting was carried out at additional sites in vegetation communities of like structure and floristic composition.

A search of the Department of Conservation and Land Management's Declared Rare and Priority Flora records known to occur in the region was undertaken prior to survey (Department of Conservation and Land Management, 1992). During the survey, particular attention was directed towards searching for endangered flora.

All plant specimens collected during the field survey were handled and identified in accordance with the requirements of the Western Australian Herbarium. When necessary, specimens were compared with pressed specimens housed at the Western Australian Herbarium, and plant taxonomists with specialist skills were consulted. Nomenclature of recorded species follows Western Australian Herbarium protocols (2003).

4.2 Vegetation

The studies by E.M. Mattiske and Associates field included regular recordings and were taken at sites within different vegetation communities to assist in the vegetation mapping and definition of conservation values. The transport corridor was surveyed to 50m by two people walking the route.

The vegetation map of 1:10,000 was prepared using:

- field data collected in December 1992, April 1993 and October 1993;
- foot, road and track traverses and opportunistic field observations; and
- aerial photographs supplied by Gwalia Consolidated Ltd.

4.3 Conservation Significance of Vegetation

The local and regional significance of the vegetation communities recorded were ascertained by:

- presence of EPP wetlands, as per the ***Environmental Protection (Coastal Plain Lakes) Policy*** (EPP 1992, 1999);
- location of Conservation Wetlands defined by the Water and Rivers Commission
- locally and regionally significant communities highlighted by the mapping work of Heddle *et al*. (1980) and the floristic studies of Gibson *et al*. (1994);
- English and Blyth (1997)'s Threatened Ecological Community study;
- Threatened Ecological Communities as defined and listed under EPBC Act (1999);

- Perth's Bush Forever (Environmental Protection Authority *et al*., 1998);
- unusual or uncommon vegetation types;
- threatened ecological communities (including similar communities);

- native species diversity per vegetation community;
- weed species diversity per vegetation community;
- species diversity compared with Gibson *et al*. (1994) floristic data.

5. RESULTS

5.1 Flora

A total of 65 families, 174 genera, and 365 plant taxon (including varieties and subspecies) were recorded in the mine area from December 1992 to and October 1998 by field studies, Appendix A. The species by site-vegetation types as defined by E.M. Mattiske and Associates (1993c) are summarized in Appendix B.

Native species representation was greatest in the Cyperaceae, Restionaceae, Proteaceae, Papilionaceae, Epacridaceae and Myrtaceae families, a flora composition typical of the Bassendean (Central and South) botanical complex, as described by Heddle *et al.,* 1980. Wetland systems were dominated by species from the Restionaceae, Cyperaceae and Myrtaceae families. Appendix A lists flora species recorded in the proposed mine area and transport route.

5.2 Introduced Species

58 weed species were recorded in the survey areas, occurring predominantly in the Asteraceae (11 taxon), Poaceae (10 taxon) and Papilionaceae (7 taxon) families. Appendix A lists introduced species (denoted by an asterisk) in the survey areas. Weed encroachment was low, with the exception of pasture and cleared areas.

The most common species are annuals or short lived perennials, dominated by Blowfly grass *(Briza maxima),* Shivery grass *(Briza minor),* Smooth catsear *(Hypochaeris glabra)* and Hair's tail grass *(Lagurus ovatus).* These species inhabit the following communities:
Blowfly grass *(Briza maxima)* **–** in communities A1, A2, A3, C1, C3, D1, E2, G1, G2, H1.
Shivery grass *(Briza minor)* **–**in communitiesA3, B1, C3, E3, G2.
Smooth catsear *(Hypochaeris glabra)* **–** in communities B1, C3, D2, G2, H1.
Hair's tail grass *(Lagurus ovatus)* – in communities A3, E2, F1, H1.

Three major aggressive species have been recorded in the survey area, namely:

- Bulrush *(Typha occidentalis)*. This aggressive coloniser of the Swan Coastal Plain inhabits seasonally inundated *Melaleuca rhaphiophylla* woodlands (community F2)
- Bulbil Watsonia *(Watsonia meriana* var. *bulbillifera)* is a serious invader of clay wetlands on the Swan Coastal Plain and occurs on the lower slope *Eucalyptus marginata-Banksia* spp. woodlands (community A-3), and
- Tagasaste *(Chamaecystis palmensis)* prolifically regenerates from seed. This species was found in cleared pasture areas.

5.3 Declared Rare or Priority Flora

Following a search of the databases managed by the Department of Conservation and Land Management (2002) a total of:

- four Declared Rare *Flora (Caladenia huegelii, Diuris purdiei, Drakaea elastica, Drakaea micrantha*),
- no Priority 1 species,
- three Priority 2 species (*Oligochaetochilus* sp. Yalgorup (G.Brockman GBB463) (pn), *Boronia capitata* subsp. *capitata, Haloragis aculeolata*),
- ten Priority 3 species (*Schoenus* sp. Waroona (G.J. Keighery 12235) (pn*), Chamaescilla gibsonii, Acacia semitrullata, Lasiopetalum membranaceum, Hibbertia spicata* subsp. *leptotheca, Verticordia attenuata, Haloragis tenuifolia, Myriophyllum echinatum, Hemigenia microphylla, Rhodanthe pyrethrum*) and
- five Priority 4 species (*Conostylis pauciflora* subsp. *pauciflora, Caladenia speciosa, Jacksonia sparsa, Pultenaea skinneri, Anthotium junciforme*).

Of these species, *Caladenia huegelii, Diuris purdiei* and *Drakaea elastica* are listed as Endangered under the EPBC Act (1999) and *Drakaea micrantha* is listed as Vulnerable under the EPBC Act (1999).

In the specific project area, one Declared Rare Flora species, *Conostylis micrantha* (R), pursuant to subsection (2) of section 23F of the Wildlife Conservation Act (1950), was located by Ecos Consulting Pty Ltd (1998) and Arbortech Pty Ltd (1997). The collection needs verification as it has not been recorded on other surveys in the area. The latter species is listed as Endangered under the Environmental Protection and Biodiversity Conservation Act (1999).

Six Priority flora species were located within the project area over an extended period, although specific locations are not available for all of these species as some records were collected by other consultants and this data was not available at the time of this review of information (Figure 1). The six species included *Boronia juncea* subsp. *juncea* (P1), *Boronia gracilis* subsp. *gracilis* (P2), *Acacia semitrullata* (P3), *Goodenia filiformis* (P3), *Caladenia speciosa* (P4) and *Acacia flagelliformis* (P4).

Boronia juncea subsp. *juncea* (P1) characteristically occurs in low scrub in sand between Bunbury and Mandurah and flowers in April (CALM, 1998) In October 1993, Mattiske (1993c) located 4 populations in excess of 50 plants, and two of less than 3 plants in communities H1, H2, F1 (and abutting F1, F3, H1 and H2). Ecos Consulting Pty Ltd (1998) located another population along a 100m stretch of the cleared margin of the return drain within vegetation community H1 (see map). Field observations suggested this species is short lived and an early coloniser of disturbed areas. Muir Environmental (1999) located *Boronia* populations in the north-east and south (Muir study site locations 67, 91 and 155) in damplands associated with dense *Pericalymma ellipticum* and/or *Astartea fascicularis*. The Department of Conservation’s Wildlife Branch considers that further survey work is necessary to determine whether this species should be recommended for conservation (Keighery, 1998).

A detailed search of wetlands for *Boronia juncea* subsp. *juncea* was undertaken near the project area in October 1993. These wetlands included Benger Swamp and a chain of wetlands up to 50km to the north. Only one population of 50 plants was located, in a heath area approximately south of the Kemerton Sands proposed mining area. Many of the wetlands inspected occurred on private property and were disturbed by grazing and infested with weeds.

Boronia capitata subsp. *gracilis* (P2) inhabits winter-wet swamps and hillsides in white/grey or black sand between Yarloop and Yallingup (CALM, 1998). E.M. Mattiske and Associates recorded this species once in the project area at 13750mN/11550mE in vegetation community A-3 (E.M. Mattiske and Associates 1993a and c).

Acacia semitrullata (P3) has been found in wetland areas and sandplains in white/grey sand, sometimes over laterite clay in Kemerton, Collie, Donnybrook, Harvey, Yallingup and Yarloop. The flowering period is June to August (CALM, 1998). E.M. Mattiske and Associates (1993c) found this species throughout the survey area in vegetation communities A1, A3, B1, E1, E2, G1, G2, H1. Muir Environmental (1999) recorded populations in dampland sites 91 and 155, along swamp fringes and in damplands.

Cyathochaeta stipoides (P3) occurs in grey or red-brown sands of seasonally wet flats from Bow Bridge to Scott River Plain, and from the Capel Nature Reserve. The flowering period is between October to December or in January (CALM, 1998). Keighery (1998) located one population in the wetland adjacent to the northern margin of the silica sand dredge pond. This is the only record of this species on the Plain, represents the most northerly population and is one of only four or five *Cyathochaeta* species recorded on the Swan Coastal Plain.

Dillwynia dillwynioides (P3) inhabits in winter wet depressions in sandy soils in the coastal strip between Gingin and Harvey and flowers between August to December (CALM, 1998). Keighery (1998) located this species in the heavy wetland communities towards the eastern side of the Plain and wetlands to the west and expects this species to inhabit vegetation communities H1 and potentially in H2, F1 and F2 (ie. the Western Extension area).

Myriophyllum echinatum (P3) has been recorded in *Melaleuca* scrub in winter wet flats in clay soils in Guildford and near Busselton. This species flowers in November (CALM, 1998). Keighery (1998) located this species in the heavy wetland communities towards the eastern side of the Plain.

Acacia flagelliformis (P4) inhabits sandy soils in winter wet areas in the Harvey, Eaton, Bunbury, Capel, Busselton and Donnybrook areas and flowers between July to September (CALM 1998). Mattiske collected this species twice within the project area at 8500mN/11200mE and 9000mN/10500mE in vegetation communities H1 and H2. This species was recorded by Muir Environmental (1999) in the Kemerton Industrial Estate in a post-fire dampland complex of *Melaleuca preissiana, Calothamnus lateralis* and *Hakea varia*. Muir considers that other damplands are likely to contain dormant seeds of this species.

Anthotium junciforme (P4) occurs in sandy clay or sand in *Melaleuca* shrublands or heathlands in winter wet depressions in the coastal strip just above Perth to Augusta. The flowering period is January to March or in November or (CALM, 1998). Keighery (1998) located this species in the heavy wetland communities towards the eastern side of the Plain.

Caladenia speciosa ms (P4) inhabits Eucalypt and *Banksia* woodlands in the dunes above paperbark swamps on white grey or black sand, between North Dandalup and Busselton (CALM, 1998). The flowering period is September to October. E.M. Mattiske and Associates (1993c) located this species in vegetation community H1.

Immature specimens collected in the project area by Keighery (1998) were thought to be *Schoenus* ?sp. Waroona (G.J.Keighery 12335)(P3) and *Drosera occidentalis* subsp. *occidentalis* (P4). *Schoenus* sp. Waroona is an annual herb that occurs on winter wet flats of Melaleuca thickets in clay and sandy clay. *Drosera occidentalis* subsp. *occidentalis* has been recorded in swamps and wet depressions on sandy and clayey soils in Cannington, Wattlegrove and Bullsbrook (CALM, 1998).

As a result of the merging of the findings on the flora and also subsequent taxonomic changes, there is a need to update the information on the flora through some targeted survey work to search for a few species and subspecies (namely – *Adenanthos cygnorum* subsp. *chamaephyton* (P3), *Eucalyptus rudis* subsp. *cratyantha* (P4) and *Pimelea ciliata* subsp. *longituba* (P3) which have been recorded previously at the species level but not the subspecies level). All of the latter subspecies have been recorded previously in the general area and therefore need to be re-checked. In addition, *Stylidium scandens*, has been recorded previously but not allocated to a particular assessments.

Consequently, there is a need to undertake further investigations on targeted species, in order to clarify the possibility of locating these taxa on the project area.

In summary, many of these species have been recorded in the Kemerton survey area and consequently there is a need to undertake specific targeted work to further delineate the populations and update Figures 1 and 8 prior to delineating proposed disturbance areas.

5.4 Vegetation

The vegetation was mapped at a detailed level by E.M.Mattiske and Associates (1993a,b,c, d) which defined a total of 24 vegetation communities and 27 vegetation mapping units for the Kemerton Sands survey area, with three of the mapping units comprising disturbed stages of vegetation communities, Figures 3 and 3a. Appendix B summarizes the vascular plant species recorded in each vegetation community at the proposed Kemerton survey area in the E.M. Mattiske and Associates reports (1993a, 1993b, 1993c and 1993d).

Vegetation communities are listed in the following text and, summarised on enclosed vegetation maps. Keighery (1998) reported that the project area also contains *Eucalyptus decipiens* Closed Tree Mallee populations associated with Muchea Limestone communities within vegetation communities D2, F1 and F3. Appendix B illustrates plant species recorded for each vegetation community at the proposed Kemerton Sands Project Area in the Mattiske 1993a,b,c,d reports. Based on interpretations from geological records limestone was not recorded within these areas at Kemerton and therefore the issue of whether the Eucalyptus decipiens reflects a particular community or not is still open to interpretation. After reviewing the distribution of this mallee species on FloraBase it appears that although it is associated with the limestone it is not confined to these Muchea limestone areas.

Table 3 summarizes the vegetation communities in the survey area, compares key species and community structures to vegetation studies by Gibson ***et al.*** (1994) and community rarity assessments by English and Blyth (1997). There are some similarities between the communities but are not necessarily directly comparable. Several need further clarification in relation to the overlap between community composition and those types as defined by Gibson ***et al.*** (1994).

5.5 Wetlands

Wetlands and their fringing vegetation support a diverse range of flora. Vegetation communities are closely related to flora species composition, the local water table, climate and soils (Havel 1975, Muir 1983). Even minor differences in ground water levels result in differing vegetation community types and flora species compositions (Muir, 1999). Consequently, a wetland's integrity and health is closely tied to changes in the local water regime, in addition to bushland fragmentation and disturbance.

The survey area contains a total of 12 wetlands (See Map 3). The following vegetation communities could be considered to dominate the sumplands and damplands in the project area.

C3	Closed Woodland of *Agonis flexuosa* - *Eucalyptus rudis* and *Corymbia calophylla* with occasional *Banksia littoralis,* over *Xanthorrhoea preissii, Macrozamia riedlei* and sparse mixed shrubs and sedges.
D-1	Open Woodland of *Eucalyptus rudis* and *Kunzea ericifolia* over *Hypocalymma angustifolium, Xanthorrhoea preissii* and mixed shrubs over mixed grasses and sedges.
D-2	Woodland of *Eucalyptus rudis* - *Melaleuca preissiana* and occasional *Banksia littoralis* over Myrtaceae spp. over mixed sedges.
D-3	Woodland of *Eucalyptus rudis* and *Melaleuca rhaphiophylla* over *Melaleuca teretifolia* and *Astartea fascicularis* over *Lepidosperma longitudinale.*
E-1	Low Open Woodland of *Melaleuca preissiana* and occasional *Eucalyptus marginata* and *Kunzea ericifolia* over *Hypocalymma angustifolium* and *Calytrix* spp. over *Dasypogon bromeliifolius.*
E-2	Low Woodland of *Melaleuca preissiana* and occasional *Nuytsia floribunda* over *Hypocalymma angustifolium, Pelicalymma ellipticum* and mixed shrubs over mixed sedges.
E-3	Low Woodland of *Melaleuca preissiana* and *Agonis flexuosa* over *Astartea fascicularis* and mixed shrubs over *Lepidosperma longitudinale.*
E-4	Closed Low Forest of *Melaleuca preissiana,* with occasional *Corymbia calophylla* over dense *Agonis linearifolia* over *Pteridium esculentum* and dense *Lepidosperma longitudinale.*
F-1	Seasonally inundated Low Closed Forest of *Melaleuca rhaphiophylla* over Myrtaceae spp. over mixed sedges
F-2	Seasonally inundated Low Open Woodland of *Melaleuca rhaphiophylla* over *Melaleuca viminea* and *Melaleuca cuticularis* over mixed shrubs over mixed sedges
F-3	Waterlogged, Low Woodland of *Melaleuca rhaphiophylla* over *Baumea articulata.*

(Note – *Agonis linearifolia* has been changed to *Taxandria linearifolia,* see Appendix *A*)

Table 3. Relationship between Vegetation Communities, Floristic Community Types, and Threatened Ecological Communities

Community[1]	Description[1]	Floristic Community Types[2]			Ecological Community Category[3]
		Type	Reservation Status	Conservationa Status	
A	**Woodland to Open Woodland of *Eucalyptus marginata* and *Banksia spp.***				
A –1	Upper slope Open Woodland dominated by *Eucalyptus marginata* - *Banksia* spp. and *Kunzea ericifolia* over *Stirlingia latifolia* and mixed shrubs over *Dasypogon bromeliifolius.*	21a	Well Reserved	Low Risk	Low Risk
A –2	Upper slope Open Woodland of *Eucalyptus marginata* - *Banksia attenuata* and *Kunzea ericifolia* over *Allocasuarina humilis, Stirlingia latifolia* and mixed shrubs.	21a	Well Reserved	Low Risk	Low Risk
A –3	Lower slope Open Woodland of *Eucalyptus marginata* - *Banksia spp.* and *Kunzea ericifolia* over *Melaleuca thymoides, Calytrix fraseri* and mixed shrubs.	21a	Well Reserved	Low Risk	Low Risk
B	**Open Woodland of *Eucalyptus marginata* and *Corymbia calophylla***				
B –1	Open woodland of *Eucalyptus marginata, Corymbia calophylla* and *Kunzea ericifolia* over *Pericalymma ellipticum* and *Acacia pulchella* over Poaceae sp.	-	-	-	-
C	**Woodland to Forest of *Agonis flexuosa***				
C –1	Open Forest of *Agonis flexuosa* and *Eucalyptus marginata* over grasses.	21b	Well Reserved	Susceptible	Insufficient information
C –2	Open Woodland of *Agonis flexuosa*, with occasional *Banksia attenuata, Banksia ilicifolia* and *Nuytsia floribunda* over mixed shrubs.	21b	Well Reserved	Susceptible	Insufficient information
C –3	Closed Woodland of *Agonis flexuosa* - *Eucalyptus rudis* and *Corymbia calophylla* with occasional *Banksia littoralis,* over *Xanthorrhoea preissii, Macrozamia reidlei* and sparse mixed shrubs and sedges.	11	Well Reserved	Low Risk	Low Risk
D	**Woodland to Open Woodland of *Eucalyptus rudis***				
D –1	Open Woodland of *Eucalyptus rudis* and *Kunzea ericifolia* over *Hypocalymma angustifolium, Xanthorrhoea preissi* and mixed shrubs over mixed grasses and sedges.	11	Well Reserved	Low Risk	Low Risk
D –2	Woodland of *Eucalyptus rudis* - *Melaleuca preissiana* and occasional *Banksia littoralis* over Myrtaceae spp. over mixed sedges.	4	Well Reserved	Low Risk	Low Risk
D –3	Woodland of *Eucalyptus rudis* and *Melaleuca rhaphiophylla* over *Melaleuca teretifolia* and *Astartea fascicularis* over *Lepidosperma longitudinale.*	12	Well Reserved	Low Risk	Low Risk
E	**Low Woodland to Forest of *Melaleuca preissiana***				
E –1	Low Open Woodland of *Melaleuca preissiana* and occasional *Eucalyptus marginata* and *Kunzea ericifolia* over *Hypocalymma angustifolium* and *Calytrix* spp. over *Dasypogon bromeliifolius.*	4	Well Reserved	Low Risk	Low Risk
E –2	Low Woodland of *Melaleuca preissiana* and occasional *Nutsia floribunda* over *Hypocalymma angustifolium, Pelicalymma ellipticum* and mixed shrubs over mixed sedges.	4	Well Reserved	Low Risk	Low Risk

Table 3. Relationship between Vegetation Communities, Floristic Community Types and Threatened Ecological Communities

Community	Description	Floristic Community Types[1]			Rarity[2]
		Type	Reservation Status	Conservational Status	
E –3	Low Woodland of *Melaleuca preissiana* and *Agonis flexuosa* over *Astartea fascicularis* and mixed shrubs over *Lepidosperma longitudinale.*	4	Well Reserved	Low Risk	Low Risk
E –4	Closed Low Forest of *Melaleuca preissiana,* with occasional *Corymbia calophylla* over dense *Agonis linearifolia* over *Pteridium esculentum* and dense *Lepidosperma longitudinale.*	4	Well Reserved	Low Risk	Low Risk
F	**Low Woodland to Forest of *Melaleuea rhaphiophylla***				
F –1	Seasonally inundated Low Closed Forest of *Melaleuca rhaphiophylla* over Myrtaceae spp. over mixed sedges.	12	Well Reserved	Low Risk	Low Risk
F –2	Seasonally inundated Low Open Woodland of *Melaleuca rhaphiophylla* over *Melaleuca viminea* and *Melaleuca cuticularis* over mixed shrubs over mixed sedges.	7	Well Reserved	Vulnerable	Vulnerable
F –3	Waterlogged, Low Woodland of *Melaleuca rhaphiophylla* over *Baumea articulata.*	13	Well Reserved	Low Risk	Low Risk
G	**Shrubland of Myrtaceae and Proteaceae spp.**				
G –1	Tall Shrubland of dense *Kunzea ericifolia* over *Hypocalymma angustifolium* and mixed shrubs over *Leptocarpus scariosus.*	11	Well Reserved	Low Risk	Low Risk
G –2	Dense Shrubland of *Agonis linearifolia,* with occasional *Eucalyptus marginata* over grasses.	11	Well Reserved	Low Risk	Low Risk
G –3	Shrubland of *Hakea varia, Melaleuca* spp. and *Astartea fascicularis* over *Lepidosperma longitudinale* and *Leptocarpus coangustatus*.	13	Well Reserved	Low Risk	Low Risk
G –4	Waterlogged Shrubland of *Melaleuca viminea*	7	Well Reserved	Vulnerable	Vulnerable
H	**Closed Heath of Myrtaceae spp.**				
H –1	Low Closed Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* and mixed shrubs over mixed sedges, with occasional emergent trees.	11	Well Reserved	Low Risk	Low Risk
H –2	Closed Heath of *Astartea fascicularis, Calothamnus lateralis* and *Cassytha racemosa* over mixed sedges.	11	Well Reserved	Low Risk	Low Risk
H –3	Closed Heath of *Melaleuca lateritia* and *Astartea fascicularis* over *Lepidosperma longitudinale* and *Leptocarpus tenax.*	12	Well Reserved	Low Risk	Low Risk
I	**Disturbance Communities**				
I –1	Disturbed lower slope Open Woodland of *Eucalyptus marginata* and *Banksia* spp.	21b	Well Reserved	Susceptible	Insufficient information
I –2	Cleared area with occasional *Eucalyptus marginata* over *Cartonema philydroides.*	21b	Well Reserved	Susceptible	Insufficient information
I –3	Regenerating community beneath power-line. Sparse *Kunzea ericifolia* over *Aotus gracillima, Pimelea angustifolia* and *Pericalymma ellipticum* over mixed sedges.	11	Well Reserved	Low Risk	Low Risk

[1] Mattiske & Associates (1993a,b,c): [2] Gibson *et al.* (1994) : [3] English and Blyth (1997)

The sensitivity of wetlands in Western Australia to development and altered hydrological regimes has been recognized by the Environmental Protection Authority of Western Australian and the Water and Rivers Commission (Guidance Statement (Environmental Protection Authority 2003). The sensitivity and significance of these areas was recognized in the *Environmental Protection (Swan Coastal Lakes) Policy*, 1992 (Lakes EPP). The latter provides statuary protection for Swan Coastal Plain lakes from filling, draining, mining and effluent discharge. Landowners, proponents, the State and local Government Authorities are responsible for ensuring the lakes are not affected by the above activities. The Lakes EPP policy area extends from Moore River to Dunsborough on the Swan Coastal Plain, and encompasses lakes depicted on the Department of Land Administration Miscellaneous Plan No. 1815. Lakes are defined in the Lakes EPP as those wetlands containing a minimum of 1000m^2 of standing (free) water in the first week of December 1991.

The damplands and sumplands have been recognized as being significant in the area, and although the boundaries were defined largely on the basis of aerial photographic interpretation, the extent of these vegetation communities is apparent from the previous listings and the vegetation map (Figure 3).

The presence of the EPP wetlands on the Kemerton area has been incorporated into site specific planning and the extent of the conservation category wetlands has been documented and mapped in other correspondence associated with the project area. In summary there is no doubt that the area has significant local and regional values associated with the series of damplands, sumplands and EPP wetlands.

5.6 Species Richness

Species richness is defined as a measure of the number of plant species present within a specific area. The species richness results from Gibson *et al.* (1994) for the project area's floristic groupings are compared with species richness data collated as part of the E.M. Mattiske and Associates (1993c) studies. High species diversity is defined by Safstrom and Craig (1996) as over 25-30 perennial species per 100 square metres.

Table 4: Species Richness in Vegetation Communities

Plant Community E M.Mattiske and Associates (1993c)	Gibson et al. (1994)	
	Floristic type	Mean Species Richness
A1	21a	54.6
A2	21a	54.6
A3	21a	54.6
B1	--	--
C1	21b	61.3
C2	21b	61.3
C3	11	27.2
D1	11	27.2
D2	4	36.9
D3	12	26.4
E1	4	36.9
E2	4	36.9
E3	4	36.9
E4	4	36.9
F1	12	26.4
F2	7	46.4
F3	13	17.4
G1	11	27.2
G2	11	27.2
G3	13	17.4
G4	7	46.4
H1	11	27.2
H2	11	27.2
H3	12	26.4
I1	21b	61.3
I2	21b	61.3
I3	11	27.2

5.7 Dieback

Dieback species (known as *Phytophthora* sp.) occur in the project area. These soil-borne pathogens can dramatically alter native vegetation composition by targeting susceptible flora in certain soils and climatic conditions (Old *et al.*, 1980). Many of the species inhabiting the dune systems, and in particular on the lower moist slopes, are vulnerable to this disease.

Dieback has been located at the project area:

- adjacent to the majority of access roads by Ecos Consulting Pty Ltd (1998). The main access road to the plant site, the road to both the dredge pond and the settling pond, the Western Power easement and the Epic Energy Natural Gas Pipeline easement were all found to be infested or was uninterpretable, with a high probability of being infested.
- around the return pond. Dieback was isolated by Arbortech (1997) from samples of dying or dead *Banksia attenuata* around this area.
- in pockets throughout the project area by general observations during vegetation mapping by Mattiske (1993a,b,c,d).

The potential direct and indirect effects of the dieback disease caused by this fungus is an important concern in the short-term management of the vegetation during operations. Based on the information gathered during the above assessments, a dieback management plan prepared by Ecos Consulting Ltd is now in place in the mining area. The Hygiene Management programme involves:

- ensuring the hygiene of vehicles and equipment entering and leaving the project area;
- provision of 'safe' access ways for movement within the area and hygiene prescriptions for management of movement of vehicles and equipment to and from those safe access ways; and
- workforce awareness and training in the nature and management of forest disease.

6. DISCUSSION

This report provides an updated summary of previous botanical studies within the Kemerton project area, previously collated for Gwalia Consolidated Ltd by Mattiske Consulting Pty Ltd's (1999).

The initial operation was assessed and approved by the Environmental Protection Authority in July 1994, subject to conditions stated in the *Kemerton Silica Sand Mining Proposal Gwalia Consolidated Ltd. Report and Recommendations, Bulletin 471* (Environmental Protection Authority 1994).

Eight botanical studies were undertaken in the project area between 1993 and the 1999 by Mattiske & Associates (1993 a,b,c,d), Ecos Consulting Pty Ltd (1998), Arbortech Pty Ltd (1997) and Muir Environmental (1999). A total of 65 families, 174 genera, and 365 plant taxon (including varieties and subspecies) were recorded. Species representation was greatest in the Papilionaceae (34 taxon), Myrtaceae (39 taxon), Proteaceae (18 taxon) and Cyperaceae (21 taxon) families. This flora composition is typical of the Bassendean (Central and South) Complex, as described by Heddle *et al.*, 1980. 58 introduced taxon were recorded, occurring predominantly in the Asteraceae (11 taxon), Poaceae (10 taxon) and Papilionaceae (7 taxon) families. Weed encroachment was low, with the exception of pasture and cleared areas within the project area.

As a result of the merging of the findings on the flora and also subsequent taxonomic changes, there is a need to update the information on the flora through some targeted survey work to search for a few species and subspecies. Further there is a need to update the information as collated with recent changes in taxonomic nomenclature.

Of particular significance in the specific project area, is the need to clarify the significance of the Declared Rare Flora species, *Conostylis micrantha* (R), pursuant to subsection (2) of section 23F of the Wildlife Conservation Act (1950), was located by Ecos Consulting Pty Ltd (1998) and Arbortech Pty Ltd (1997). The collection needs verification as it has not been recorded on other surveys in the area. The latter species is listed as Endangered under the Environmental Protection and Biodiversity Conservation Act (1999). Further investigations are required to address the distribution of the rare and priority species on the project area, as defined above (E.M. Mattiske and Associates 1993a, 1993b, 1993c, 1993d; Ecos Consulting Pty Ltd 1998 and Arbortech Pty Ltd 1997). In addition surveys are required to search for the species as defined above, which may occur in the area (as defined by Keighery 1998 and Muir Environmental 1999).

In summary the key issues related to the flora and vegetation values on the Kemerton area:

- The area is recognized as supporting regionally significant vegetation as large sections of the Swan Coastal Plain have been cleared and modified for agricultural and urbanization activities.
- The southern section of the Kemerton survey area has been part of a previous negotiation to protect some of the values in a conservation area (see conservation zones in Bunbury regional planning reports).
- There are a series of EPP wetlands within the Kemerton survey area.
- There are a significant number of conservation category wetlands (including sumplands and damplands) in the Kemerton survey area.
- There are a range of rare and priority species that have been either recorded in the Kemerton survey area or in adjacent areas (and consequently may potentially occur within the project area).
- The vegetation communities provide an east-west corridor in an area where few corridors of native vegetation remain. The latter is significant for native fauna movement through the area.
- The vegetation communities, as a result of their very structure and composition provide habitats for vertebrate fauna.
- The structure of the vegetation in some areas has been modified by historical logging as sections of the area were logged in preparation for clearing and pine plantations, which did not eventuate.
- There are several pockets of *Phytophthora cinnamomi* on the survey area and this has significant implications for operational activities as the area is low lying and seasonally wet. The dieback mapping which has been undertaken to date requires updating as the coverage of the area was relatively limited.

In addition, following the clarification of the status of targeted species as mentioned above, there is a need to update the presentation of the information as edited in relation to the recently published Guidance Statement by the Environmental Protection Authority (2003). Ideally this should be undertaken during the spring months, however in light of other schedules and the amount of work already undertaken on the project some of the work should commence sooner than spring.

Following the latter targeted research there is a need to finalize and update information in relation to the specific proposed area, once the proposed impact areas are defined.

7. LIST OF PARTICIPANTS

The following personnel of Mattiske Consulting Pty Ltd. were involved with this project:

Principal Ecologist:	Dr E Mattiske
Senior Botanist:	Mrs B Koch
Botanists:	Mrs A O'Connor Ms B Ryan Mr M Braimbridge Ms V Clarke

8. REFERENCES

Arbortech Pty Ltd. 1997. *Kemerton silica Sand Environmental Monitoring Report*. Unpublished report prepared for Gwalia Consolidated Ltd.

Balla, S. 1994. *Wetlands of the Swan Coastal Plain. Vol 1. Their Nature and Management.* Department of Environmental Protection and Water Authority.

Beard, J.S. 1990. *Plant Life of Western Australia*. Kangaroo Press Pty Ltd, NSW.

Beard, J.S. 1979. *The Vegetation of the Perth Area, Western Australia. Map and Explanatory Memoir 1: 250 000 Series.* Vegmap Publications, Perth.

Beard, L.S. (1980)
A New Phytogeographic Map of Western Australia. Western Australian Herbarium Notes Number 3: 37-58.

Beard, L.S. (1981)
Vegetation Survey of Western Australia. Swan. Map and Explanatory Notes, Sheet 7, 1: 1,000,000, Series, University of Western Australia Press, Nedlands.

Beard, J.S. and Webb, M.J. (1974).
The Vegetation Survey of Western Australia : Its Aims, Objects and Methods. Part 1 of Explanatory Notes to Map Sheet 2 of Vegetation Survey of Western Australia. Great Sandv Desert. University of Western Australia Press, Nedlands.

Bridgewater, P.B. 1987. Connectivity: An Australian Perspective. In: D. Saunders, G. Arnold, A. Burbidge, A. Hopkins (Eds.). *Nature Conservation: The Role of Remnants of Native Vegetation*. Surrey Beatty and Sons Pty Ltd, Australia.

BSD Consultants Pty Ltd (1997). Kemerton Expansion Study. Final Draft Report. For Study Management Group: Department of Resources Development, Land Corp, Western Australian Planning Commission and South West Development Committee.

Churchward, H.M. and McArthur, W.M. 1980. Landforms and Soils of the Darling System, Western Australia. In*: Atlas of Natural Resources Darling System Western Australia.* Department of Conservation and Environment.

Dendy, T. 1987. The Value of Corridors (and Design Features of Same) and Small Patches of Habitat. In: D. Saunders, G. Arnold, A. Burbidge, A. Hopkins (Eds.). *Nature Conservation: The Role of Remnants of Native Vegetation*. Surrey Beatty and Sons Pty Ltd, Australia.

Department of Conservation and Environment 1983. *Conservation Reserves for Western Australia as recommended by the Environmental Protection Authority, - 1983. The Darling System - System 6. Part II. Recommendations for Specific Localities.* Report No. 13. October 1983). Published by the Department of Conservation and Environment. Perth.

Diels, L. (1906)
Die Pflanzenwelt von West-Australien sudlich des Wenderkreises.
Vegn. Erde 7: Leipzig.

Department of Conservation and Land Management 1998a. *Declared Rare and Priority Flora List for Western Australia*. Published list by the Department of Conservation and Land Management, Western Australia.

Department of Conservation of Land Management 1998b. *Western Australia's Threatened Flora.* Department of Conservation of Land Management, Western Australia.

Department of Conservation and Land Management 2003. *Declared Rare and Priority Flora List for Western Australia*. Published list by the Department of Conservation and Land Management, Western Australia.

Department of Conservation and Environment 1981. *The Darling System, Western Australia. Proposals for Parks and Reserves.* The System 6 Study Report, Western Australia.

Department of Conservation and Environment 1983. *Conservation Through Reserves. Report for the Darling System, Western Australia.* The System 6 Study Report, Western Australia

Department of Environmental Protection 1996. System 6 and part 1 Update Program. Unpublished bushland plot and area records and analysis.

Diels, L. 1906. Die Pflanzenwelt von West Australien sudlich des Wendekreises. In A. Engler and O. Drude (Eds.). *Vol. 7 of Die Vegetation der Erde.* Engelmann, Leipzig.

Ecos Consulting (Aust) Pty Ltd 1998. *Kemerton silica Sand Environmental Monitoring Report*. Unpublished report prepared for Gwalia Consolidated Ltd.

English, V. and Blyth, J. 1997. *Identifying and Conserving Threatened Ecological Communities (TECS) in the South West Botanical Province.* Department of Conservation and Land Management.

Environmental Protection Authority, Western Australian Planning Commission, National Parks and Nature Conservation Authority, and Water and Rivers Commission 1998. *Perth's Bushplan.* Department of Environmental Protection, Perth.

Environmental Protection Authority 1999. Review of the *Environmental Protection (Swan Coastal Plain Lakes) Policy.* Environmental Protection Authority, Perth.

Environmental Protection Authority 1994. *Kemerton Silica Sand Mining Proposal. Gwalia Consolidated Ltd. Report and Recommendations of the Environmental Protection Authority. Bulletin 471.* Environmental Protection Authority, Perth.

Environmental Protection Authority 1992. *Coastal Plain Lakes Environmental Protection Policy.* Environmental Protection Authority, Perth, WA, 1992

Environmental Protection Authority 1990a. *Protection of the Groundwater, Wetlands and Associated Ecosystems of the Swan Coastal Plain. A* Public Discussion Paper. Environmental Protection Authority, Perth, Western Australia, June 1990.

Environmental Protection Authority 1990b. *A Guide to Wetland Management in Perth.* Environmental Protection Authority, Perth, Western Australia, Bulletin 374, November 1990.

Environmental Protection Authority 2003. Level of assessment for proposals affected natural areas within the System 6 region and Swan Coastal Plain portion of System 1. Guidance Statement for the Assessment of Environmental Factors. No. 10, January 2003.

Gibson, N, Keighery, B., Keighery, G., Burbidge, A. and Lyons, M. 1994. *A Floristic Survey of the Swan Coastal Plain.* Unpublished Report for the Australian Heritage Commission prepared by the Department of Conservation and Land Management and the Conservation Council of Western Australia.

Gwalia Consolidated Ltd. 1993. *Kemerton Silica Sand Project. Public Environmental Review - July 1993.* Gwalia Consolidated Ltd, Perth.

Havel, J.J. 1968. *The Potential of the Northern Swan Coastal Plain for Pinus pinaster Ait Plantations.* Bulletin 76, Forests Department of Western Australia.

Heddle, E.M., Loneragan, O.W. and Havel, J.J. 1980a. Vegetation Complexes of the Darling System, Western Australia. In*: Atlas of Natural Resources Darling System Western Australia.* Department of Conservation and Environment.

Heddle, E.M., Havel J.J., and Loneragan, O.W. 1980b. *Focus on Northern Jarrah Forest Conservation and Recreation Areas.* Forest Focus Number 22. January 1980. Forests Department of Western Australia. Perth.

Hoffman, N. and Brown, A. 1992. *Orchids of South-west Australia, Second Edition.* University of Western Australia Press, Perth.

Hopper, S.D., van Leeuwen, S., Brown, A.P., and Patrick, S.J. 1990. *Western Australia's Endangered Flora.* Department of Conservation and Land Management, Wanneroo, Western Australia.

Hussey, B.M.J., Keighery, G.J., Cousens, R.D., Dodd, J. and Lloyd, S.G. 1997. *Western Weeds – A guide to the weeds of Western Australia*. The Plant Protection Society of Western Australia (Inc.), Western Australia.

John Consulting Services 1997. *Kemerton Silica Sand Project - Western Extension.* Prepared for Kemerton Silica Sands Pty Ltd. Perth.

Keighery, B 1998. *Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area*. Unpublished report to Department of Conservation and Environment.

Keighery, G.J. and Keighery, B.J., and Bibson. 1997. Floristics of Reserves and Bushland Areas in the Perth Region (System 6) Part XIII: In: *Floristics of Reserves and Bushland Areas of the Perth Region (System 6)* Parts V-IX.

Keighery, G.J. and Keighery, B.J. 1995. *Muchea Limestones - Floristics*. Unpublished report to Australian Nature Conservation Authority Natural Reserves Network and Department of Conservation and Environment.

Mattiske, E.M. and Associates 1993a. *Gwalia Consolidated Limited - Kemerton Sand Project: Flora and Vegetation Studies. Report One - February 1993.* Unpublished report prepared for John Consulting Services.

Mattiske, E.M. and Associates 1993b. *Gwalia Consolidated Limited - Kemerton Sand Project: Flora and Vegetation. Report Two - June 1993.* Unpublished report prepared for John Consulting Services.

Mattiske, E.M. and Associates 1993c. *Gwalia Consolidated Limited - Kemerton Sand Project: Updated Flora and Vegetation Report. Report Three - November 1993.* Unpublished report prepared for John Consulting Services.

Mattiske, E.M. and Associates 1993d. *Gwalia Consolidated Limited - Kemerton Sand Project: Vegetation Mapping of Proposed Transport Corridor. Report Four - November 1993.* Unpublished report prepared for John Consulting Services.

Muir Environmental. 1999. *Report of Biological Survey - Phase 1: Kemerton Industrial Estate. Volume 1 - Report and Volume 2 - Appendices*. Unpublished report for LandCorp.

Safstrom, R. and Craig. G. 1996. *Environmental Evaluation of Native Vegetation in the Wheatbelt of Western Australia - Principals and Criteria Used to Appraise Land Clearing Proposals*. Prepared for the Department of Environmental Protection. Supporting Manual 4.2. Memorandum of Understanding for the Protection of Remnant Vegetation on Private Land in the Agricultural Region of Western Australia. 18pp.

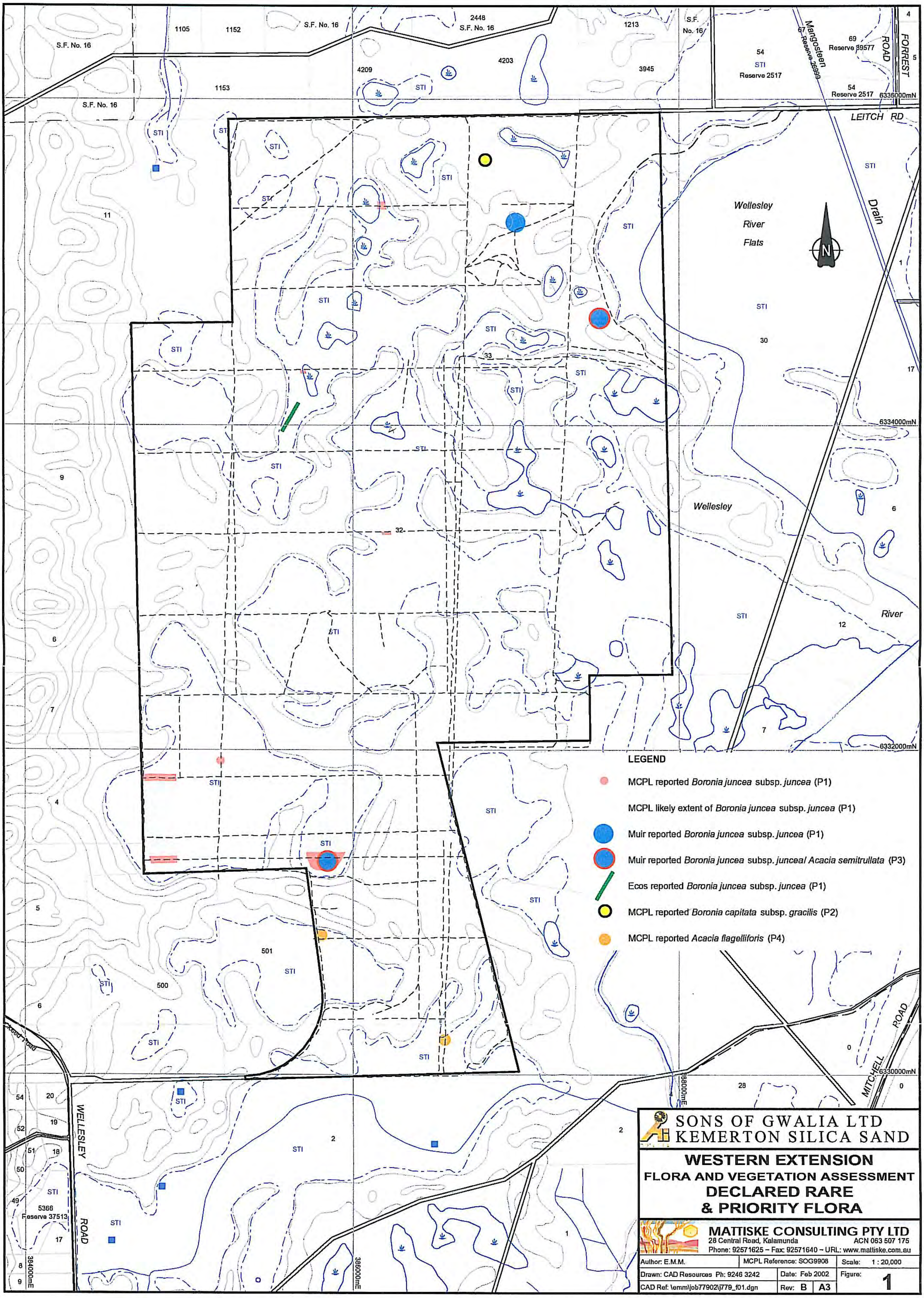
Seddon, G. (1972).
Sense of Place; a response to an environment, the Swan Coastal Plain, Western Australia. University of Western Australia Press, Nedlands.

Semeniuk, C.A. (1987)
Wetlands of the Darling System - A Geomorphic Classification. J. Roy. Soc. W. Aust. 69: 95-112.

Smith, F.G. 1974. *Vegetation survey of Western Australia: Vegetation map of the Collie sheet*, 1:250,000. Department of Agriculture, Western Australia.

Western Australian, Water Resources Council (1987)
Environmental Significance of Wetlands in the Perth to Bunbury Region. Report and Appendices to Western Australian Water Resources Council by LeProvost, Semeniuk & Chalmer (1987), Perth.

Western Australian Herbarium 1999. *Florabase – Information on the Western Australian Flora*. Department of Conservation and Land Management. http://www.calm.wa.gov.au/science/florabase.html



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MCPL reported Boronia juncea subsp. juncea (P1)
MCPL likely extent of Boronia juncea subsp. juncea (P1)
Muir reported Boronia juncea subsp. juncea (P1)
Muir reported Boronia juncea subsp. juncea/ Acacia semitrullata (P3)
Ecos reported Boronia juncea subsp. juncea (P1)
MCPL reported Boronia capitata subsp. gracilis (P2)
MCPL reported Acacia flagelliforis (P4)
Wellesley River Flats
Wellesley River
LEITCH RD
FORREST ROAD
WELLESLEY ROAD
MITCHELL ROAD
Drain
SONS OF GWALIA LTD
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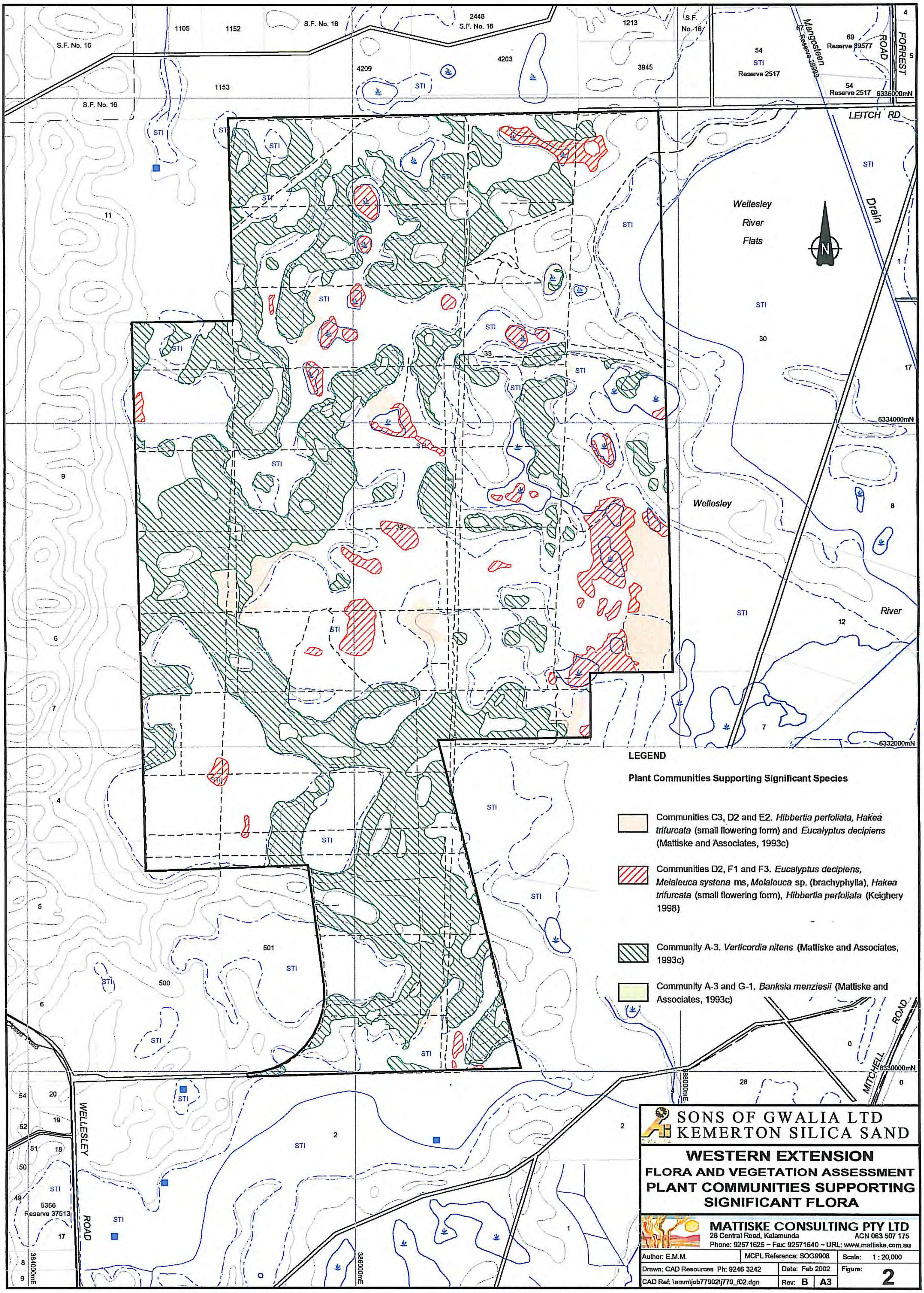
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MITCHELL ROAD
WELLESLEY ROAD
Mangosteen
Reserve 2517
Reserve 39577
Reserve 37513
S.F. No. 16
STI
6336000mN
6334000mN
6332000mN
6330000mN
384000mE
386000mE
388000mE
LEGEND
Plant Communities Supporting Significant Species
Communities C3, D2 and E2. *Hibbertia perfoliata, Hakea trifurcata* (small flowering form) and *Eucalyptus decipiens* (Mattiske and Associates, 1993c)
Communities D2, F1 and F3. *Eucalyptus decipiens, Melaleuca systena* ms, *Melaleuca* sp. (brachyphylla), *Hakea trifurcata* (small flowering form), *Hibbertia perfoliata* (Keighery 1998)
Community A-3. *Verticordia nitens* (Mattiske and Associates, 1993c)
Community A-3 and G-1. *Banksia menziesii* (Mattiske and Associates, 1993c)
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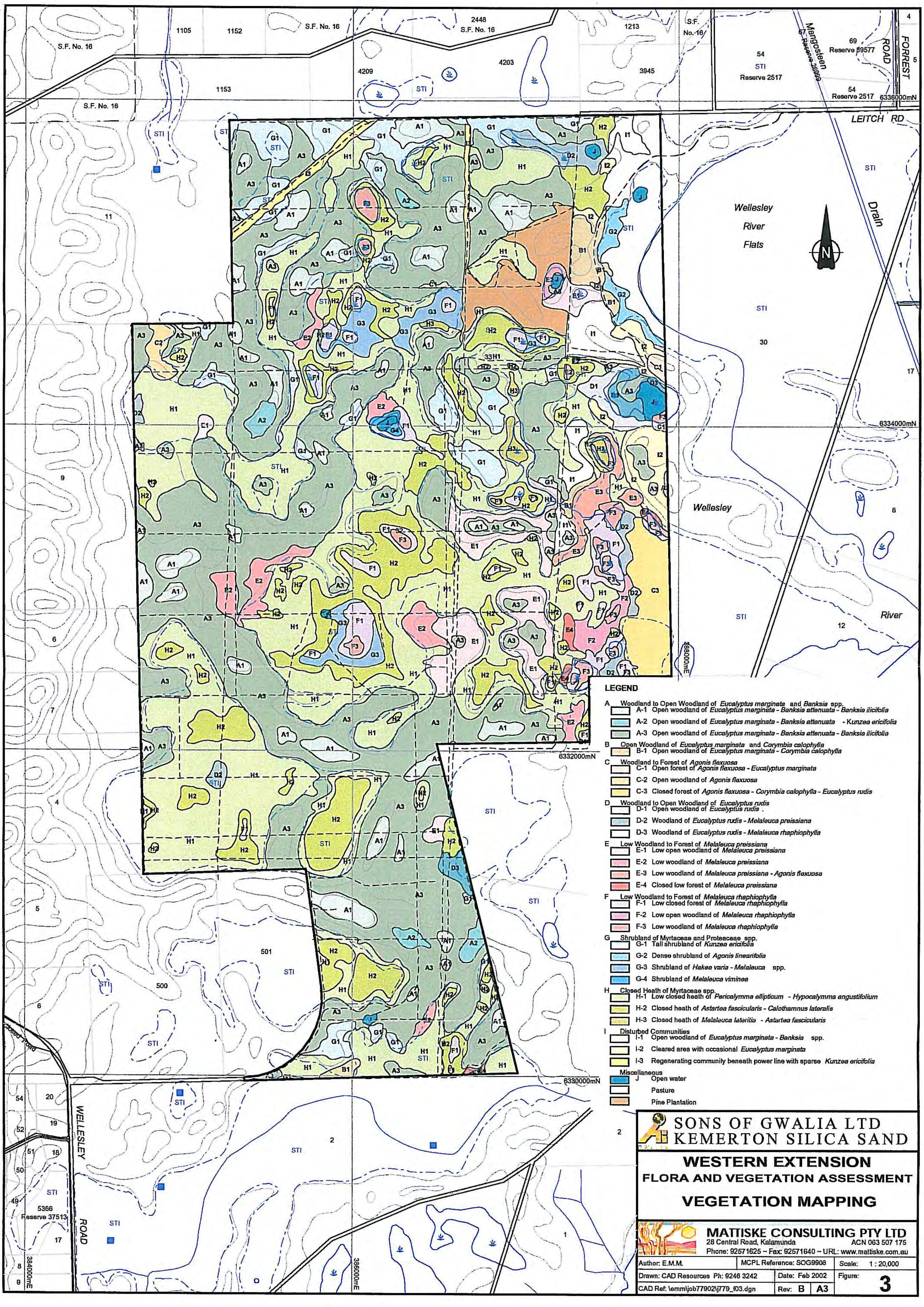

Wellesley River Flats
Wellesley River
Drain
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Reserve 37513
S.F. No. 16
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LEGEND
A Woodland to Open Woodland of Eucalyptus marginata and Banksia spp.
A-1 Open woodland of Eucalyptus marginata - Banksia attenuata - Banksia ilicifolia
A-2 Open woodland of Eucalyptus marginata - Banksia attenuata - Kunzea ericifolia
A-3 Open woodland of Eucalyptus marginata - Banksia attenuata - Banksia ilicifolia
B Open Woodland of Eucalyptus marginata and Corymbia calophylla
B-1 Open woodland of Eucalyptus marginata - Corymbia calophylla
C Woodland to Forest of Agonis flexuosa
C-1 Open forest of Agonis flexuosa - Eucalyptus marginata
C-2 Open woodland of Agonis flexuosa
C-3 Closed forest of Agonis flexuosa - Corymbia calophylla - Eucalyptus rudis
D Woodland to Open Woodland of Eucalyptus rudis
D-1 Open woodland of Eucalyptus rudis .
D-2 Woodland of Eucalyptus rudis - Melaleuca preissiana
D-3 Woodland of Eucalyptus rudis - Melaleuca rhaphiophylla
E Low Woodland to Forest of Melaleuca preissiana
E-1 Low open woodland of Melaleuca preissiana
E-2 Low woodland of Melaleuca preissiana
E-3 Low woodland of Melaleuca preissiana - Agonis flexuosa
E-4 Closed low forest of Melaleuca preissiana
F Low Woodland to Forest of Melaleuca rhaphiophylla
F-1 Low closed forest of Melaleuca rhaphiophylla
F-2 Low open woodland of Melaleuca rhaphiophylla
F-3 Low woodland of Melaleuca rhaphiophylla
G Shrubland of Myrtaceae and Proteaceae spp.
G-1 Tall shrubland of Kunzea ericifolia
G-2 Dense shrubland of Agonis linearifolia
G-3 Shrubland of Hakea varia - Melaleuca spp.
G-4 Shrubland of Melaleuca viminea
H Closed Heath of Myrtaceae spp.
H-1 Low closed heath of Pericalymma ellipticum - Hypocalymma angustifolium
H-2 Closed heath of Astartea fascicularis - Calothamnus lateralis
H-3 Closed heath of Melaleuca lateritia - Astartea fascicularis
I Disturbed Communities
I-1 Open woodland of Eucalyptus marginata - Banksia spp.
I-2 Cleared area with occasional Eucalyptus marginata
I-3 Regenerating community beneath power line with sparse Kunzea ericifolia
Miscellaneous
J Open water
Pasture
Pine Plantation
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A Woodland to Open Woodland of *Eucalyptus marginata* and *Banksia* spp.

- A-1 Upper slope open woodland of *Eucalyptus marginata* - *Banksia attenuata* - *Banksia ilicifolia* and *Kunzea ericifolia* over *Stirlingia latifolia, Calytrix fraseri, Adenanthos meisneri* and mixed shrubs over *Dasypogon bromeliifolius*.
- A-2 Upper slope open woodland of *Eucalyptus marginata* - *Banksia attenuata* - *Kunzea ericifolia* over *Allocasuarina humilis, Stirlingia latifolia* and mixed shrubs.
- A-3 Lower slope open woodland of *Eucalyptus marginata* - *Banksia attenuata* - *Banksia ilicifolia* and *Kunzea ericifolia* with occasional *Nuytsia floribunda* and *Corymbia calophylla* over *Melaleuca thymoides, Calytrix fraseri, Acacia pulchella* and mixed shrubs.

B Open Woodland of *Eucalyptus marginata* and *Corymbia calophylla*

- B-1 Open woodland of *Eucalyptus marginata* - *Corymbia calophylla* and *Kunzea ericifolia* over *Pericalymma ellipticum* and *Acacia pulchella* over Poaceae spp.

C Woodland to Forest of *Agonis flexuosa*

- C-1 Open forest of *Agonis flexuosa* - *Eucalyptus marginata* over grasses.
- C-2 Open woodland of *Agonis flexuosa*, with occasional *Banksia attenuata, Banksia ilicifolia* and *Nuytsia floribunda* over mixed shrubs.
- C-3 Closed forest of *Agonis flexuosa* - *Corymbia calophylla* - *Eucalyptus rudis* with occasional *Banksia littoralis*, over *Xanthorrhoea preissii, Macrozamia riedlei* and sparse mixed shrubs and sedges.

D Woodland to Open Woodland of *Eucalyptus rudis*

- D-1 Open woodland of *Eucalyptus rudis* and *Kunzea ericifolia* over *Hypocalymma angustifolium, Xanthorrhoea preissii* and mixed shrubs over mixed grasses and sedges.
- D-2 Woodland of *Eucalyptus rudis* - *Melaleuca preissiana* and occasional *Banksia littoralis* over Myrtaceae spp. over mixed sedges.
- D-3 Woodland of *Eucalyptus rudis* - *Melaleuca rhaphiophylla* over *Melaleuca teretifolia* and *Astartea fascicularis* over *Lepidosperma longitudinale*.

E Low Woodland to Forest of *Melaleuca preissiana*

- E-1 Low open woodland of *Melaleuca preissiana* and occasional *Eucalyptus marginata* and *Kunzea ericifolia* over *Hypocalymma angustifolium* and *Calytrix* spp. over *Dasypogon bromeliifolius*.
- E-2 Low woodland of *Melaleuca preissiana* and occasional *Nuytsia floribunda* over *Hypocalymma angustifolium, Pericalymma ellipticum* and mixed shrubs over sedges.
- E-3 Low woodland of *Melaleuca preissiana* - *Agonis flexuosa* over *Astartea fascicularis* and mixed shrubs over *Lepidosperma longitudinale*.
- E-4 Closed low forest of *Melaleuca preissiana* with occasional *Corymbia calophylla*, over dense *Agonis linearifolia* over *Pteridium esculentum* and dense *Lepidosperma longitudinale*.

F Low Woodland to Forest of *Melaleuca rhaphiophylla*

- F-1 Seasonally inundated low closed forest of *Melaleuca rhaphiophylla* over Myrtaceae spp. over mixed sedges.
- F-2 Seasonally inundated low open woodland of *Melaleuca rhaphiophylla* over *Melaleuca viminea* and *Melaleuca cuticularis* over mixed shrubs over mixed sedges.
- F-3 Waterlogged, low woodland of *Melaleuca rhaphiophylla* over *Baumea articulata*.

G Shrubland of Myrtaceae and Proteaceae spp.

- G-1 Tall shrubland of dense *Kunzea ericifolia* over *Hypocalymma angustifolium* and mixed shrubs over *Meeboldina scariosa*, with occasional emergent *Eucalyptus marginata, Banksia attenuata* and *Banksia ilicifolia*.
- G-2 Dense shrubland of *Agonis linearifolia* with occasional *Eucalyptus marginata*, over grasses.
- G-3 Shrubland of *Hakea varia* - *Melaleuca* spp. and *Astartea fascicularis* over *Lepidosperma longitudinale* and *Meeboldina coangustata*.
- G-4 Waterlogged shrubland of *Melaleuca viminea*.

H Closed Heath of Myrtaceae spp.

- H-1 Low closed heath of *Pericalymma ellipticum* - *Hypocalymma angustifolium* shrubs over mixed sedges, with occasional emergent *Melaleuca preissiana*, *Nuytsia floribunda* and very occasional *Banksia littoralis* trees.
- H-2 Closed heath of *Astartea fascicularis* - *Calothamnus lateralis* and *Cassytha racemosa* over mixed sedges.
- H-3 Closed heath of *Melaleuca lateritia* - *Astartea fascicularis* over *Lepidosperma longitudinale* and *Leptocarpus tenax*.

I Disturbed Communities

- I-1 Disturbed lower slope of open woodland of *Eucalyptus marginata* and *Banksia* spp.
- I-2 Cleared area with occasional *Eucalyptus marginata* over *Cartonema philydroides*.
- I-3 Regenerating community beneath power line. Sparse *Kunzea ericifolia* over *Aotus gracillima, Pimelea angustifolia* and *Pericalymma ellipticum* over mixed sedges.

Miscellaneous

- J Open water
- Pasture
- Pine Plantation

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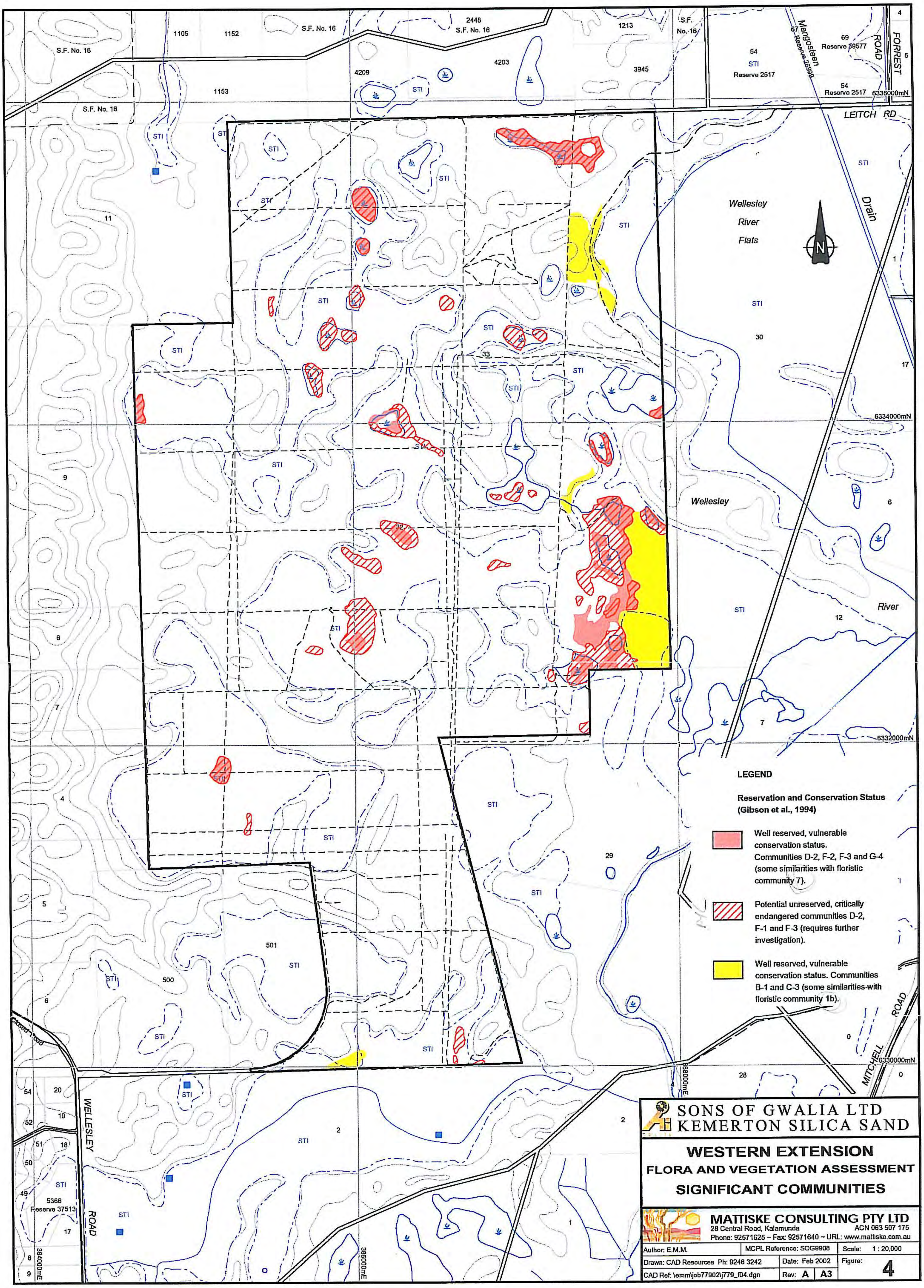
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Reservation and Conservation Status (Gibson et al., 1994)
Well reserved, vulnerable conservation status. Communities D-2, F-2, F-3 and G-4 (some similarities with floristic community 7).
Potential unreserved, critically endangered communities D-2, F-1 and F-3 (requires further investigation).
Well reserved, vulnerable conservation status. Communities B-1 and C-3 (some similarities with floristic community 1b).
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SIGNIFICANT COMMUNITIES
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WELLESLEY ROAD
MITCHELL ROAD
Wellesley River Flats
Wellesley River
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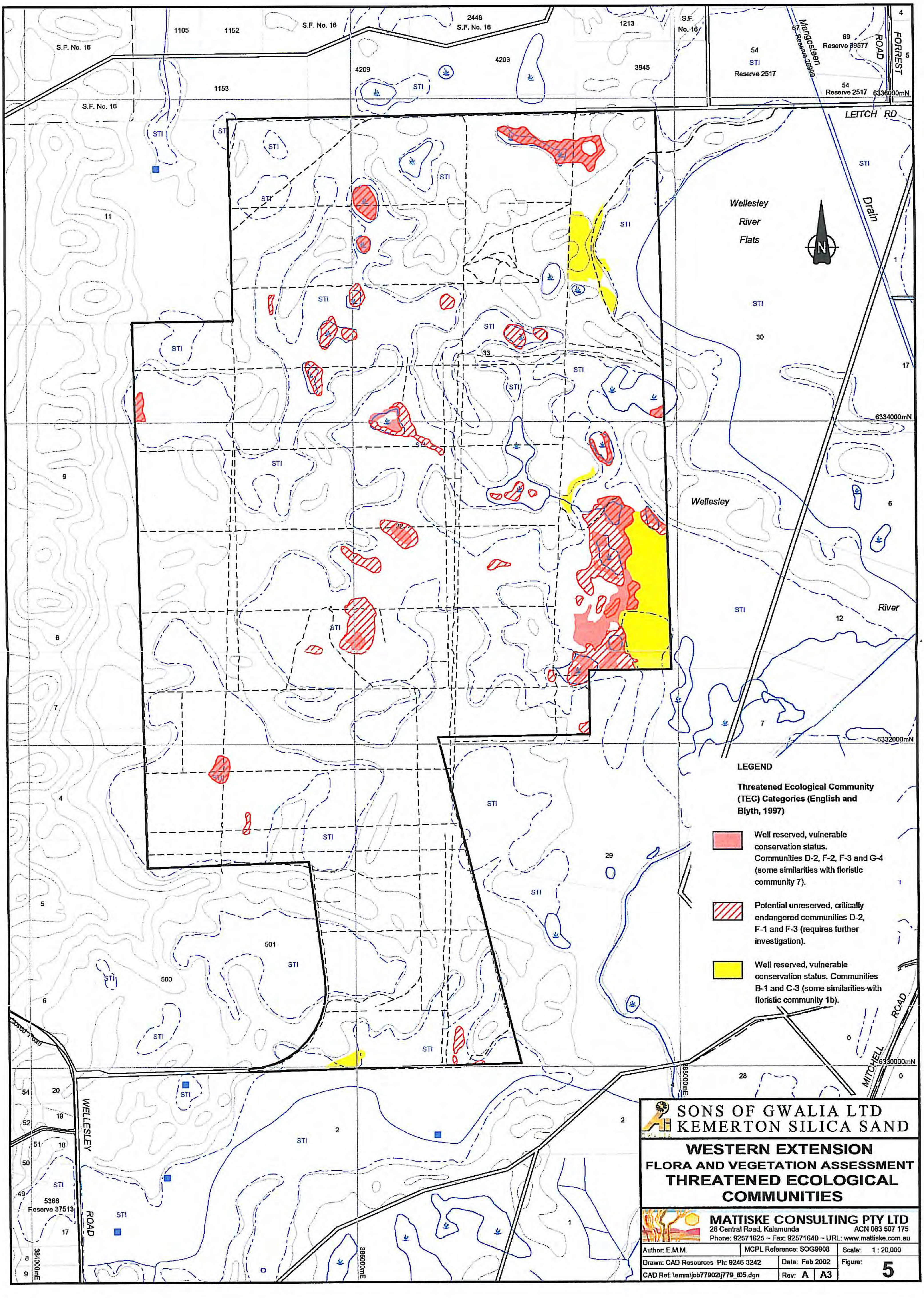
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Wellesley River Flats
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LEGEND
Threatened Ecological Community (TEC) Categories (English and Blyth, 1997)
Well reserved, vulnerable conservation status. Communities D-2, F-2, F-3 and G-4 (some similarities with floristic community 7).
Potential unreserved, critically endangered communities D-2, F-1 and F-3 (requires further investigation).
Well reserved, vulnerable conservation status. Communities B-1 and C-3 (some similarities with floristic community 1b).
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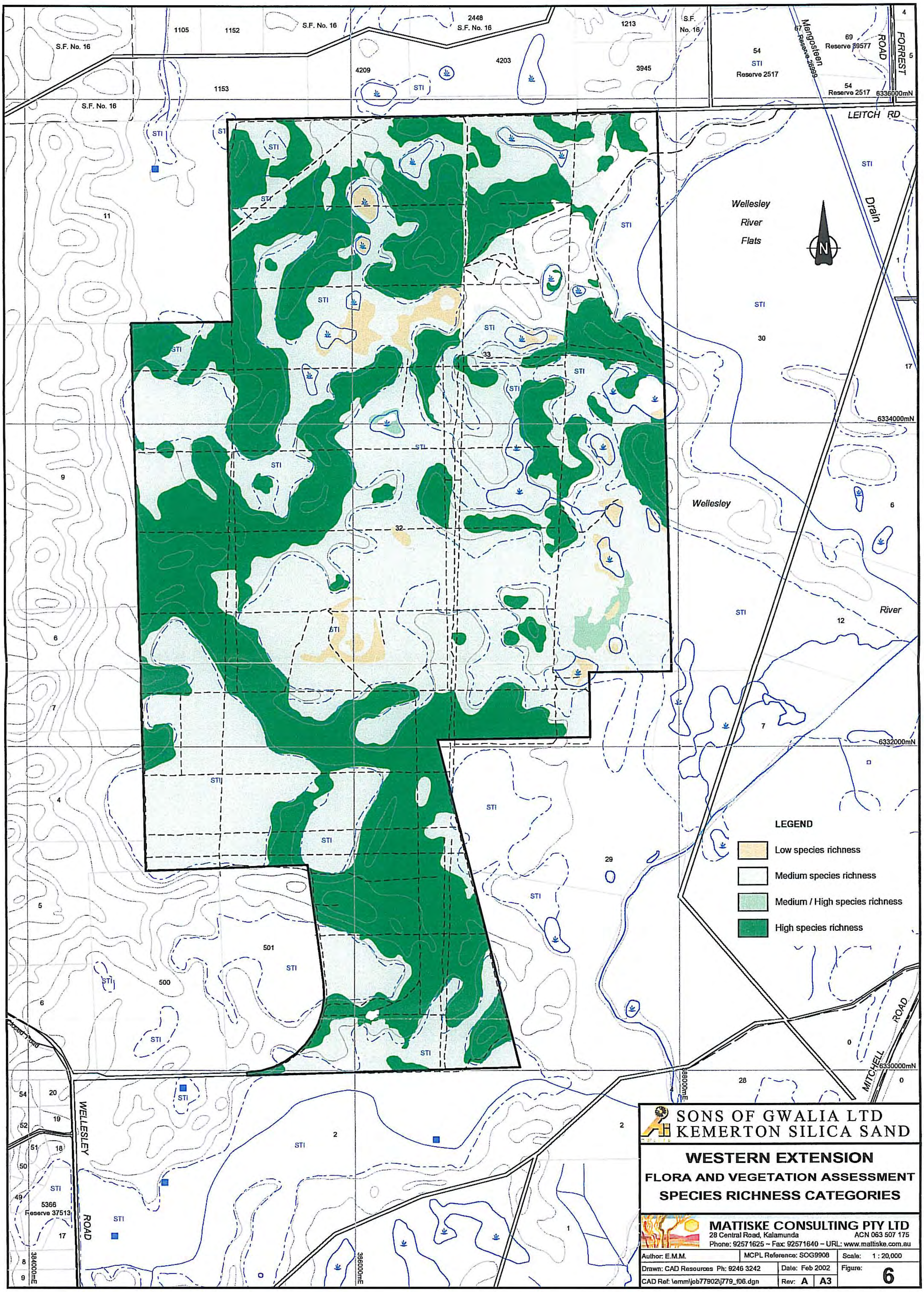

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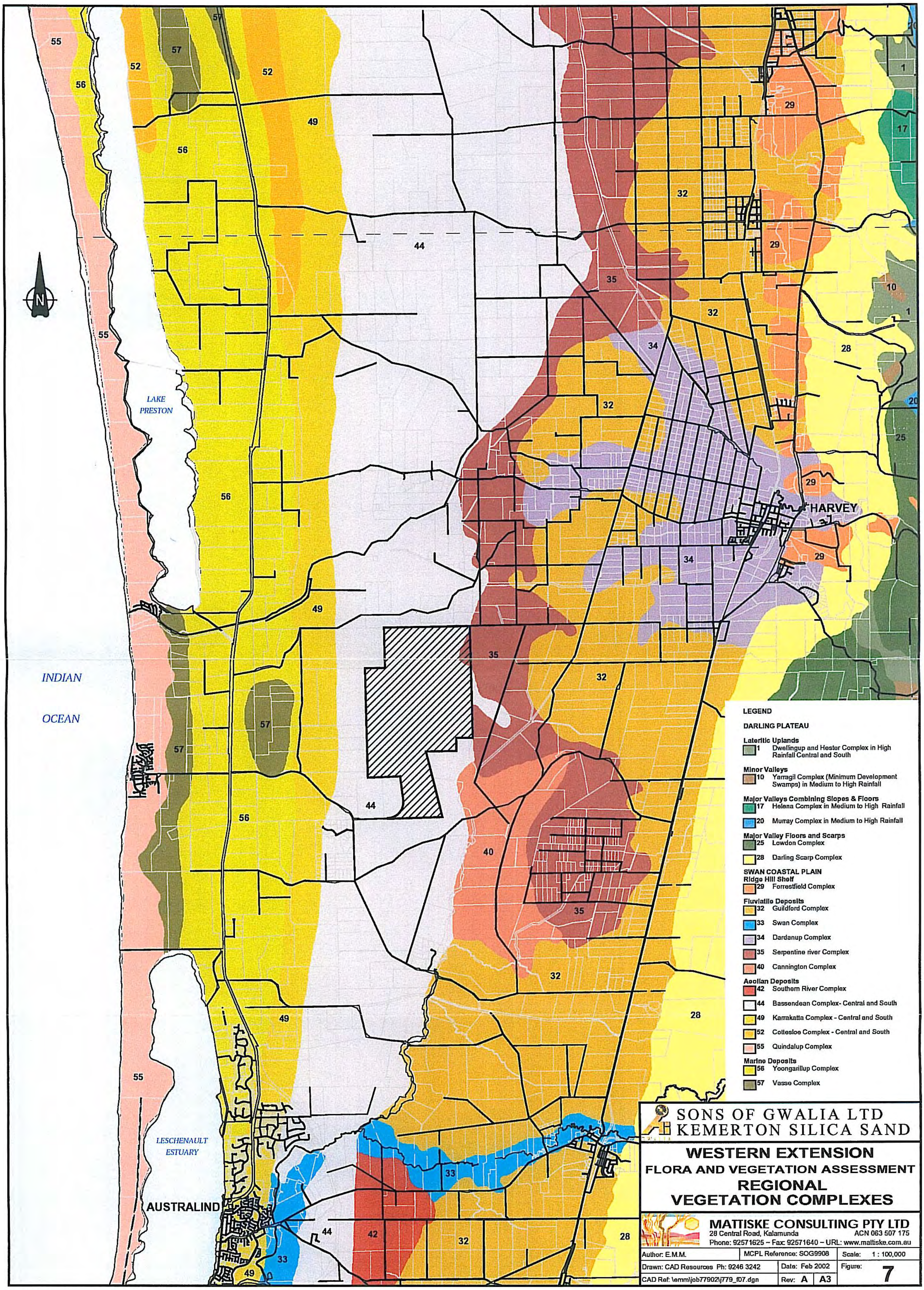

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LEGEND
DARLING PLATEAU
Lateritic Uplands
1 Dwellingup and Hester Complex in High Rainfall Central and South
Minor Valleys
10 Yarragil Complex (Minimum Development Swamps) in Medium to High Rainfall
Major Valleys Combining Slopes & Floors
17 Helena Complex in Medium to High Rainfall
20 Murray Complex in Medium to High Rainfall
Major Valley Floors and Scarps
25 Lowdon Complex
28 Darling Scarp Complex
SWAN COASTAL PLAIN
Ridge Hill Shelf
29 Forrestfield Complex
Fluviatile Deposits
32 Guildford Complex
33 Swan Complex
34 Dardanup Complex
35 Serpentine river Complex
40 Cannington Complex
Aeolian Deposits
42 Southern River Complex
44 Bassendean Complex- Central and South
49 Karrakatta Complex - Central and South
52 Cottesloe Complex - Central and South
55 Quindalup Complex
Marine Deposits
56 Yoongarillup Complex
57 Vasse Complex
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MCPL Reference: SOG9908
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Date: Feb 2002
Figure: 7
CAD Ref: \emm\job77902\j779_f07.dgn
Rev: A
A3

DARLING PLATEAU

Lateritic Uplands

1. **Dwellingup and Hester Complex in High Rainfall Central and South:**
Open forest of *Eucalyptus marginata - Corymbia calophylla* . Dominant Vegetation types S, T; less consistently O, P, R.

Minor Valleys

10. **Yarragil Complex (Minimum Development Swamps) in Medium to High Rainfall:**
Open forest of *Eucalyptus marginata - Corymbia calophylla* on upper slopes with a mixture of *Eucalyptus patens* and *Eucalyptus megacarpa* on the valley floors. Dominant vegetation types C, D, W; less consistently Q, T, U.

Major Valleys Combining Slopes & Floors

17. **Helena Complex in Medium to High Rainfall:**
Vegetation ranges from open forest *of Eucalyptus marginata - Corymbia calophylla- Eucalyptus patens* through heath and herbland to lichens on granite rock. Dominant vegetation types G, R; less consistently C, Q, T.

20. **Murray Complex in Medium to High Rainfall**
Vegetation ranges from open forest of *Eucalyptus marginata - Corymbia calophylla* with *Eucalyptus patens* on the slopes to fringing woodland of *Eucalyptus rudis-Melaleuca rhaphiophylla* on the valley floors. Dominant vegetation types C, Q, U, T; less consistently D, O, R, W.

Major Valley Floors and Scarps

25. **Lowdon Complex:**
Open forest of *Eucalyptus marginata - Corymbia calophylla* and low open forest of *Agonis flexuosa* on the slopes, fringing woodland *of Eucalyptus rudis - Melaleuca rhaphiophylla* in the gullies. Less consistently woodland of *Eucalyptus wandoo* on slopes.

28. **Darling Scarp Complex:**
Vegetation ranges from low open woodland to lichens according to depths of soils. Woodland components chiefly *Eucalyptus wandoo* with *Eucalyptus laeliae* in the north. *Corymbia haematoxylon* in the south, and *Corymbia calophylla* throughout the region. Dominant vegetation types R, G.

SWAN COASTAL PLAIN

Ridge Hill Shelf

29. **Forrestfield Complex:**
Vegetation ranges from open forest of *Corymbia calophylla Eucalyptus wandoo- Eucalyptus marginata* to open forest of *Eucalyptus marginata - Corymbia calophylla- Allocasuarina fraseriana - Banksia* spp. Fringing woodland of *Eucalyptus rudis* in the gullies that dissect this landform.

Fluviatile Deposits

32. **Guildford Complex:**
A mixture of open forest to tall open forest of *Corymbia calophylla - Eucalyptus wandoo - Eucalyptus marginata* and woodland of *Eucalyptus wandoo* (with rare occurrences of *Eucalyptus lane-poolei*). Minor components include *Eucalyptus rudis - Melaleuca rhaphiophylla* .

33. **Swan Complex:**
Fringing woodland of *Eucalyptus rudis - Melaleuca rhaphiophylla* with localised occurrence of low open forest of *Casuarina obesa* and *Melaleuca cuticularis*.

34. **Dardanup Complex:**
Mosaic of vegetation types characteristic of adjacent vegetation complexes such as Serpentine River, Southern River and Guildford.

35. **Serpentine river Complex:**
Closed scrub of *Melaleuca* spp. and fringing woodland of *Eucalyptus rudis - Melaleuca rhaphiophylla* along streams.

40. **Cannington Complex:**
Mosaic of vegetation from adjacent vegetation complexes of Bassendean, Karrakatta, Southern River and Vasse.

Aeolian Deposits

42. **Southern River Complex:**
Open woodland of *Corymbia calophylla - Eucalyptus marginata - Banksia* spp. with fringing woodland of *Eucalyptus rudis - Melaleuca rhaphiophylla* along creek beds.

44. **Bassendean Complex- Central and South:**
Vegetation ranges from woodland of *Eucalyptus marginata - Allocasuarina fraseriana - Banksia* spp. to low woodland of *Melaleuca* spp. and sedgelands on the moister sites. This includes the transition of *Eucalyptus marginata* to *Eucalyptus todtiana* in the vicinity of Perth.

49. **Karrakatta Complex - Central and South:**
Predominantly open forest of *Eucalyptus gomphocephala - Corymbia calophylla* and woodland of *Eucalyptus marginata - Banksia* spp.

52. **Cottesloe Complex - Central and South:**
Mosaic of woodland of *Eucalyptus gomphocephala* and open forest of *Eucalyptus gomphocephala - Eucalyptus marginata - Corymbia calophylla* ; closed heath on the limestone outcrops.

55. **Quindalup Complex:**
Coastal dune complex consisting mainly of two alliances - the strand and fore dune alliance and the mobile and stable dune alliance. Local variations include the low closed of *Melaleuca lanceolata - Callitris preissii* and the closed scrub of *Acacia rostellifera*.

Marine Deposits

56. **Yoongarillup Complex:**
Woodland to tall woodland of *Eucalyptus gomphocephala* with *Agonis flexuosa* in the second storey. Less consistently an open forest of *Eucalyptus gomphocephala - Eucalyptus marginata - Corymbia calophylla*.

57. **Vasse Complex:**
Mixture of the closed scrub of *Melaleuca* spp. fringing woodland of *Eucalyptus rudis - Melaleuca* spp. and open forest of *Eucalyptus gomphocephala - Eucalyptus marginata - Corymbia calophylla.*

SONS OF GWALIA LTD
KEMERTON SILICA SAND

WESTERN EXTENSION
FLORA AND VEGETATION ASSESSMENT
REGIONAL VEGETATION COMPLEXES - LEGEND

MATTISKE CONSULTING PTY LTD
28 Central Road, Kalamunda ACN 063 507 175
Phone: 92571625 ~ Fax: 92571640 ~ URL: www.mattiske.com.au

Author: E.M.M.	MCPL Reference: SOG9908	Scale:
Drawn: CAD Resources Ph: 9246 3242	Date: Feb 2002	Figure: 7a
CAD Ref: \emm\job37909\37910_07a.dgn	Rev: A A4	

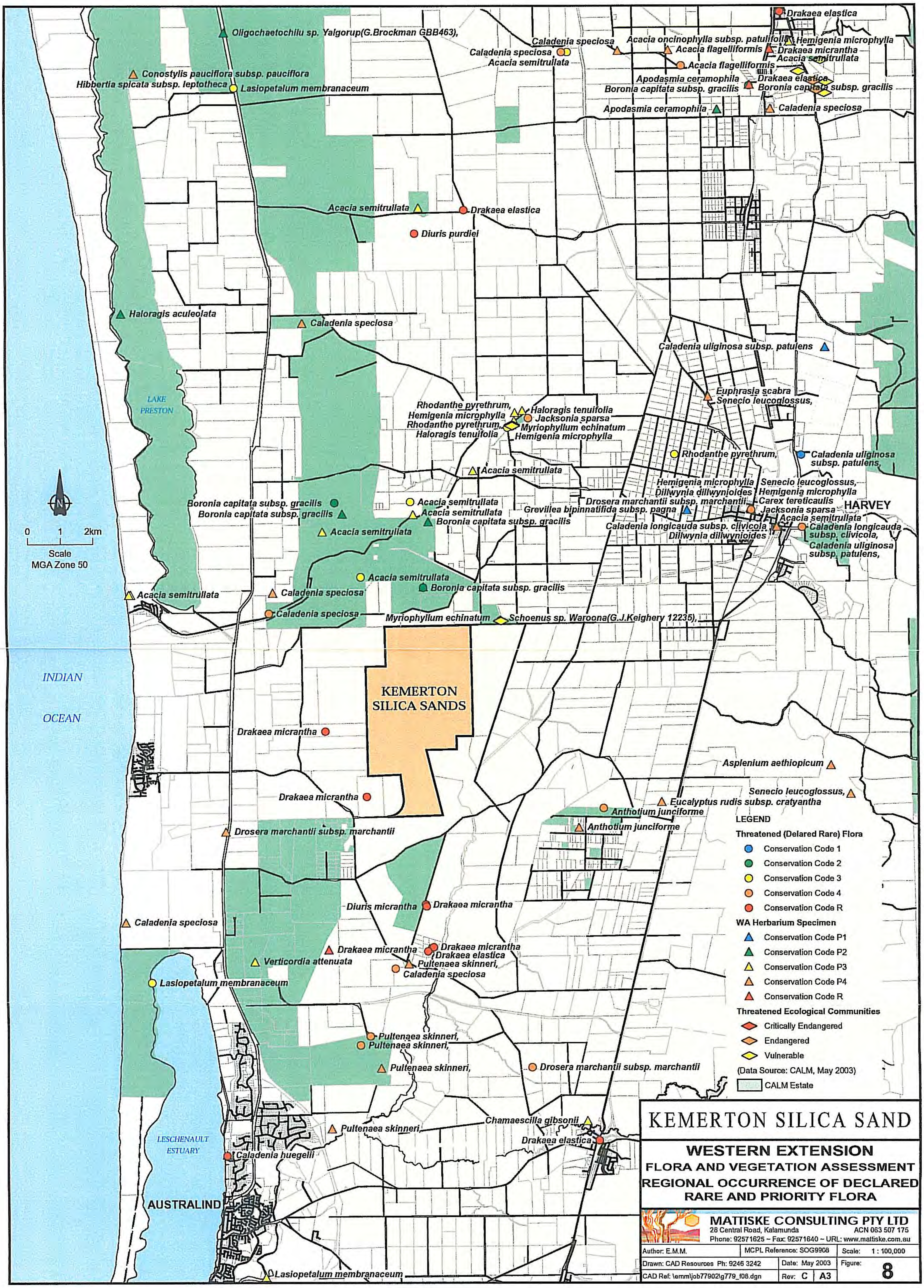
Oligochaetochilu sp. Yalgorup(G.Brockman GBB463),
Conostylis pauciflora subsp. pauciflora
Hibbertia spicata subsp. leptotheca
Lasiopetalum membranaceum
Caladenia speciosa
Acacia semitrullata
Acacia oncinophylla subsp. patulifolia
Hemigenia microphylla
Drakaea elastica
Acacia flagelliformis
Drakaea micrantha
Apodasmia ceramophila
Boronia capitata subsp. gracilis
Diuris purdiei
Haloragis aculeolata
LAKE PRESTON
Caladenia uliginosa subsp. patulens
Euphrasia scabra
Senecio leucoglossus,
Rhodanthe pyrethrum,
Hemigenia microphylla
Haloragis tenuifolia
Jacksonia sparsa
Myriophyllum echinatum
Dillwynia dillwynioides
Drosera marchantii subsp. marchantii
Carex tereticaulis
Grevillea bipinnatifida subsp. pagna
Caladenia longicauda subsp. clivicola
HARVEY
Schoenus sp. Waroona(G.J.Keighery 12235),
0 1 2km
Scale
MGA Zone 50
INDIAN
OCEAN
KEMERTON
SILICA SANDS
Asplenium aethiopicum
Eucalyptus rudis subsp. cratyantha
Anthotium junciforme
Diuris micrantha
Verticordia attenuata
Pultenaea skinneri,
Chamaescilla gibsonii
Caladenia huegelii
LESCHENAULT ESTUARY
AUSTRALIND
LEGEND
Threatened (Delared Rare) Flora
Conservation Code 1
Conservation Code 2
Conservation Code 3
Conservation Code 4
Conservation Code R
WA Herbarium Specimen
Conservation Code P1
Conservation Code P2
Conservation Code P3
Conservation Code P4
Conservation Code R
Threatened Ecological Communities
Critically Endangered
Endangered
Vulnerable
(Data Source: CALM, May 2003)
CALM Estate
KEMERTON SILICA SAND
WESTERN EXTENSION
FLORA AND VEGETATION ASSESSMENT
REGIONAL OCCURRENCE OF DECLARED RARE AND PRIORITY FLORA
MATTISKE CONSULTING PTY LTD
28 Central Road, Kalamunda ACN 063 507 175
Phone: 92571625 ~ Fax: 92571640 ~ URL: www.mattiske.com.au
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Figure: 8
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Rev: C A3

APPENDIX A : VASCULAR PLANT SPECIES RECORDED ON THE GWALIA PROJECT AREA BETWEEN 1992 AND 1999

Note: 1 - December 1992 Gwalia Project Area Survey (Mattiske, 1993a)
2 - April 1993 Gwalia Project Area Survey (Mattiske, 1993b)
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FAMILY	GENUS	SPECIES	Botanical Studies 1	2	3	4	5	6
SELAGINELLACEAE	* *Selaginella*	*gracillima*						+
DENNSTAEDTIACEAE	*Pteridium*	*esculentum*		+	+	+		+
ZAMIACEAE	*Macrozamia*	*riedlei*		+	+	+	+	
PODOCARPACEAE	*Podocarpus*	*drouynianus*				+		
PINACEAE	* *Pinus*	*radiata*		+	+			
CUPRESSACEAE	*Actinostrobus*	*pyramidalis*	+	+	+			
TYPHACEAE	* *Typha*	*orientalis*	+	+	+			
POACEAE	* *Aira*	*caryophyllea*	+	+	+	+		+
	Austrostipa	*compressa*						+
	Austrostipa	*?compressa*			+			
	Austrostipa	*flavescens*						+
	* *Avena*	*fatua*				+		
	* *Briza*	*maxima*	+	+	+	+		+
	* *Briza*	*minor*	+	+	+			+
	* *Cynodon*	*dactylon*						+
	Dichanthium	sp.		+	+			
	* *Holcus*	*lanatus*	+	+	+			
	* *Lagurus*	*ovatus*		+	+			
	* *Lolium*	sp.						+
	Neurachne	*alopecuroidea*		+	+			
	* *Polypogon*	*monspeliensis*		+	+			
	* *Vulpia*	*myuros*		+	+			
	* *Vulpia*	sp.			+			
	Poaceae	sp.		+	+		+	
CYPERACEAE	*Baumea*	*articulata*			+		+	+
	Baumea	*juncea*	+	+	+			
	Cyathochaeta	*avenacea*		+	+		+	
	Cyathochaeta	*stipoides* (P3)						+
	* *Cyperus*	*tenellus*			+			
	Evandra	*pauciflora*		+	+			+
	Gahnia	*trifida*	+	+	+			+
	Gahnia	sp.		+	+			
	* *Isolepis*	*marginata*						+
	Lepidosperma	*drummondii*		+	+		+	+
	Lepidosperma	*effusum*						+
	Lepidosperma	*longitudinale*		+	+			+
	Lepidosperma	*squamatum*		+	+	+		
	Lepidosperma	sp.	+	+	+			
	Mesomelaena	*graciliceps*		+	+			
	Mesomelaena	*tetragona*		+	+			
	Schoenus	*cruentus*		+	+			

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			Botanical Studies					
FAMILY	**GENUS**	**SPECIES**	**1**	**2**	**3**	**4**	**5**	**6**
CYPERACEAE	*Schoenus*	*curvifolius*					+	
(Continued)	*Schoenus*	*efoliatus*	+	+	+			
	Schoenus	*pedicellatus*		+	+			
	Schoenus	?sp. Waroona (G.J.Keighery 12235)(P3)						+
LEMNACEAE	*Lemna*	*disperma*						+
RESTIONACEAE	*Anarthria*	*gracilis*		+	+	+		
	Chaetanthus	*aristatus*		+	+			
	Chaetanthus	*leptocarpoides*		+	+			
	Desmocladus	*flexuosus*		+	+	+		
	Hypolaena	*exsulca*		+	+		+	+
	Hypolaena	*pubescens*		+	+			
	Lepidobolus	sp.	+	+	+			
	Leptocarpus	*tenax*		+	+			
	Leptocarpus	sp.		+	+			
	Lepyrodia	*glauca*						+
	Lepyrodia	*muirii*					+	
	Lyginia	*barbata*	+	+	+			
	Meeboldina	*coangustata*	+	+	+			
	Meeboldina	*scariosa*	+	+	+	+	+	
	Meeboldina	sp.						+
	Restionaceae	sp.		+	+			
CENTROLEPIDACEAE	*Aphelia*	*cyperoides*						+
	Centrolepis	*aristata*		+	+			+
XYRIDACEAE	*Xyris*	*lacera*		+	+			
COMMELINACEAE	*Cartonema*	*philydroides*		+	+			
JUNCACEAE	* *Juncus*	*bufonius*			+			
	Juncus	*kraussii*	+			+		
	Juncus	*pallidus*	+	+	+	+	+	
DASYPOGONACEAE	*Dasypogon*	*bromeliifolius*		+	+	+	+	+
	Lomandra	*hermaphrodita*		+	+		+	
	Lomandra	*integra*					+	
	Lomandra	*micrantha* subsp. *micrantha*					+	
	Lomandra	*sericea*		+	+		+	
	Lomandra	*sonderi*		+	+			
	Lomandra	*suaveolens*		+	+			
	Lomandra	*?suaveolens*		+	+			
XANTHORRHOEACEAE	*Xanthorrhoea*	*brunonis*		+	+	+		+
	Xanthorrhoea	*preissii*		+	+	+	+	+
PHORMIACEAE	*Dianella*	*revoluta*		+	+	+		+

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FAMILY	GENUS	SPECIES	1	2	3	4	5	6
ANTHERICACEAE	*Agrostocrinum*	*scabrum*			+			
	Chamaescilla	*corymbosa*			+			
	Johnsonia	*acaulis*			+			
	Thysanotus	*manglesianus*			+			
	Thysanotus	*multiflorus*		+	+		+	+
COLCHICACEAE	*Burchardia*	*umbellata*		+	+	+		
HAEMODORACEAE	*Anigozanthos*	*manglesii* subsp. *manglesii*	+	+	+	+		+
	Conostylis	*aculeata*					+	
	Conostylis	*juncea*		+	+	+		
	Conostylis	*micrantha*					+	
	Phlebocarya	*ciliata*		+	+	+		
	Tribonanthes	?*violacea*		+	+			
IRIDACEAE	*Patersonia*	*occidentalis*		+	+	+	+	+
	Patersonia	?*occidentalis*		+	+			
	Patersonia	*umbrosa*	+	+				
	Patersonia	sp.		+	+			
	* *Romulea*	*rosea*		+		+		
	* *Romulea*	*rosea* var. *australis*			+			
	* *Watsonia*	*meriana* var. *bulbillifera*			+			
ORCHIDACEAE	*Caladenia*	*flava* subsp. *flava*			+	+		
	Caladenia	*flava* subsp. *sylvestris*			+			
	Caladenia	*paludosa*			+			
	Caladenia	*speciosa* (P4)			+			
	* *Disa*	*bracteata*			+			
	Elythranthera	*brunonis*			+			
	Epiblema	*grandiflorum* var. *grandiflorum*						+
	Microtis	*media* subsp. *media*			+			+
	Praecoxanthus	*aphyllus*		+	+			
	Pyrorchis	*nigricans*		+	+	+	+	
	Thelymitra	*flexuosa*			+			
	Thelymitra	sp.					+	
	Orchidaceae	sp.					+	
	Orchidaceae	sp.1					+	
	Orchidaceae	sp.2					+	
	Orchidaceae	sp.3					+	
CASUARINACEAE	*Allocasuarina*	*fraseriana*	+	+	+			
	Allocasuarina	*humilis*		+	+			
PROTEACEAE	*Adenanthos*	*cygnorum*		+	+			
	Adenanthos	*meisneri*	+	+	+	+		+
	Adenanthos	*obovatus*	+		+			+
	Banksia	*attenuata*	+	+	+	+	+	+
	Banksia	*grandis*		+	+	+	+	
	Banksia	*ilicifolia*	+	+	+	+	+	+
	Banksia	*littoralis*	+	+	+	+	+	+

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PROTEACEAE (Continued)	*Banksia*	*menziesii*		+	+			+
	Hakea	*ceratophylla*	+	+	+			
	Hakea	*sulcata*		+	+			
	Hakea	*trifurcata* (small flowering form)	+	+	+	+		+
	Hakea	*varia*	+	+	+	+	+	
	Hakea	sp.	+	+	+			
	Persoonia	*longifolia*		+	+	+		
	Persoonia	*saccata*		+	+			
	Petrophile	*linearis*		+	+	+		
	Stirlingia	*latifolia*		+	+	+		
	Xylomelum	*occidentale*		+	+	+		
SANTALACEAE	*Leptomeria*	*pauciflora*			+			
LORANTHACEAE	*Nuytsia*	*floribunda*	+	+	+	+	+	
CHENOPODIACEAE	* *Chenopodium*	*macrospermum*		+	+	+		
	Chenopodium	*pumilio*		+	+			
PHYTOLACCACEAE	* *Phytolacca*	*octandra*		+	+			
CARYOPHYLLACEAE	* *Petrorhagia*	*dubia*			+			
	* *Silene*	*gallica*						+
LAURACEAE	*Cassytha*	*flava*						+
	Cassytha	*racemosa*	+	+	+	+	+	+
DROSERACEAE	*Drosera*	*gigantea*			+	+		
	Drosera	*glanduligera*			+			
	Drosera	*nitidula* subsp. *nitidula*						+
	Drosera	?*occidentalis* subsp. *occidentalis* (P4)						+
	Drosera	*paleacea*		+	+			
	Drosera	*paleacea* subsp. *paleacea*						+
	Drosera	*platystigma*					+	
	Drosera	*stolonifera* subsp. *stolonifera*			+			
	Drosera	sp.		+	+	+	+	
CRASSULACEAE	*Crassula*	*colorata*			+			+
PITTOSPORACEAE	*Billardiera*	*variifolia*		+	+			
MIMOSACEAE	*Acacia*	*barbinervis*		+	+			
	Acacia	*cyclops*						+
	Acacia	*divergens*					+	
	Acacia	*extensa*		+	+	+		
	Acacia	*flagelliformis* (P4)		+	+			
	Acacia	*huegelii*		+	+	+		
	Acacia	*incurva*		+	+			
	Acacia	*pulchella*	+	+	+	+	+	+
	Acacia	*saligna*	+	+	+			
	Acacia	*semitrullata* (P3)		+	+	+		+
	Acacia	*stenoptera*						+

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			Botanical Studies					
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PAPILIONACEAE	*Aotus*	*gracillima*		+	+			+
	Aotus	*procumbens*		+	+			
	Bossiaea	*eriocarpa*		+	+	+		+
	Bossiaea	*ornata*		+	+	+	+	
	* *Chamaecytisus*	*palmensis*				+		
	Daviesia	*incrassata* subsp. *incrassata*	+	+	+	+		
	Dillwynia	*dillwynioides* (P3)						+
	Euchilopsis	*linearis*	+	+	+			+
	Eutaxia	*virgata*		+	+			+
	Gompholobium	*aristatum*		+	+			
	Gompholobium	*capitatum*		+	+			+
	Gompholobium	*confertum*		+	+			
	Gompholobium	*tomentosum*		+	+	+	+	+
	Gompholobium	*venustum*		+	+			
	Hardenbergia	*comptoniana*		+	+		+	+
	Hovea	*trisperma*			+			+
	Jacksonia	*furcellata*	+	+	+	+	+	+
	Jacksonia	*sternbergiana*		+	+	+	+	
	Kennedia	*coccinea*		+	+			
	Kennedia	*prostrata*		+	+	+		
	Latrobea	*tenella* var. *tenella*		+	+			
	* *Lotus*	*subbiflorus*		+	+			+
	* *Lupinus*	*angustifolius*			+	+		
	* *Medicago*	sp.			+			
	Nemcia	*reticulata*		+	+			
	Oxylobium	*lineare*	+	+	+			+
	Pultenaea	*ochreata*		+	+			
	Pultenaea	*reticulata*		+	+			
	* *Trifolium*	sp.		+		+		+
	* *Trifolium*	sp. 1			+			
	* *Trifolium*	sp. 2			+			
	Viminaria	*juncea*	+	+	+			+
	Papilionaceae	sp.1		+				
	Papilionaceae	sp.			+			
GERANIACEAE	* *Pelargonium*	sp.		+	+	+		
RUTACEAE	*Boronia*	*capitata* subsp. *gracilis* (P2)		+	+			
	Boronia	*dichotoma*		+	+			+
	Boronia	*fastigiata*		+	+	+		
	Boronia	*juncea* subsp. *juncea* (P1)		+	+		+	+
	Boronia	*ramosa* subsp. *anethifolia*						+
	Philotheca	*spicata*		+	+	+		
TREMANDRACEAE	*Platytheca*	*galioides*			+			+
	Tetratheca	*hirsuta*		+	+	+		
	Tetratheca	?*hirsuta*			+			

APPENDIX A : VASCULAR PLANT SPECIES RECORDED ON THE GWALIA PROJECT AREA BETWEEN 1992 AND 1999

Note: 1 - December 1992 Gwalia Project Area Survey (Mattiske, 1993a)
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3 - October 1993 Gwalia Project Area Survey (Mattiske, 1993c)
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5 - Gwalia 1997 & 1998 Monitoring Plots (Ecos Consulting Pty Ltd & Arbotech Pty Ltd)
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* denotes Introduced Species

			Botanical Studies					
FAMILY	**GENUS**	**SPECIES**	**1**	**2**	**3**	**4**	**5**	**6**
POLYGONACEAE	* *Acetosella*	*vulgaris*		+	+			+
	Comesperma	*calymega*		+	+			
	Comesperma	*confertum*		+	+			
	Comesperma	*flavum*		+	+			
	Comesperma	*virgatum*	+	+	+		+	+
	Comesperma	sp.	+					
EUPHORBIACEAE	*Phyllanthus*	*calycinus*		+	+	+		
STACKHOUSIACEAE	*Stackhousia*	*monogyna*			+		+	
DILLENIACEAE	*Hibbertia*	*huegelii*		+	+	+		
	Hibbertia	*hypericoides*		+	+	+	+	
	Hibbertia	*perfoliata*		+	+			+
	Hibbertia	*racemosa*		+	+			
	Hibbertia	*stellaris*	+	+	+			+
	Hibbertia	*subvaginata*		+	+	+	+	
	Hibbertia	*vaginata*		+	+			+
THYMELAEACEAE	*Pimelea*	*angustifolia*		+	+			
	Pimelea	?*brevifolia*		+	+			
	Pimelea	*ciliata*		+	+			
	Pimelea	*lanata*		+	+			+
	Pimelea	*lehmanniana* subsp. *nervosa*		+	+			
	Pimelea	*rosea*						+
	Pimelea	sp.	+					
LYTHRACEAE	* *Lythrum*	*hyssopifolia*						+
MYRTACEAE	*Agonis*	*flexuosa*	+	+	+	+		+
	Astartea	*fascicularis*	+	+	+	+	+	+
	Calothamnus	*lateralis*		+	+	+	+	+
	Calytrix	*angulata*	+	+	+			+
	Calytrix	*flavescens*	+	+	+		+	
	Calytrix	*fraseri*	+	+	+	+	+	
	Calytrix	sp.		+	+			
	Corymbia	*calophylla*	+	+	+	+	+	
	Darwinia	*oederoides*		+	+			
	?*Eremaea*	*pauciflora*					+	
	Eucalyptus	*decipiens*		+	+			+
	Eucalyptus	*marginata* subsp. *marginata*	+	+	+	+	+	+
	Eucalyptus	*rudis*	+	+	+			+
	Hypocalymma	*angustifolium*	+	+	+	+	+	+
	Kunzea	*ericifolia* subsp. *ericifolia*	+	+	+	+	+	+
	Kunzea	*micrantha*						+
	Kunzea	*recurva*	+	+	+			
	Melaleuca	*cuticularis*	+	+	+			
	Melaleuca	*incana* subsp. *incana*	+	+	+			+
	Melaleuca	?*incana*		+	+			
	Melaleuca	*lateriflora* subsp. *acutifolia*		+	+			

APPENDIX A : VASCULAR PLANT SPECIES RECORDED ON THE GWALIA PROJECT AREA BETWEEN 1992 AND 1999

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			Botanical Studies					
FAMILY	**GENUS**	**SPECIES**	**1**	**2**	**3**	**4**	**5**	**6**
MYRTACEAE	*Melaleuca*	*lateritia*	+	+	+			+
(Continued)	*Melaleuca*	*pauciflora*		+	+			
	Melaleuca	*preissiana*	+	+	+	+	+	+
	Melaleuca	*rhaphiophylla*	+	+	+		+	+
	Melaleuca	*systena*						+
	Melaleuca	*teretifolia*		+	+			+
	Melaleuca	*thymoides*	+	+	+	+	+	+
	Melaleuca	*uncinata*	+	+	+			
	Melaleuca	*viminea*	+	+	+		+	
	Melaleuca	sp.	+					
	Melaleuca	sp. (*brachyphylla* B.Keighery)						+
	Melaleuca	sp.1		+	+			
	Melaleuca	sp.2		+	+			
	Pericalymma	*ellipticum*	+	+	+	+		+
	Taxandria	*linearifolia ms*		+	+			
	Verticordia	*nitens*		+	+			+
	Verticordia	*plumosa*	+	+	+			
HALORAGACEAE	*Gonocarpus*	*cordiger*		+	+			
	Gonocarpus	*pithyoides*						+
	?Gonocarpus	sp.			+			
APIACEAE	*Centella*	*asiatica*	+	+	+	+		
	Homalosciadium	*homalocarpum*						+
	Platysace	*compressa*		+	+	+	+	+
	Platysace	*tenuissima*		+	+			
	Trachymene	*pilosa*			+			+
	Trachymene	sp.					+	
	Xanthosia	*huegelii*			+			
EPACRIDACEAE	*Astroloma*	*drummondii*		+	+			
	Astroloma	*pallidum*					+	
	Brachyloma	*preissii*		+	+		+	
	Conostephium	*pendulum*		+	+		+	
	Leucopogon	*australis*	+	+	+	+		
	Leucopogon	*conostephioides*		+	+	+	+	
	Leucopogon	*polymorphus*		+	+			
	Leucopogon	*propinquus*		+	+			
	Leucopogon	*racemulosus*		+	+			
	Leucopogon	*sprengelioides*		+	+			
	Leucopogon	sp. (white)					+	
	Lysinema	*ciliatum*		+	+			+
	Styphelia	*tenuiflora*					+	
PRIMULACEAE	* *Anagallis*	*arvensis*			+	+		+
LOGANIACEAE	*Logania*	*vaginalis*		+	+			+
	Phyllangium	*paradoxum*			+			+
GENTIANACEAE	* *Centaurium*	*erythraea*	+	+	+			
	* *Centaurium*	*pulchellum*						+

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			Botanical Studies					
FAMILY	GENUS	SPECIES	1	2	3	4	5	6
MENYANTHACAEAE	*Villarsia*	*albiflora*					+	+
	Villarsia	*capitata*						+
ASCLEPIADACEAE	* *Gomphocarpus*	*fruticosus*		+	+			
LAMIACEAE	*Hemiandra*	*pungens*		+	+	+		
	* *Mentha*	*pulegium*		+	+			
	* *Mentha*	sp.	+					
SOLANACEAE	* *Solanum*	*nigrum*		+	+			+
SCROPHULARIACEAE	* *Dischisma*	*arenarium*			+			
	Gratiola	*pubescens*		+	+			
	* *Misopates*	*orontium*						+
	* *Parentucellia*	*latifolia*			+			
	* *Parentucellia*	*viscosa*						+
OROBANCHACEAE	* *Orobanche*	*minor*			+			+
LENTIBULARIACEAE	*Utricularia*	*multifida*			+			
RUBIACEAE	*Opercularia*	*hispidula*		+	+		+	+
CAMPANULACEAE	*Wahlenbergia*	*preissii*			+			
LOBELIACEAE	*Lobelia*	*alata*		+	+			
	Lobelia	*tenuior*						+
	* *Monopsis*	*debilis*						+
GOODENIACEAE	*Anthotium*	*humile*		+	+			
	Anthotium	*junciforme* (P4)						+
	Dampiera	*linearis*		+	+	+		+
	Goodenia	*filiformis* (P3)		+	+			
	Lechenaultia	*biloba*		+	+	+		
	Lechenaultia	*expansa*						+
	Scaevola	*calliptera*		+	+			
STYLIDIACEAE	*Stylidium*	*amoenum*					+	
	Stylidium	*brunonianum*		+	+	+		+
	Stylidium	*caespitosum*						+
	Stylidium	*calcaratum*		+	+			+
	Stylidium	*despectum*						+
	Stylidium	*divaricatum*		+	+			+
	Stylidium	*guttatum*		+	+			+
	Stylidium	*inundatum*		+	+			
	Stylidium	*junceum*		+	+			+
	Stylidium	*piliferum*		+	+			
	Stylidium	*repens*		+	+			
	Stylidium	*scandens*						
	Stylidium	*schoenoides*			+			
	Stylidium	sp.	+	+	+	+		

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* denotes Introduced Species

FAMILY	GENUS	SPECIES	Botanical Studies 1	2	3	4	5	6
ASTERACEAE	* *Arctotheca*	*calendula*			+	+		
	Brachyscome	*iberidifolia*			+			
	* *Conyza*	*bonariensis*		+	+			
	Cotula	*coronopifolia*			+			
	* *Dittrichia*	*graveolens*		+	+			
	Gnephosis	*drummondii*		+	+			
	Hyalosperma	*cotula*			+	+		
	* *Hypochaeris*	*glabra*		+	+	+		+
	Ixiolaena	*viscosa*						+
	Myriophyllum	*echinatum* (P3)						+
	Olearia	*elaeophila*		+	+			
	Podotheca	*angustifolia*			+			
	Podotheca	*chrysantha*			+			
	* *Pseudognaphalium*	*luteoalbum*						+
	Rhodanthe	*citrina*			+			
	Senecio	*lautus* subsp. *dissectifolius*			+			
	* *Senecio*	*vulgaris*						+
	Senecio	sp.		+	+			
	Siloxerus	*filifolius*		+	+			+
	* *Sonchus*	*oleraceus*						+
	* *Symphyotrichum*	*subulatum*		+	+			
	* *Taraxacum*	*officinale*		+	+			
	* *Ursinia*	*anthemoides*	+	+	+	+		+
	* Asteraceae	sp. 1		+	+			
	* Asteraceae	sp. 2		+	+			

APPENDIX B : SUMMARY OF PLANT SPECIES IN THE VEGETATION COMMUNITIES OF THE GWALIA PROJECT AREA, OCTOBER 1993 (Mattiske 1993c)

Note : * denotes introduced species; Disturbance communities I1, I2 and I3 not included in this Appendix

	Plant Communities																							
Species	**A-1**	**A-2**	**A-3**	**B-1**	**C-1**	**C-2**	**C-3**	**D-1**	**D-2**	**D-3**	**E-1**	**E-2**	**E-3**	**E-4**	**F-1**	**F-2**	**F-3**	**G-1**	**G-2**	**G-3**	**G-4**	**H-1**	**H-2**	**H-3**
Acacia barbinervis	+	+	+	+							+	+						+				+		
Acacia extensa	+	+	+							+	+		+									+		
Acacia flagelliformis (P4)																						+	+	
Acacia huegelii			+					+																
Acacia pulchella	+	+	+	+	+			+	+		+	+			+			+	+			+	+	
Acacia saligna			+						+						+	+						+		
Acacia semitrullata (P3)	+		+	+							+	+						+	+			+		
* *Acetosella vulgaris*							+												+					
Actinostrobus pyramidalis															+									
Adenanthos cygnorum				+																				
Adenanthos meisneri	+		+	+					+		+	+						+				+		
Adenanthos obovatus				+					+		+	+			+			+		+		+	+	
Agonis flexuosa					+	+	+		+	+														
Agrostocrinum scabrum			+	+																				
* *Aira caryophyllea*				+																				
Allocasuarina fraseriana			+																					
Allocasuarina humilis		+																						
* *Anagallis arvensis*					+																			
Anarthria gracilis	+	+	+								+	+						+				+		
Anigozanthos manglesii subsp. manglesii			+																					
Anthotium humile															+									
Aotus gracillima																						+		
Aotus procumbens	+																							
* *Arctotheca calendula*					+																			
Astartea fascicularis									+	+	+	+	+	+	+	+		+	+	+		+	+	+
* Asteraceae sp. 1			+																					
* Asteraceae sp. 2									+															
Astroloma drummondii	+		+																					
Austrostipa ?compressa				+																				
Banksia attenuata	+	+	+			+												+						
Banksia grandis		+	+																					
Banksia ilicifolia	+		+			+			+		+							+				+		

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Note : * denotes introduced species; Disturbance communities I1, I2 and I3 not included in this Appendix

	Plant Communities																							
Species	**A-1**	**A-2**	**A-3**	**B-1**	**C-1**	**C-2**	**C-3**	**D-1**	**D-2**	**D-3**	**E-1**	**E-2**	**E-3**	**E-4**	**F-1**	**F-2**	**F-3**	**G-1**	**G-2**	**G-3**	**G-4**	**H-1**	**H-2**	**H-3**
Banksia littoralis							+		+											+		+	+	
Banksia menziesii			+															+						
Baumea articulata										+							+					+		
Baumea juncea			+												+					+				
Billardiera variifolia			+						+															
Boronia capitata subsp. *gracilis* (P2)			+																					
Boronia dichotoma			+																					
Boronia fastigiata	+		+																			+		
Boronia juncea subsp. *juncea* (P1)									+														+	
Bossiaea eriocarpa	+	+	+	+							+	+						+						
Bossiaea ornata	+		+																					
Brachyloma preissii	+	+	+															+						
Brachyscome iberidifolia	+																							
* *Briza maxima*			+	+			+						+						+					
* *Briza minor*	+	+	+		+		+	+				+						+	+			+		
Burchardia umbellata	+																							
Caladenia flava subsp. *flava*	+	+	+	+			+				+							+	+			+		
Caladenia flava subsp. *sylvestris*			+																					
Caladenia paludosa																						+		
Caladenia speciosa (P4)																						+		
Calothamnus lateralis									+		+				+					+		+	+	+
Calytrix angulata	+		+			+																		
Calytrix flavescens	+	+	+								+							+						
Calytrix fraseri	+	+	+								+	+						+						
Cartonema philydroides		+	+		+	+		+											+					
Cassytha racemosa			+						+	+	+		+		+			+		+		+	+	+
* *Centaurium erythraea*																				+				
Centella asiatica																							+	
Centrolepis aristata															+									
Chaetanthus aristatus									+				+		+	+								
Chaetanthus leptocarpoides																							+	
Chamaescilla corymbosa			+																					

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	Plant Communities																							
Species	**A-1**	**A-2**	**A-3**	**B-1**	**C-1**	**C-2**	**C-3**	**D-1**	**D-2**	**D-3**	**E-1**	**E-2**	**E-3**	**E-4**	**F-1**	**F-2**	**F-3**	**G-1**	**G-2**	**G-3**	**G-4**	**H-1**	**H-2**	**H-3**
* *Chenopodium macrospermum*																							+	
Chenopodium pumilio															+									
Comesperma calymega															+									
Comesperma confertum																						+	+	
Comesperma flavum												+											+	
Comesperma virgatum																							+	
Conostephium pendulum	+		+																					
Conostylis juncea	+		+															+						
Corymbia calophylla	+		+	+			+	+	+		+			+	+			+	+			+	+	
Cotula coronopifolia			+																					
Crassula colorata																						+		
Cyathochaeta avenacea																						+		
* *Cyperus tenellus*																						+	+	
Dampiera linearis																		+				+		
Darwinia oederoides																						+		
Dasypogon bromeliifolius	+	+	+	+		+					+	+						+				+	+	
Daviesia incrassata subsp. *incrassata*	+	+																				+		
Desmocladus flexuosus	+											+												
Dianella revoluta			+																					
Dichanthium sp.															+									
* *Disa bracteata*																		+						
* *Dischisma arenarium*					+																			
* *Dittrichia graveolens*									+															
Drosera gigantea									+															
Drosera glanduligera				+																				
Drosera paleacea			+															+				+		
Drosera stolonifera subsp. *stolonifera*			+																					
Drosera sp.	+	+	+															+				+		
Elythranthera brunonis	+	+	+																					
Eucalyptus decipiens									+															
Eucalyptus marginata subsp. *marginata*	+	+	+	+	+							+						+	+			+		
Eucalyptus rudis							+	+	+	+								+				+		

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Note : * denotes introduced species; Disturbance communities I1, I2 and I3 not included in this Appendix

Species	Plant Communities																							
	A-1	A-2	A-3	B-1	C-1	C-2	C-3	D-1	D-2	D-3	E-1	E-2	E-3	E-4	F-1	F-2	F-3	G-1	G-2	G-3	G-4	H-1	H-2	H-3
Euchilopsis linearis		+							+						+			+				+	+	
Eutaxia virgata																							+	+
Evandra pauciflora																						+		
Gahnia trifida									+						+	+								
Gahnia sp.																							+	
Gnephosis drummondii															+									
* *Gomphocarpus fruticosus*															+									
Gompholobium aristatum	+		+	+														+						
Gompholobium capitatum			+															+						
Gompholobium confertum			+																					
Gompholobium tomentosum	+	+	+					+	+									+						
Gompholobium venustum			+																					
Gonocarpus cordiger			+															+						
? *Gonocarpus* sp.					+																			
Goodenia filiformis (P3)									+														+	
Gratiola pubescens																						+		
Hakea ceratophylla															+									
Hakea sulcata															+									
Hakea trifurcata (small flowering form)									+			+												
Hakea varia			+				+								+	+		+		+			+	
Hakea sp.																							+	
Hardenbergia comptoniana					+	+			+										+					
Hemiandra pungens	+	+	+																					
Hibbertia huegelii									+	+												+	+	
Hibbertia hypericoides	+	+	+	+		+	+											+						
Hibbertia perfoliata							+		+															
Hibbertia racemosa	+						+											+						
Hibbertia stellaris																							+	
Hibbertia subvaginata	+		+			+												+					+	
Hibbertia vaginata	+	+	+				+		+									+		+		+		
* *Holcus lanatus*				+																				
Hovea trisperma																						+		

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	Plant Communities																							
Species	**A-1**	**A-2**	**A-3**	**B-1**	**C-1**	**C-2**	**C-3**	**D-1**	**D-2**	**D-3**	**E-1**	**E-2**	**E-3**	**E-4**	**F-1**	**F-2**	**F-3**	**G-1**	**G-2**	**G-3**	**G-4**	**H-1**	**H-2**	**H-3**
Hyalosperma cotula	+		+																					
Hypocalymma angustifolium			+	+		+		+	+	+	+	+			+			+		+		+	+	
* *Hypochaeris glabra*				+			+		+										+			+		
Hypolaena exsulca															+									
Hypolaena pubescens													+											
Jacksonia furcellata	+		+	+				+			+	+							+			+		
Jacksonia sternbergiana	+	+	+			+	+		+	+		+						+				+		
Johnsonia acaulis				+																				
* *Juncus bufonius*																							+	
Juncus pallidus																							+	
Kennedia coccinea			+																					
Kennedia prostrata			+																					
Kunzea ericifolia subsp. *ericifolia*	+	+	+	+		+		+	+		+	+			+	+	+	+		+		+		
Kunzea recurva	+						+		+						+	+						+		
* *Lagurus ovatus*			+									+			+							+		
Latrobea tenella var. *tenella*	+																					+		
Lechenaultia biloba			+																					
Lepidobolus sp.															+									
Lepidosperma drummondii																						+		
Lepidosperma longitudinale							+		+	+	+		+	+	+	+		+	+	+		+	+	+
Lepidosperma squamatum	+	+	+									+						+						
Lepidosperma sp.																						+		
Leptocarpus tenax									+					+	+			+		+		+	+	+
Leptomeria pauciflora		+	+																					
Leucopogon australis		+																+					+	
Leucopogon conostephioides	+	+	+															+						
Leucopogon polymorphus			+																					
Leucopogon propinquus	+	+	+															+						
Leucopogon racemulosus	+		+																			+		
Leucopogon sprengelioides		+																						
Lobelia alata																		+					+	
Logania vaginalis							+		+															

APPENDIX B : SUMMARY OF PLANT SPECIES IN THE VEGETATION COMMUNITIES OF THE GWALIA PROJECT AREA, OCTOBER 1993 (Mattiske 1993c)

Note : * denotes introduced species; Disturbance communities I1, I2 and I3 not included in this Appendix

	Plant Communities																							
Species	**A-1**	**A-2**	**A-3**	**B-1**	**C-1**	**C-2**	**C-3**	**D-1**	**D-2**	**D-3**	**E-1**	**E-2**	**E-3**	**E-4**	**F-1**	**F-2**	**F-3**	**G-1**	**G-2**	**G-3**	**G-4**	**H-1**	**H-2**	**H-3**
Lomandra hermaphrodita	+	+	+															+				+		
Lomandra sonderi			+	+					+									+				+		
Lomandra suaveolens	+								+													+		
Lomandra ?suaveolens			+																					
* *Lotus subbiflorus*															+									
Lyginia barbata	+	+	+	+		+	+		+			+						+				+	+	+
Lysinema ciliatum																						+		
Macrozamia riedlei	+	+	+		+		+											+						
Meeboldina coangustata			+						+			+	+		+					+		+	+	+
Meeboldina scariosa	+	+	+	+		+		+	+		+	+			+			+				+	+	+
Melaleuca cuticularis																+								
Melaleuca incana subsp. *incana*			+						+						+	+								
Melaleuca lateriflora subsp. *acutifolia*															+									
Melaleuca lateritia														+	+								+	+
Melaleuca pauciflora									+						+					+				
Melaleuca preissiana			+	+		+	+		+		+	+	+	+	+		+	+		+		+	+	+
Melaleuca rhaphiophylla										+			+	+	+	+	+							+
Melaleuca teretifolia										+					+							+	+	
Melaleuca thymoides	+	+	+	+	+	+					+	+						+				+		
Melaleuca viminea									+						+	+	+			+	+		+	+
Melaleuca sp. 1																							+	
Melaleuca sp. 2																							+	
* *Mentha pulegium*									+														+	
Mesomelaena graciliceps																						+		
Mesomelaena tetragona																							+	
Microtis media subsp. *media*																						+		
Nemcia reticulata	+		+															+						
Neurachne alopecuroidea																								
Nuytsia floribunda			+	+					+		+	+			+			+				+		
Olearia elaeophila	+																							
Opercularia hispidula					+		+	+	+			+												
* *Orobanche minor*																						+		

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Note : * denotes introduced species; Disturbance communities I1, I2 and I3 not included in this Appendix

	Plant Communities																							
Species	**A-1**	**A-2**	**A-3**	**B-1**	**C-1**	**C-2**	**C-3**	**D-1**	**D-2**	**D-3**	**E-1**	**E-2**	**E-3**	**E-4**	**F-1**	**F-2**	**F-3**	**G-1**	**G-2**	**G-3**	**G-4**	**H-1**	**H-2**	**H-3**
Oxylobium lineare	+	+	+						+						+								+	
Papilionaceae sp.																						+		
* *Parentucellia latifolia*					+																			
Patersonia occidentalis			+																			+		
Patersonia ?occidentalis																		+						
Patersonia sp.												+												
* *Pelargonium* sp.					+																			
Pericalymma ellipticum			+	+				+	+		+	+						+		+		+	+	
Persoonia longifolia	+		+																					
Persoonia saccata	+	+	+																					
Petrophile linearis	+	+	+															+						
Philotheca spicata			+																					
Phlebocarya ciliata	+	+	+																			+		
Phyllangium paradoxum																						+		
Phyllanthus calycinus			+																					
Pimelea angustifolia									+									+				+		
Pimelea ?brevifolia																						+		
Pimelea ciliata																	+							
Pimelea lanata							+															+	+	
Pimelea lehmanniana subsp. *nervosa*																						+		
Platysace compressa	+		+	+		+		+				+	+					+	+					
Platysace tenuissima																		+					+	
Platytheca galioides	+		+																			+		
Poaceae sp.				+			+												+					
Podotheca angustifolia		+																						
Podotheca chrysantha		+																						
* *Polypogon monspeliensis*															+									
Praecoxanthus aphyllus			+																					
Pteridium esculentum										+				+					+					
Pultenaea ochreata			+									+								+		+		
Pultenaea reticulata			+															+						
Pyrorchis nigricans								+										+						

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Note : * denotes introduced species; Disturbance communities I1, I2 and I3 not included in this Appendix

	Plant Communities																							
Species	**A-1**	**A-2**	**A-3**	**B-1**	**C-1**	**C-2**	**C-3**	**D-1**	**D-2**	**D-3**	**E-1**	**E-2**	**E-3**	**E-4**	**F-1**	**F-2**	**F-3**	**G-1**	**G-2**	**G-3**	**G-4**	**H-1**	**H-2**	**H-3**
Restionaceae sp.	+		+						+		+	+						+				+	+	
Rhodanthe citrina			+																					
* *Romulea rosea* var. *australis*					+																			
Scaevola calliptera									+															
Schoenus cruentus																							+	
Schoenus efoliatus												+										+		
Schoenus pedicellatus															+									
Senecio sp.			+																			+		
Siloxerus filifolius															+									
* *Solanum nigrum*							+																	
Stackhousia monogyna	+		+																					
Stirlingia latifolia	+	+	+															+						
Stylidium brunonianum	+	+	+															+				+	+	
Stylidium calcaratum																						+		
Stylidium divaricatum																							+	
Stylidium guttatum															+									
Stylidium inundatum															+									
Stylidium junceum									+															
Stylidium piliferum			+																					
Stylidium repens																		+						
Stylidium schoenoides															+									
* *Symphyotrichum subulatum*				+																				
Taxandria linearifolia ms									+				+	+			+		+			+	+	+
Tetratheca hirsuta			+																					
Tetratheca ?hirsuta	+																							
Thelymitra flexuosa			+															+						
Thysanotus manglesianus																						+		
Thysanotus multiflorus			+																					
Trachymene pilosa			+																					
Tribonanthes ?violacea															+									
* *Trifolium* sp. 1							+																	
* *Trifolium* sp. 2					+																			

APPENDIX B : SUMMARY OF PLANT SPECIES IN THE VEGETATION COMMUNITIES OF THE GWALIA PROJECT AREA, OCTOBER 1993 (Mattiske 1993c)

Note : * denotes introduced species; Disturbance communities I1, I2 and I3 not included in this Appendix

Species	Plant Communities																							
	A-1	A-2	A-3	B-1	C-1	C-2	C-3	D-1	D-2	D-3	E-1	E-2	E-3	E-4	F-1	F-2	F-3	G-1	G-2	G-3	G-4	H-1	H-2	H-3
* *Typha orientalis*																+								
* *Ursinia anthemoides*	+		+																			+		
Utricularia multifida																		+						
Verticordia nitens			+																					
Verticordia plumosa																						+		
Viminaria juncea													+											
* *Vulpia* sp.															+									
Wahlenbergia preissii	+		+	+														+						
* *Watsonia meriana* var. *bulbillifera*			+																					
Xanthorrhoea brunonis	+				+				+			+						+				+		
Xanthorrhoea preissii	+	+	+	+			+	+	+	+	+	+			+			+				+	+	
Xanthosia huegelii			+																					
Xylomelum occidentale			+																					
Xyris lacera																						+		

APPENDIX 5:
KEMERTON SIGNIFICANT FLORA AND WETLANDS
JUNE 2004
BENNETT ENVIRONMENTAL CONSULTING PTY LTD

KEMERTON
SIGNIFICANT FLORA AND WETLANDS

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June 2004

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SUMMARY

Bennett Environmental Consulting Pty Ltd was contracted by Martinick Bosch Sell Pty Ltd to undertake a Declared Rare Flora (DRF) and Priority Flora (PF) survey, and mapping these plants and wetlands and to assess the importance of the wetlands at the Kemerton Silica Sand site, Kemerton. Several botanical surveys have been undertaken of the Kemerton area, including Kemerton Silica Sand (Mattiske E.M. and Associates, 1993a-d and Muir Environmental, 1999).

The current survey resulted in the following significant species being recorded.

- *Boronia juncea* subsp. *juncea* a Priority 1 species. This species occurred typically associated with *Astartea scoparia* or with other species where there was water on the surface during the September 2003 survey.
- *Boronia capitata* subsp. *gracilis* a Priority 2 species was only recorded along the powerline track that traverses the northern section from SW to NE.
- *Acacia semitrullata* a Priority 3 species was common in the higher ground associated with *Kunzea glabrescens, Banksia ilicifolia, Banksia attenuata* and/or *Eucalyptus marginata* subsp. *marginata*.
- *Eucalyptus rudis* subsp. *cratyantha* a Priority 3 species was the only subspecies of *Eucalyptus rudis* recorded during the survey.
- *Dillwynia dillwynioides* a Priority 3 species was common in the damp areas where water was on the surface in the September and October surveys but where it was drier in November.
- *Acacia flagelliformis* a Priority 4 species was only recorded in the southern section of the survey area but was common where it did occur.
- *Caladenia speciosa* a Priority 4 species was only recorded from 2 locations.
- *Jacksonia sparsa* a Priority 4 species was very common through the survey area in the higher ground.
- *Evandra pauciflora* is a species restricted to the damplands of the Swan Coastal Plain. It was relatively common in the area occurring on the edge of the wetlands as scattered plants or as the dominant species.
- *Verticordia nitens* is a species at its most southern range extension. It was only located in the south eastern section of the survey area.
- *Banksia menziesii,* recorded by Mattiske Consulting Pty Ltd (2003), is a species at the southern most end of its distribution. One plant was sighted along the fence line at the south west of the property.

The wetlands varied between sumplands, damplands, floodplains and palusplains depending on the soil, shape and standing water. They are within the Jandakot consanguineous wetland suite (Semeniuk, 1998). As the land had been grazed previously the vegetation condition was recorded as very good (vegetation condition 3) for most of the wetlands, some as good (vegetation condition 4) but none were degraded (vegetation condition 5) or completely degraded (vegetation condition 6). Each of the wetlands was a mosaic of vegetation units and, apart from areas of *Melaleuca rhaphiophylla* or *Melaleuca viminea* in standing water during the September and October surveys, was impossible to map in fine detail using an aerial photograph. The scale of the aerial photograph was the limiting factor. Vegetation units present at each wetland were described.

The wetland suites, a combination of one or more of the wetlands, were assessed using the questionnaire in Environmental Protection Authority (1993). This resulted in all being classified as Conservation (Environmental Protection Authority, 1993 and Water and Rivers Commission, 2001). This indicates that the wetlands at the site are of conservation importance although there is an area in wetland suite WC3 which already has infrastructures, including a drain at the wetland. Wetland Suite WC3 also includes EPP wetland 4.

The Environmental Protection Authority (2002) provides selection criteria for the identification of regionally significant natural areas on the southern Swan Coastal Plain. Kemerton Silica Sand met all these selection criteria with the exception that the land is privately owned. There is:

- Less than 30% of the pre-clearing extent of the Bassendean Complex – Central and South (27% remains);
- The area is in excess of 20ha;
- The vegetation is vegetation condition 3, very good.;
- Both uplands and wetlands occur;
- The area has importance for a linkage from the Spearwood system to the west, through the Bassendean Complex – Central and South and the Guildford system to the east.

Using the criteria identified by the Environmental Protection Authority (2002) for assessing the regional significance of an area within the Bunbury Greater Region, Kemerton Silica Sand is considered to be regionally significant. This is provided in the planning scheme of the Environmental Protection Authority (2003) in their consideration of the Greater Bunbury Region Scheme. This plan had not been resolved at the time of this report. If approval is received to extend the mining area care will need to be exercised to ensure that the remnant and conservation classified wetlands are not compromised.

1. INTRODUCTION

Bennett Environmental Consulting Pty Ltd was contracted by Martinick Bosch Sell Pty Ltd to undertake an assessment of the wetlands and significant flora at the Kemerton Silica Sand site. This included to:

- undertake a survey to located Declared Rare Flora (DRF) and Priority Flora (PF) survey;
- map Declared Rare Flora and Priority Flora located;
- assess vegetation units of the wetlands;
- record the vegetation condition of the wetlands; and
- assess the wetlands using the questionnaire in Department of Environmental Protection (1993).

There have been several vegetation surveys undertaken of the site and the surrounding area over the last 10 years with most of the data being summarised in Mattiske Consulting Pty Ltd (2003). In this publication it was recommended that a search be undertaken to extend the known distribution of recorded DRF and PF within the site. Muir Environmental (1999) undertook a vegetation survey of the Kemerton Industrial Estate, which includes the Kemerton Silica Sand site in a more extensive area.

The Kemerton Silica Sand project area contains areas of the Bassendean Complex (Central and South), Guildford Complex and the interface between them with the Karrakatta Complex abutting to the west (Keighery, 1998). Within the Greater Bunbury Region, 39% of the Bassendean Complex Central and South remain vegetated and less than 4% of the Guildford Complex (Environmental Protection Authority, 2002). Only 1% of the Bassendean Complex Central and South remains in secure tenure in the Greater Bunbury Region. Within the area surveyed during this study there was only a small area of Guildford Complex included and that occurred in the section to the north of the proposed conservation area.

A large percentage of the project area consists of wetlands and is included in the Jandakot consanguineous wetland suite (Semeniuk, 1998). Consanguineous wetlands are genetically related types based on wetland type, wetland geometry, stratigraphy, inferred origin and water characteristics. The primary wetlands identified for the Jandakot consanguineous wetland suite are damplands and sumplands typically occurring in peat or peaty sand or humic sand overlying quartz sand where the groundwater surfaces is at or near the surface in depressions to develop water table basins.

2. METHODS

Prior to undertaking the field work a list of Declared Rare Flora (DRF) and Priority Flora (PF) was obtained from the Department of Conservation and Land Management by Martinick Bosch Sell Pty Ltd. In addition Mattiske Consulting Pty Ltd (2003) was consulted for the list of species previously recorded from the location. All staff involved with the field work then checked and made notes on these species against the specimens housed at the Western Australian Herbarium to ensure their recognition in the field.

The field work was undertaken in three stages to ensure that the potential DRF and PF within the area were located. The first field work was undertaken between 22nd and 26th September, the second between 15th and 17th October and the third between 3rd and 5th November 2003. The project consisted of two sections, the first a search for DRF and PF, and the second the mapping and consideration of the importance of the wetlands at the site.

A team of three qualified environmentalists walked transects through the area at 100m intervals during the September survey. It had been intended to walk transects at 50m intervals but the bushland was very thick making progress very slow. The location of the transects are indicated in Appendix A. DRF and PF were again searched for at the October and November surveys when additional notes were made on the wetlands.

A collection of each species of DRF and PF was made for lodging at the Western Australian Herbarium. When these species were located a GPS reading in WGS84 datum was recorded together with a brief note about the associated vegetation. Where possible a photograph of each species was made but conditions when the field work was undertaken were not conducive for photography.

As the transects were walked, the different vegetation units traversed through the wetlands were recorded. The dominant species of each stratum within the different vegetation units was recorded, together with the presence of standing water. As the field work was undertaken each wetland or section of wetland was allocated a letter and the different vegetation units present within this recorded. As variations were small and often impossible to delineate on the aerial photographs the wetland as a whole is described. Areas of *Melaleuca rhaphiophylla/Melaleuca viminea* were often obvious and could be mapped. Where appropriate the mapping provided by Mattiske Consulting Pty Ltd (2003) was incorporated.

To ensure all wetlands had been thoroughly surveyed an afternoon was spent specifically completing all those not covered as a result of the transects. This included those to the east of the SW-NE powerline track and those to the east of the limestone track not covered by the transects.

3 RESULTS

3.1 Significant Flora

3.1.1 Background Information

The search of the Department of Conservation and Land Management records of occurrence of declared rare and priority species conducted in May 2003 resulted in the following species likely to be present.

- Four Declared Rare Flora species (*Caladenia huegelii*, *Diuris purdiei, Drakaea elastica* and *Drakaea micrantha*).
- No Priority 1 species.
- Three Priority 2 species (*Boronia capitata* subsp. *capitata*$^+$, *Haloragis aculeolata* and *Oligochaetochilus* sp. Yalgorup (G Brockman GBB463).
- Ten Priority 3 species (*Acacia semitrullata*$^+$*, Chamaescilla gibsonii, Haloragis tenuifolia, Hemigenia microphylla, Hibbertia spicata* subsp. *leptotheca, Lasiopetalum membranaceum, Myriophyllum echinatum, Rhodanthe pyrethrum, Schoenus* sp. *Waroona* (GJ Keighery 12235) (pn)$^+$ and *Verticordia attenuata)*.
- Five Priority 4 species (*Anthotium junciforme, Caladenia speciosa*$^+$*, Conostylis pauciflora* subsp. *pauciflora, Jacksonia sparsa* and *Pultenaea skinneri)*.

NOTE: $^+$ Indicated have or may previously have been recorded from the Kemerton Silica Sand project area in previous surveys.

In surveys undertaken by Mattiske Consulting Pty Ltd (1993a-d) the additional species were recorded:

- One Priority 1 species (*Boronia juncea* subsp. *juncea*).
- One Priority 2 species (*Boronia capitata* subsp. *gracilis)*.
- One Priority 3 species (*Goodenia filiformis*).
- One Priority 4 species (*Acacia flagelliformis*).

B. Keighery (1998) also suggested that *Hydatella dioica* (DRF), *Centrolepis caespitosa* (DRF), *Schoenus* sp. Waroona (GJ Keighery 12235) (pn), *Drosera occidentalis* subsp. *occidentalis* and *Schoenus capillifolius* (P2) are likely to occur in the project area. She also listed the following taxa as uncommon and restricted on the Swan Coastal Plain:

- A form of *Melaleuca systena* growing to two metres;
- *Melaleuca* sp. (*brachyphylla* – B.Keighery) an uncommon species on the Plain;
- *Hakea trifurcata* – a small flowered form;
- *Hibbertia perfoliata* – an uncommon and poorly collected species on the Plain (Muir, 1999).

In addition B. Keighery (1998) noted *Verticordia nitens* and *Banksia menziesii* are at the southern limits of their range and *Evandra pauciflora* as a distinctive sedge that inhabits damplands on the Swan Coastal Plain. This resulted in a relatively extensive list of significant species that could occur in the area.

3.1.2 Field Results

Ten of the significant species listed for the area were recorded during the survey. The occurrence of these is mapped and the number recorded is provided in Appendix B.

Boronia juncea subsp. *juncea* P1 was common through a lot of the wetlands, but only where there was standing water present during the September survey. Although not in flower it was readily recognised by the bright red stems, its height up to 1m and branching method. Some plants had commenced to flower when the November survey was undertaken.

Shrub and flower of *Boronia juncea* subsp. *juncea*

Shrubs of *Boronia juncea* subsp. *juncea* readily identified by their red colour. Photograph taken in September. Standing water visible.

Boronia capitata subsp. *gracilis* (P2) was recorded from along the SW/NE power line track in the northern area of the lease. There were hundreds of plants in this area, which had recently been disturbed. The site where Mattiske Consulting Pty Ltd (2003) had recorded the species was searched thoroughly but no plants were recorded. It is possible that when the original Mattiske Consulting survey was undertaken that the area had been recently disturbed, and that if the area is disturbed again the species will reappear.

Boronia capitata subsp. *gracilis*

Acacia semitrullata (P3) was very common through the damp and slightly higher ground. It occurred as scattered plants throughout the location. It was so common that its distribution is illustrated broadly on the map. It was so abundant that all sites were not recorded with a GPS reading.

Acacia semitrullata

Dillwynia dillwynioides (P3) blended in with the surrounding vegetation until it was in full flower. In the October and November survey there were many plants of this species recorded in areas that were currently or until recently were in standing water. The bright orange flowers contrasted markedly with the surrounding vegetation. When in bud or flower this species can be positively identified by the dense long hairs on the calyx.

Dillwynia dillwynioides shrub in flower

Eucalyptus rudis subsp. *cratyantha* (P3) was the only *E. rudis* recorded from the location. It is stated in 'Flora of the South West Bunbury – Augusta – Denmark' (Wheeler *et al*., 2003) that only this subspecies occurs within the area covered by this publication. Often this species occurred as individual trees but there were a few locations were it was the dominant tree in the upper storey as was the case where it was recorded in the northern section to the east of the limestone track. This subspecies has larger buds and fruits than the typical subspecies.

Trees of *Eucalyptus rudis* subsp. *cratyantha*

Acacia flagelliformis (P4) was reasonably common in the southern section of the lease, only being recorded in the swamp to the south of the power line track on both the east and west sides of the access road. It is a rush-like shrub that is readily recorded when in flower but when in fruit can often be overlooked when a general survey is undertaken. Where this species was recorded generally there were many plants present.

Acacia flagelliformis

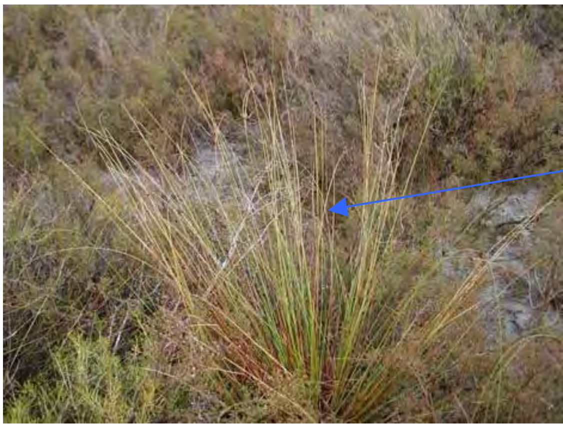
Caladenia speciosa (P4) was recorded from 3 sites. This is another species which is readily overlooked if not in flower as it has the characteristic hairy leaf of most 'Spider orchids'. NO photograph was taken of this species.

Jacksonia sparsa (P4) like *Acacia semitrullata* was widespread through the slightly higher ground. It was common in the *Kunzea glabrescens* thickets as well as in the Jarrah and Banksia woodlands. The general area of distribution of this species is indicated on the map as being so common all locations were not recorded with a GPS reading.

Banksia menziesii (southern extension) one plant was observed just off the area surveyed. This was to the east of the fenceline, south of the power line track. No other trees of this species were observed during the survey.

Verticordia nitens (southern extension) was only recorded to the east of the access road and to the south of where the mining is currently taking place. Where it was recorded there were generally several plants present. This species is readily recognised by the characteristic inflorescence even when not in flower. C. Karelse (pers. comm.) stated that a few plants were observed in flower in December 2003 along the edge of the west side of this road. The limestone used as a base for the access road may influence its occurrence in this location.

Evandra pauciflora (sedge of damplands of the Swan Coastal Plain) was recorded from many of the wetlands as indicated in Appendix C. At some locations it was the dominant species at others there were scattered plants through the wetland. At the time of the survey it was readily identified as the inflorescence were held above the height of the surrounding bushland.



Evandra pauciflora

3.1.3 Comments on Priority Flora not located during the survey

Careful searching of the wetlands was undertaken at the two later surveys to look for those species that occur on the wetland margins. These included the following annual and ephemeral species:

- *Diuris purdiei, Centrolepis caespitosa, Hydatella dioica* (DRF);
- *Haloragis aculeolata, Schoenus capillifolius* (P2);
- *Chamaescilla gibsonii, Drosera occidentalis* subsp. *occidentalis, Haloragis tenuifolia, Myriophyllum echinatum, Rhodanthe pyrethrum, Schoenus* sp. Waroona (GJ Keighery 12235) (pn) (P3)
- *Anthotium junciforme* (P4)

Anthotium junciforme has previously been recorded from the project area. This is a summer flowering species but the leaves should have been visible at the time of the survey. No plants of this species were recorded although plants of *Stylidium dichotomum* were collected to check their identity.

Centrolepis caespitosa has recurved leaves as does *Centrolepis glabra* but *C. caespitosa* has the inflorescence hidden in the leaves whereas the inflorescence of *C. glabra* is exserted and obvious. *C. .glabra* was recorded from the location but not *C. caespitosa*.

3.1.4 Checks on previous species

It was suggested by Mattiske Consulting Pty Ltd (2003) that the record of *Conostylis micrantha*, a species occurring north of Perth should be checked. This species is restricted to the Dongara - Mingenew area (Western Australian Herbarium, 2003) so it is likely that the plant collected at Kemerton was misidentified. If the plants were only collected in a vegetative form they could have been *Conostylis juncea* recorded from the area by Mattiske Consulting Pty Ltd (2003).

Goodenia filiformis collected during the Mattiske surveys (Mattiske, 2003) has recently been renamed as *Goodenia pulchella* subsp. Coastal Plain, and is not a priority species (L. Sage, pers. comm.). *Goodenia filiformis* is restricted to the Albany area and is a priority flora (L. Sage, pers. comm).

Other species that include subspecies recorded as priority flora were also noted by Mattiske Consulting Pty Ltd (2003) to be checked. These were:

- *Adenanthos cygnorum* subsp. *chamaephyton* – at Kemerton they were *Adenanthos cygnorum* subsp. *cygnorum*;
- *Eucalyptus rudis* subsp. *cratyantha* – all plants at Kemerton were of this subspecies*; and*
- *Pimelea ciliata* subsp. *longituba* – at Kemerton were *Pimelea ciliata* subsp. *ciliata.*

Keighery (1998) also recorded *Cyathochaeta stipoides* in the wetland adjacent to the northern margin of the dredge pond, which is to the east of the current search area. None of these plants were located during the current search. Most of the research undertaken by Keighery at Kemerton has been on the eastern side of the entrance road in the Gwalia Nature Reserve, which contains an area of Muchea limestone. This area supports species different to those in the remainder of the lease area. Species considered characteristic of the Muchea limestone include *Eucalyptus decipiens, Pimelea rosea, Austrostipa flavescens, Gahnia trifida, Verticordia nitens* and *Logania vaginalis*. *Gahnia trifida* was recorded in one of the vegetation units at the northern area of the lease to the east of the limestone track and *Verticordia nitens* has been discussed previously.

3.2 Wetlands

3.2.1 Background Information

Most of the site surveyed consisted of areas defined as wetlands. Semenuik (1987) states that a consensus of Western Australian researchers define wetlands as:

> 'Areas of seasonally, intermittently or permanently waterlogged soils or inundated land, whether natural or otherwise, fresh or saline, eg waterlogged soils, ponds, billabongs, lakes, swamps, tidal flats, estuaries, rivers and their tributaries.'

Using the classification of Semeniuk (1987) the wetlands surveyed at the Kemerton area would be classified as consisting of:

- Sumpland – seasonally inundated basin
- Dampland – seasonally waterlogged basin
- Floodplain – seasonally inundated flat and
- Palusplain – seasonally waterlogged flat.

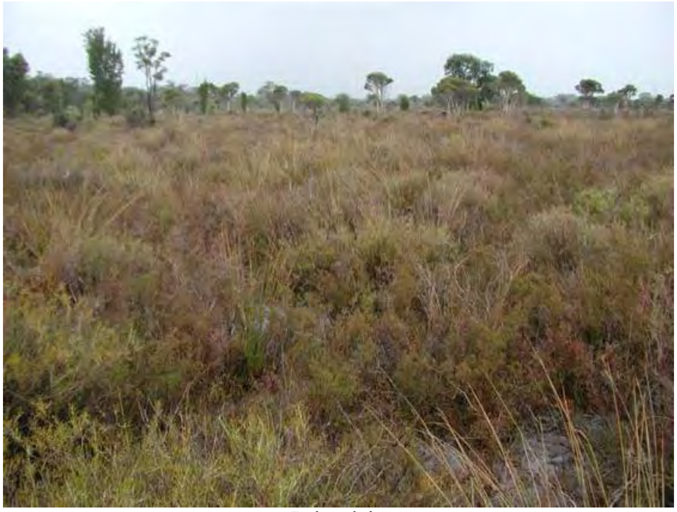
From the data provided in Semeniuk (1998) the study area would be included in the Jandakot consanguineous wetland suite where the characteristic wetlands are damplands and sumplands. The Guildford Complex occurs in the Pinjarra Plain, which is characterised by the consanguineous Keysbrook wetland suite. In this suite the primary wetlands are palusplains, floodplains and creeks typically occurring in clay overlying lateritic clay and sand.

A marked variation was noted whilst undertaking the field work between the wetlands in the southern section of the area surveyed and those in the north and again between the northern ones from west to east ie Jandakot and Keysbrook wetland suites. The wetlands in the southern section occurred in sandy soil as did most of those in the north west of the study site, but those in the north east were in clay soils.

3.2.2 Wetland Types

The different wetlands identified at the site are mapped in Appendix C, Map 1.

The wetlands in the southern section of the area were examples of palusplains as they were mostly seasonally waterlogged flats. Sections of these wetlands were deeper and held the water for a longer period than the remainder of the wetland. The species and therefore the vegetation units varied with changes in water retention. For example where the ground was only damp *Pericalymma ellipticum* and *Hypocalymma angustifolium* dominated, but where the water was retained for a longer period *Astartea* scoparia became dominant. These variations were still considered to be a palusplain.



Palusplain

In a few of these palusplains there were damplands where *Melaleuca rhaphiophylla* became dominant. These areas retained water on the surface for a much longer period than the remaining areas of the palusplain and would be expected to have the water table at a higher level throughout the dry period. Where these damplands were extensive they were mapped as individual groups but occasionally they were relatively small and could not be mapped at the scale provided.

Dampland

There were a few sumplands in the central and middle sections of the area. These sumplands were obvious as they were approached due to the obvious nature of the depression. Typically these consisted of a fringe of *Astartea scoparia* Shrubland around the perimeter, with a ring of Tall Shrubland of *Melaleuca viminea* extending into the centre with *Melaleuca rhaphiophylla*. The water was retained for longer than the other wetlands in the area and many were still underwater when the survey was undertaken in November. *Baumea articulata* was a common sedge in these wetter areas. When these sumplands dried they left a floor of litter where the water had been which inhibits the growth of annual species.

Sumplands included those listed as Environmental Protection Policy (EPP) wetlands. EPP wetlands are subject to permanent or seasonal inundation or waterlogging, whether by water that is fresh, brackish, or saline, or flowing or static but does not include estuaries, rivers or their tributaries.

Sumpland

Floodplains were identified in the north eastern section to the north of the conservation area. The floodplains had more clay in the soil and extensive herblands not recorded in the other wetland types. The dominant vegetation varied from Woodlands of *Melaleuca rhaphiophylla* and/or *Melaleuca viminea* to Dense Shrublands of *Melaleuca teretifolia*. These vegetation units are mapped in Mattiske Consulting Pty Ltd (2003).

Floodplain

3.2.3 Vegetation of Wetlands

The wetland boundaries could be readily mapped from aerial photographs. However sections of each wetland were often 'separated' by thickets dominated by *Kunzea glabresens* and *Banksia ilicifolia*. Although not classified as wetlands (Semeniuk, 1987) they are an integral part of the health and maintenance of the wetlands and as such shall be included in this discussion as units associated with the wetlands. Very few areas of Jarrah (*Eucalyptus marginata*) as mapped by Mattiske Consulting Pty Ltd (2003) were observed during the survey, most of the higher ground consisting of *Kunzea glabresens* usually associated with *Banksia ilicifolia*.

Wetlands are not simple units and the vegetation cannot be described as one individual unit. This was particularly apparent, as the areas identified on an aerial photograph as representing a wetland were not a simple vegetation unit but a mosaic of units. Mattiske Consulting Pty Ltd (2003) also noted this when they mapped the vegetation of the site. With this current study it was found impossible to map the individual vegetation units within the wetland so the different wetlands marked on the aerial photographs were each allocated an identifier and the different vegetation units present described. This current survey was not a detailed vegetation survey or a listing of all species present in each unit as Mattiske Consulting Pty Ltd has undertaken this, but was to identify and determine the environmental significance of each wetland and the area as a whole.

A description of the vegetation recorded at each of the wetlands is described below using the vegetation layers as given in Table 1. The location of each is mapped in Appendix C, Map 1.

Table 1. Vegetation layers. Adapted from: Bush Forever (Department of Environmental Protection, 2000)

Life Form/ Height Class	**Canopy Cover**			
	100-70%	**70-30%**	**30-10%**	**10-2%**
Trees over 30m	Tall Closed Forest	Tall Open Forest	Tall Woodland	Tall Open Woodland
Trees 10-30m	Closed Forest	Open Forest	Woodland	Open Woodland
Trees under 10m	Low Closed Forest	Low Open Forest	Low Woodland	Low Open Woodland
Tree mallee(8m tall)	Closed Tree Mallee	Tree Mallee	Open Tree Mallee	Very Open Tree Mallee
Shrub mallee(under 8m tall)	Closed Shrub Mallee	Shrub Mallee	Open Shrub Mallee	Very Open Shrub Mallee
Shrubs over 2m	Closed Tall Scrub	Tall Open Scrub	Tall Shrubland	Tall Open Shrubland
Shrubs 1-2m	Closed Heath	Open Heath	Shrubland	Open Shrubland
Shrubs under 1m	Closed Low Heath	Open Low Heath	Low Shrubland	Low Open Shrubland
Grasses	Closed Grassland	Grassland	Open Grassland	Very Open Grassland
Herbs	Closed Herbland	Herbland	Open Herbland	Very Open Herbland
Sedges	Closed Sedgeland	Sedgeland	Open Sedgeland	Very Open Sedgeland

WETLAND A

Palusplain

- The centre of this wetland is Closed Heath dominated by *Astartea scoparia* and *Pericalymma ellipticum* over bare ground.
- There is a zone of Low Open Forest of *Banksia littoralis* over Open Heath dominated by *Astartea* scoparia surrounding this Heath.
- To the east there is Low Woodland of *Melaleuca preissiana* over a Sedgeland of *Lepidosperma longitudinale.*

Significant Flora

None recorded

WETLAND B

Palusplain

- The centre of this wetland consists of Closed Heath of mixed species dominated by *Hakea varia, Astartea scoparia, Calothamnus lateralis* and *Melaleuca lateritia* over a Sedgeland of *Lepidosperma longitudinale* and *Meeboldina coangustata* and a Very Open Herbland of *Villarsia albiflora*. The area when surveyed in September was very moist but there was no standing water. *Boronia juncea* subsp. *juncea* was common in this wetland. The edge of this unit heading to the north consisted mainly of dead shrubs. The soil was very dry compared to the surrounding area but there was no indication as to the cause. The same vegetation unit to the south did not record these deaths.
- Where there was standing water there was Open Heath of *Astartea scoparia* over a Sedgeland of *Lepidosperma longitudinale*.
- Scattered occurrences of Closed Tall Scrub of *Melaleuca viminea* occurred in the wetland sometimes associated with Low Woodland of *Melaleuca rhaphiophylla* over a Sedgeland of *Lepidosperma longitudinale*.
- Most of the surrounding wetland was Low Open Woodland of *Melaleuca preissiana* and *Kunzea glabrescens* over Closed Low Heath of mixed species dominated by *Adenanthos obovatus, Adenanthos meisneri, Hypocalymma angustifolium* and *Pultenaea ochreata.*
- Areas of Open to Dense Herbland dominated by *Dasypogon bromeliifolius.*

Higher Ground

- The wetland was surrounded by Tall Open Scrub of *Kunzea glabrescens* over a Shrubland dominated by *Hypocalymma angustifolium*.

Significant Flora

None recorded

WETLAND C

Palusplain

- Most of the surrounding wetland was Low Open Woodland of *Melaleuca preissiana* and *Kunzea glabrescens* over Closed Low Heath of mixed species dominated by *Pericalymma ellipticum, Astartea scoparia, Calothamnus lateralis* over Open Sedgeland of *Meeboldina coangustata* and *Meeboldina tephrina* or bare ground. Most of the *Melaleuca preissiana* were 3m tall but there were occasional areas where they were up to 12m tall. Where Astartea became abundant there was shallow standing water but the remainder of the area was damp. In some areas there were several plants of **Hypochaeris glabra*. (Photograph below.)

- Where *Melaleuca preissiana* was 12m tall the understorey was as in the above description but there were additional *Astartea scoparia*.

Sumpland

- Where there was standing water it was Open Forest of *Melaleuca rhaphiophylla* and *Eucalyptus rudis* subsp. *cratyantha* over a Sedgeland of *Baumea articulata*. In addition there were several clumps of *Eucalyptus rudis* subsp. *cratyantha* scattered through this wetland.

Higher Ground

- Higher ground was Tall Open Scrub of *Kunzea glabrescens* and *Banksia ilicifolia* over Low Shrubland of *Hypocalymma angustifolium* and/or *Xanthorrhoea preissii* with several *Jacksonia sparsa* and *Acacia semitrullata* over a Very Open Herbland/Sedgeland of *Dasypogon bromeliifolius* and *Hypolaena exsulca* or bare ground. Weeds in this vegetation unit included **Ursinia anthemoides*.
- The higher ground (not considered part of the wetland complex) was Low Open Woodland of *Banksia attenuata* over Tall Open Scrub of *Kunzea glabrescens* over a Shrubland dominated by *Calytrix fraseri* over bare ground.

Significant Flora

Eucalyptus rudis subsp. *cratyantha*

WETLAND D

This was an extensive and varied wetland that was divided into 2 sections, D1 the southern section and D2 the northern section. In this wetland many plants of *Boronia juncea* subsp. *juncea* were recorded growing in standing water in association with *Astartea scoparia*.

D1

Palusplain

- Closed Low Heath dominated by *Pericalymma ellipticum* with *Adenanthos obovatus*, *Calothamnus lateralis, Hypocalymma angustifolium, Adenanthos meisneri* and *Euchilops linearis* over a Very Open Sedgeland of *Evandra pauciflora* and *Hypolaena exsulca*. There was no standing water.

- Closed Heath of *Astartea scoparia* and *Calothamnus lateralis* with emergent *Banksia littoralis* and *Melaleuca rhaphiophylla* over Low Open Shrubland dominated by *Hibbertia stellaris* over a Sedgeland of *Meeboldina coangustata, Meeboldina scariosa* and *Lepidosperma longitudinale* and a diverse herb layer.
- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Pericalymma ellipticum*. The ground was damp.
- Closed Heath of *Calothamnus lateralis* and *Astartea scoparia* over a Sedgeland of *Meeboldina coangustatus* in standing water. It was in this vegetation community the *Dillwynia dillwynioides* was recorded.
- Low Open Woodland of *Eucalyptus rudis* subsp. *cratyantha* and *Melaleuca preissiana* over Low Open Shrubland dominated by *Hypocalymma angustifolium* and Open Sedgeland of *Hypocalymma exsulca* with 10-30% bare ground.
- Open Low Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* in damp soil.
- Low Woodland of *Melaleuca viminea* and *Melaleuca preissiana* over Open Heath of *Astartea scoparia, Calothamnus lateralis, Melaleuca lateritia* and *Melaleuca teretifolia* over a Sedgeland dominated by *Lepidosperma longitudinale* with *Meeboldina coangustata* and *Meeboldina tephrina* in wet ground. There was a lot of dead *Melaleuca lateritia* in some sections.

Higher Ground

- Low Open Woodland of *Melaleuca preissiana* over Tall Shrubland of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium, Adenanthos meisneri, Euchilops linearis, Adenanthos obovatus* and Open Herbland of *Dasypogon bromeliifolius*. The ground was damp in September. In some sections of this unit there were scattered trees of *Nuytsia floribunda*, shrubs of *Xanthorrhoea preissii* and clumps of *Evandra pauciflora*.
- Tall Open Shrubland of *Kunzea glabrescens* and *Nuytsia floribunda* over Open Low Heath of *Hypocalymma angustifolium*, *Adenanthos meisneri* and *Xanthorrhoea preissii* over Open Sedgeland of *Anarthria laevis* and *Evandra pauciflora*. Soil moist.
- Tall Open Shrubland of *Kunzea glabrescens* and *Melaleuca preissiana* over Open Low Heath of *Hypocalymma angustifolium. Adenanthos meisneri, Euchilops linearis* and *Dasypogon bromeliifolius*. Damp ground.

Significant Flora

Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Eucalyptus rudis subsp. *cratyantha*
Evandra pauciflora

D2

Palusplain

- Tall Shrubland of *Kunzea glabrescens* with emergent *Banksia ilicifolia* and *Melaleuca preissiana* over Closed Low Heath of *Hypocalymma angustifolium* with occasional *Pericalymma ellipticum* in damp ground.
- Closed Low Heath of *Pericalymma ellipticum* with scattered *Hypocalymma angustifolium* and *Euchilops linearis* with emergent *Kunzea glabrescens* and *Melaleuca preissiana*, in damp ground.
- Closed Heath of *Pericalymma ellipticum* and *Astartea scoparia* over a Sedgeland of *Lepidosperma longitudinale* in damp ground.
- Closed Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* with scattered emergent *Melaleuca preissiana, Xanthorrhoea preissii* and occasional *Evandra pauciflora* in damp ground. (Photograph below.)

- Low Open Woodland of *Melaleuca preissiana* over a Shrubland of *Xanthorrhoea preissii* over Open Low Heath of *Hypocalymma angustifolium* and *Pericalymma ellipticum* and Open Sedgeland of *Hypolaena exsulca*. In damp nearly dry ground.
- There was a small area of Sedgeland of *Anarthria occidentalis* with emergent *Xanthorrhoea preissii* and *Melaleuca preissiana* in amongst the vegetation unit described above in damper ground.

Higher Ground

- Tall Open Scrub of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium, Pericalymma ellipticum* and scattered *Adenanthos obovatus* over bare ground in damp soil.
- Low Woodland of *Banksia ilicifolia* and *Melaleuca preissiana* over Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium* in damp soil.
- Low Open Woodland of *Banksia ilicifolia* over Tall Open Scrub of *Kunzea glabrescens* over Open Herbland of *Dasypogon bromeliifolius* and bare ground.
- Tall Open Scrub of *Kunzea glabrescens* over Open Heath of *Hypocalymma angustifolium* and *Adenanthos meisneri* over Open Herbland of *Dasypogon bromeliifolius* in damp ground.
- Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium, Adenanthos obovatus* and over Open Sedgeland of *Hypolaena exsulca* in dry soil.
- Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium*, *Platytheca verticillata, Euchilops linearis* and a Dense Sedgeland of *Hypolaena exsulca* in dry soil.

Significant Flora

Acacia semitrullata
Dillwynia dillwynioides
Eucalyptus rudis subsp. *cratyantha*
Evandra pauciflora
Jacksonia sparsa

WETLAND E

Palusplain

- Low Open Woodland of *Melaleuca preissiana* and Tall Open Shrubland of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium, Pericalymma ellipticum, Jacksonia sparsa* and *Adenanthos meisneri* in damp ground.
- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Pericalymma ellipticum* in damp ground.
- Closed Heath of *Astartea scoparia* over a Sedgeland of *Meeboldina coangustata* in wet soil.
- Slightly higher ground Closed Heath of *Astartea scoparia* and *Pericalymma ellipticum* with occasional emergent *Melaleuca preissiana* in wet soil. (Photograph below)

Dampland

- Low Open Forest of *Melaleuca rhaphiophylla* over Tall Open Scrub of *Astartea scoparia* over Open Sedgeland of *Baumea articulata* in 1m standing water. Plants of *Boronia juncea* subsp. *juncea* recorded on the edge of the deep water.

Higher Ground

- Closed Tall Scrub of *Kunzea glabrescens* over a Shrubland of *Xanthorrhoea preissii* over Open Sedgeland/Open Herbland of *Hypolaena exsulca* and *Dasypogon bromeliifolius* in dry ground.

Significant Flora

Boronia juncea subsp. *juncea*
Evandra pauciflora
Jacksonia sparsa

BETWEEN D AND E

High Ground

- Low Open Woodland of *Melaleuca preissiana* over Closed Low Heath of *Hypocalymma angustifolium* with scattered *Adenanthos obovatus* and *Euchilops linearis*.
- Large areas of Closed Sedgeland/Closed Low Heath of *Anarthria laevis* with *Hypocalymma angustifolium.*

Significant Flora

Dillwynia dillwynioides

NOTE: Wetlands D and E blend into one another .

WETLAND F

This wetland is a large basin surrounded by higher area.

Palusplain

- Sedgeland of *Evandra pauciflora* in damp ground.
- Tall Shrubland of *Melaleuca viminalis* over Open Heath of *Melaleuca teretifolia* and *Melaleuca polygaloides* in standing water. *Boronia juncea* subsp. *juncea* recorded from this unit.
- Low Open Woodland of *Melaleuca preissiana* over Closed Low Heath of *Hypocalymma angustifolium* on the edge of the wetland where it abuts the higher ground.
- Closed Low Heath of *Pericalymma ellipticum* with *Calothamnus lateralis* over Very Open Sedgeland of *Lepidosperma longitudinale* long with very scattered *Melaleuca preissiana*.
- Closed Heath of *Astartea scoparia* over a Sedgeland of *Lepidosperma longitudinale*. Many of the Astartea shrubs were dead.
- Closed Heath of *Astartea scoparia* over Open Low Heath of *Pericalymma ellipticum, Hibbertia stellaris, Calothamnus lateralis* over open dry ground.

Higher Ground

- Low Woodland of *Banksia ilicifolia* over Closed Low Heath of *Hypocalymma angustifolium* in dry soil.
- Low Open Woodland of *Melaleuca preissiana* and *Banksia ilicifolia* over Open Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* in damp ground. *Hypocalymma angustifolium* becomes dominant on the drier margins.

Significant flora recorded

Acacia flagelliformis
Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Evandra pauciflora

WETLAND G

Palusplain

- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Pericalymma ellipticum* and *Astartea scoparia* over Open Sedgeland of *Meeboldina tephrina* and *Meeboldina coangustata* over open damp ground.

Higher Ground

- Closed Tall Scrub of *Kunzea glabrescens* over bare ground surrounds the wetland.

Significant Flora

None located

WETLAND H

Dampland

- Low Open Forest of *Melaleuca rhaphiophylla* over a Sedgeland of *Baumea articulata* and *Lepidosperma longitudinale* in standing water.

- Tall Open Scrub of *Melaleuca viminea* over Closed Sedgeland of *Lepidosperma longitudinale* on the outer edge of the above.

Edge of dampland

- Tall Open Scrub of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium* in dry sand. Scattered *Melaleuca preissiana* occur further into wetland.
- Closed Heath of *Astartea scoparia* with emergent *Melaleuca preissiana* over Open Sedgeland of *Lepidosperma longitudinale* in moist soil.
- Closed Tall Scrub of *Melaleuca viminea* over a Sedgeland of *Lepidosperma longitudinale* in damp soil.

Higher ground

- Low Open Woodland of *Melaleuca preissiana* with scattered *Nuytsia floribunda* over Tall Open Shrubland of *Kunzea glabrescens* over Closed Low Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* in damp ground.

Significant Flora

None recorded

WETLAND I

Palusplain

- Closed Low Heath dominanted by *Hypocalymma angustifolium* and *Pericalymma ellipticum* with emergent *Melaleuca preissiana*.

Higher ground

- Low Open Woodland of *Melaleuca preissiana* over Tall Open Shrubland of *Kunzea glabrescens* and scattered *Banksia ilicifolia* over Closed Low Heath of *Hypocalymma angustifolium.* A few *Banksia ilicifolia* are dead. This could be due to dieback as banksias are notoriously affected by this pathogen.
- Closed Tall Scrub of *Kunzea glabrescens* with emergent *Banksia ilicifolia* and *Eucalyptus marginata* subsp. *marginat*a over Open Heath/Sedgeland of *Xanthorrhoea brunonis, Dasypogon bromeliifolius* and *Hypolaena exsulca.* Few of the *Banksia ilicifolia* are dead, could be due to dieback.
- Closed Low Heath of *Hypocalymma angustifolium* and *Pericalymma ellipticum* with emergent and scattered *Melaleuca preissiana*.

WETLAND J

This wetland is a sumpland with non-permanent standing water and surrounded by a palusplain.

Sumpland

- Low Closed Forest of *Melaleuca rhaphiophylla* and *Melaleuca viminea* cover over Open Sedgeland of *Baumea articulata* in standing water. This was the vegetation unit in the centre of the sumpland.
- Low Closed Forest of *Melaleuca preissiana* and *Melaleuca viminea* over Closed Sedgeland of *Lepidosperma longitudinale* and *Meeboldina coangustata*. This vegetation unit surrounded the one above.
- Closed Tall Scrub of *Melaleuca viminea* surrounded by Low Closed Forest *of Melaleuca preissiana* with Closed Sedgeland of *Lepidosperma longitudinale*. Soil wet with standing water.
- Closed Heath of *Astartea scoparia* with scattered emergent *Melaleuca preissiana* over a Very Open Sedgeland of *Lepidosperma longitudinale* in very damp soil.

Palusplain

- Closed Heath of *Astartea scoparia* over bare ground.
- Tall Open Scrub of *Kunzea glabrescens* with emergent *Melaleuca preissiana* over Closed Low Heath of *Hypocalymma angustifolium* and *Pericalymma ellipticum.*
- Closed Heath of *Astartea scoparia* over Open Sedgeland of *Lepidosperma longitudinale* in very damp soil.

Higher Ground

- Closed Low Heath of H*ypocalymma angustifolium, Adenanthos obovatus* and *Pultenaea ochreata* with scattered emergent *Melaleuca preissiana* and *Kunzea glabrescens* in dry soil.

Significant Flora

Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Jacksonia sparsa

WETLAND K

This is the wetland in the northern area of the lease where the soil was clay compared to the sand or sandy loam of the other wetlands.

Floodplain

- Tall Open Scrub of *Melaleuca viminea* over Open Herbland/Grassland in clay.

(Photograph below.)

- Tall Open Scrub/Tall Open Forest of *Kunzea glabrescens, Melaleuca cuticularis, Melaleuca incana*, *Melaleuca preissiana* and *Agonis flexuosa* with scattered emergent *Corymbia calophylla* over Open Low Heath of *Hypocalymma angustifolium, Melaleuca pauciflora* and *Astartea scoparia* over a Sedgeland of *Chaetanthus leptocarpoides* and *Gahnia trifida*. Scattered *Eucalyptus rudis* subsp. *cratyantha* occurred through this vegetation unit. (Photograph below.)

- Low Woodland of *Eucalyptus rudis* over Open Shrubland of *Xanthorrhoea preissii* and *Acacia saligna* over Sedgeland of *Lepidosperma longitudinale* over a Herbland of mixed species. (Photograph below.)

- Low Woodland of *Melaleuca rhaphiophylla* over Sedgeland of *Lepidosperma longitudinale* and a Herbland of *Chamaescilla corymbosa, Hypoxis occidentalis, Tribonanthes longipetala, Utricularia multifida* in moist soil. (Photograph below.)

- Tall Open Scrub of *Melaleuca teretifolia* over a Herbland. (Photograph below.)

Higher Ground

- Tall Open Shrubland of *Kunzea glabrescens* with emergent and scattered *Eucalyptus marginata* subsp. *marginata* and *Banksia ilicifolia* over a Shrubland of *Hypocalymma angustifolium* and *Xanthorrhoea brunonis* and a Sedgeland/Herbland of *Hypolaena exsulca* and *Dasypogon bromeliifolius*. Where this vegetation unit was recorded along an old cleared grid line it was degraded due to many weeds. (Photograph below.)

Significant Flora

Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Eucalyptus rudis subsp. *cratyantha*
Evandra pauciflora
Boronia capitata subsp. *gracilis* (recorded by Mattiske Consulting Pty Ltd, 2003)

WETLAND L

Palusplain

- Low Woodland of *Melaleuca preissiana* and Tall Shrubland of *Kunzea glabrescens* over Tall Shrubland of *Astartea scoparia* and *Hypocalymma angustifolium* over a Herbland of weeds. A few pines were scattered through. Very dry.
- Tall Shrubland of *Kunzea glabrescens* and *Banksia ilicifolia* over Open Low Heath of *Hypocalymma angustifolium*.

Significant Flora

Dillwynia dillwynioides

WETLAND M – EPP Wetland 8

Sumpland

- Low Open Forest of *Melaleuca rhaphiophylla* and *Melaleuca viminea* over a Sedgeland of *Lepidosperma longitudinale* with open water.
- Closed Low Scrub of *Astartea scoparia* with scattered *Oxylobium lineare* over Sedgeland of *Lepidosperma longitudinale*. Water covering ground. (Photograph below.)

View as enter the wetland from the south

Higher Ground

- Low Woodland of *Melaleuca preissiana* and Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium*.

Significant Flora

Dillwynia dillwynioides

WETLAND N

Palusplain

- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Astartea scoparia* and *Calothamnus lateralis* in wet ground.
- Closed Low Heath of mixed species dominated by *Pericalymma ellipticum*, *Hypocalymma angustifolium* and *Euchilops linearis* over a Sedgeland of *Hypolaena exsulca* and *Evandra pauciflora* in damp soil.
- Open Heath of *Astartea scoparia* over Open Low Heath of *Pericalymma ellipticum* and *Calothamnus lateralis* over Open Sedgeland of *Meeboldina coangustata* water on the surface.
- Low Woodland of *Melaleuca rhaphiophylla* over Tall Shrubland of *Melaleuca teretifolia* with water on the surface. This was only a small area within the wetland.

Higher Ground

- Tall Shrubland of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium* in damp ground on the edge of the wetland. Scattered *Eucalyptus marginata* subsp. *marginata* recorded from this vegetation unit.
- Low Open Woodland of *Melaleuca preissiana* over Open Low Heath of *Hypocalymma angustifolium* in damp ground on the edge of the wetland. Scattered *Kunzea glabrescens* was recorded in this vegetation unit.

Significant Flora

Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Evandra pauciflora

WETLAND P

Dampland

- Low Woodland of *Melaleuca rhaphiophylla* and *Melaleuca viminea* over a Sedgeland dominated by *Lepidosperma longitudinale* over standing water. Many plants were whipstick but there were some larger trees as shown in photograph below.

- Open Heath of *Melaleuca lateritia* over a Sedgeland of *Lepidosperma longitudinale* in very damp to open water. Many *Boronia juncea* subsp. *juncea* were recorded from this vegetation unit.
- Tall Open Scrub of *Melaleuca polygaloides, Melaleuca pauciflora, Astartea scoparia, Melaleuca rhaphiophylla, Hakea sulcata* over a Sedgeland of *Lepidosperma longitudinale*, over open water.
- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Hakea sulcata, Pericalymma ellipticum* and *Calothamnus lateralis* over a Sedgeland of *Meeboldina coangustata* in very wet soil.
- Low Open Woodland of *Banksia littoralis* and *Melaleuca preissiana* over Closed Sedgeland of *Lepidosperma longitudinale* in standing water in September, which was drying by November.

Palusplain

- Closed Heath of *Astartea scoparia* over a Sedgeland of *Meeboldina coangustata.* (Photograph below.)

- Closed Heath of *Astartea scoparia* over Closed Low Heath of *Pericalymma ellipticum* with scattered plants of *Hakea sulcata*. (Photograph below.)

- Low Open Woodland of *Melaleuca preissii* over Closed Low Heath of *Xanthorrhoea preissii, Pericalymma ellipticum, Adenanthos obovatus* and *Hypocalymma angustifolium* with scattered plants of *Evandra pauciflora*. (Photograph below.)

- Low Woodland of *Melaleuca preissiana* over Closed Sedgeland of *Hypolaena exsulca* in damp soil.
- Shrubland of *Astartea scoparia* over Closed Low Heath of *Pericalymma ellipticum* over Sedgeland of *Meeboldina coangustata* and *Lepidosperma longitudinale* in damp soil. Scattered *Hakea varia* and *Hakea sulcata* occur in this unit as well as the occasional *Melaleuca preissiana*.
- Closed Low Heath of *Astartea scoparia, Pericalymma ellipticum* and *Hibbertia stellaris* over bare ground.
- Closed Tall Scrub of *Hakea varia, Astartea scoparia, Melaleuca polygaloides* and *Oxylobium lineare* over Closed Sedgeland of *Lepidosperma longitudinale* and *Meeboldina tephrina*. Area damp.

Higher Ground

- Low Open Woodland of *Banksia ilicifolia* over Tall Open Shrubland of *Kunzea glabrescens* over Closed Herbland of *Dasypogon bromeliifolius*.
- Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium* in damp ground.
- Tall Open Shrubland of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium* or *Pericalymma ellipticum* in dry soil. Several plants of *Pericalymma ellipticum* are stressed or dead. (Photograph below.)

- Tall Open Scrub of *Kunzea glabrescens* with emergent trees of *Melaleuca preissiana* over Low Open Shrubland of *Hypocalymma angustifolium* and *Xanthorrhoea preissii* over Open Herbland/Sedgeland of *Hypolaena exsulca* and *Dasypogon bromeliifolius*. (Photograph below.)

Lots of weeds along this track, mainly **Hypochaeris glabra*

- Tall Open Scrub of *Kunzea glabrescens* over Open Heath of *Hypocalymma angustifolium, Xanthorrhoea brunonis* and *Adenanthos meisneri* and a Sedgeland of *Hypolaena exsulca* and bare ground in dry soil.
- Low Woodland of *Melaleuca preissiana* over a Shrubland of *Xanthorrhoea brunonis*, *Hypocalymma angustifolium, Pericalymma ellipticum* and *Adenanthos obovatus* over a Sedgeland/Herbland of *Hypolaena exsulca* and *Dasypogon bromeliifolius* in dry ground. (Photograph below.)

- Low Open Woodland of *Melaleuca preissiana* over Closed Low Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium.*

Significant Flora

Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Evandra pauciflora

WETLAND Q

This is EPP wetland 4

Sumpland

- Low Closed Forest of *Melaleuca viminea* and *Melaleuca rhaphiophylla* in and surrounding standing water. (Photograph below.)

Palusplain

- Low Open Woodland of *Melaleuca preissiana* over Open Low Heath of *Hakea varia, Astartea scoparia, Melaleuca pauciflora* and *Pericalymma ellipticum.*
- Closed Low Heath of *Pericalymma ellipticum, Xanthorrhoea preissii, Xanthorrhoea brunonis* and *Hypocalymma angustifolium* with scattered *Evandra pauciflora*. Behind and south of EEP4.

Significant Flora

Evandra pauciflora

WETLAND R

Palusplain

- Low Woodland of *Eucalyptus rudis* subsp. *cratyantha* with occasional *Banksia littoralis* and *Melaleuca preissiana* over Closed Tall Scrub of *Astartea scoparia* over a Sedgeland of L*epidosperma longitudinale*.
- Low Woodland of *Melaleuca preissiana* behind.

Significant Flora

None recorded

WETLAND S

Sumpland

- *Melaleuca rhaphiophylla* 8m tall over *Lepidosperma longitudinale* wet below. (Photograph below.)

Palusplain

- Closed Tall Scrub of *Astartea scoparia, Calothamnus lateralis* over Closed Sedgeland of *Lepidosperma longitudinale* and *Meeboldina coangustata* over bare, damp ground.

Significant Flora

Jacksonia sparsa

WETLAND T

Palusplain

- Low Open Woodland of *Melaleuca preissiana* and *Banksia ilicifolia* over Open Low Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium*.

Higher Ground

- Palusplain surrounded by *Banksia ilicifolia, Banksia attenuata* and *Eucalyptus marginata* Woodland.
- Closed Tall Scrub of *Kunzea glabrescens* over Open Sedgeland of *Schoenus efoliatus* and bare, dry ground. There were a few scattered trees of *Melaleuca preissiana*.
- Tall Open Scrub of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium* and *Pericalymma ellipticum.*

Significant Flora

Acacia flagelliformis
Acacia semitrullata
Evandra pauciflora

WETLAND U

Palusplain

- Tall Shrubland of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium* and scattered *Pericalymma ellipticum.*
- Low Open Woodland of *Melaleuca preissiana* over Open Low Heath *Pericalymma ellipticum* with scattered *Calothamnus lateralis* over Sedgeland dominated by *Meeboldina coangustata.*

- Closed Tall Scrub of *Astartea scoparia* over Closed Sedgeland of *Lepidosperma longitudinale* with open water. *Dillwynia dillwynioides* located in this vegetation unit.

Higher Ground

- Low Woodland of *Banksia attenuata* and *Banksia ilicifolia* over a Shrubland dominated by *Melaleuca thymoides* and *Verticordia nitens* on the higher ground above and to the east of the wetland.
- Tall Open Scrub of *Kunzea glabrescens* over bare ground and weeds.
- Tall Shrubland of *Kunzea glabrescens* over Open Heath of *Hypocalymma angustifolium* and *Xanthorrhoea preissii.*

Significant Flora

Acacia semitrullata
Caladenia speciosa
Dillwynia dillwynioides
Verticordia nitens

3.2.4 Condition of Wetlands

Very few weeds were recorded within the wetlands with marginally more present observed on the higher ground. Most of the weeds, where they were recorded, were along tracks, especially the limestone track from north to south, the perimeter where it adjoins farming properties and especially the north eastern section. The north eastern section had degraded areas scattered through parts in good or better condition (See Table 2). In addition to the presence of weeds, there was observed to be damage caused by feral pigs.

Table 2. Explanation of Vegetation Condition Rating (Department of Environmental Protection, 2000)

Rating	Description	Explanation
1	Pristine	Pristine or nearly so, no obvious signs of disturbance.
2	Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
3	Very Good	Vegetation structure altered, obvious signs of disturbance.
4	Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it.
5	Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management.
6	Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species.

Although most of the wetlands had very few or no weeds present, the area was previously grazed and selectively logged, so consequently it can only be rated as 3, very good as the vegetation structure has been altered although it is recovering very well. The transects through the bushland are becoming less obvious, but the tree stratum is still recovering and is much lower than that of the surrounding bushland. A track through scrubland re-opened in April 2003 has the shrubs and sedges commencing to rehabilitate from lignotubers and rhizomes, but it will be some years before the plants are of the same height as the surrounding bushland.

The areas where the vegetation were in good even bordering on degraded condition, include the area of the current stockpile and EPP Lake 4 and the original open drain connecting the soil sorting area with the stockpile area. Here the vegetation was more open and of lower size but the areas to the west, north and east of the drain were in better condition.

The higher ground to the south of Wetland F also included many weeds. This wetland also had many of the *Astartea scoparia* plants dead or dying which could be an affect from the previous dry years, but it would be expected if so that other species would also be showing these deaths. The high ground abuts the Blue gum plantation to the south which may be having an effect on the water level in the area as *Astartea scoparia* prefers soggy ground where as the other species recorded from this wetland tolerate a higher degree of drying.

Some weeds of concern along the north-west track included **Gomphocarpus fruticosus*, Swan plant, a declared plant pursuant to section 37 of the Agriculture and Related Resources Protection Act, 1976 (Department of Agriculture, 2003). This weed is classified as

- P1; Whole of the State. P1 Requirements - Prohibits movement. The movement of plants or their seeds is prohibited within the State. This prohibits the movement of contaminated machinery and produce including livestock and fodder.
- P4; Those portions of the State constituted as the Esperance, Katanning, Manjimup, Albany, Narrogin, Cunderdin, Northam, Busselton, Harvey and Lakes regions under Section 13 of the Act.

Another weed which appeared to be spreading and which should be controlled was **Centaurea melitensis*, Maltese cockspur. Both **Centaurea melitensis* and **Gomphocarpus fruticosus* have light seeds with hairy attachments that aid in their dispersal. These plants need to be removed before flowering and any seedlings should be hand pulled or sprayed with a herbicide.

3.2.5 Comparison with Wetland mapping of Mattiske Consulting Pty Ltd

In Mattiske Consulting Pty Ltd (2003), Figure 2 indicates the plant communities identified during several surveys (Mattiske E.M. and Associates, 1993a-d). These were communities that included Muchea limestone species *Eucalyptus decipiens, Melaleuca systena*, as one group and *Verticordia nitens* as a second group. In the vegetation mapping Figure 3 these areas were mapped as *Eucalyptus marginata – Banksia attenuata* associated communities. A comparison with the high ground mapping of Mattiske Consulting Pty Ltd (2003) is impossible as there are differences in the significance of the communities depending upon which of the maps are used. The Muchea limestone communities are restricted, but most of those areas occur to the east of the current survey area, where as the high ground of the area surveyed consisted of *Kunzea glabrescens* and *Banksia ilicifolia* with scattered to dense *Banksia attenuata* and some *Eucalyptus marginata* subsp. *marginata*. There were some small areas where *Eucalyptus marginata* was dominant, but it was not as common as indicated in Figure 3. In addition *Verticordia nitens* was not recorded to the west of the main access track or limestone track. It was not the brief of this contract to map the vegetation only to describe the different vegetation units of the wetlands.

This survey has shown the wetlands are basically mosaics of small vegetation units as described in Section 3.2.2 of this report.

3.2.6 Wetland Classification

A requirement of this survey was that the wetlands were to be evaluated using the questionnaire contained in Department of Environmental Protection (1993). A level of significance and therefore the appropriate management category are assigned based on the above evaluation. Completed questionnaire sheets for each wetland are provided in Appendix D. After these assessments are completed, the management category was assessed using information provided in 'A Guide to Wetland Management in the Perth and Near Perth Swan Coastal Plain Area – EPA Bulletin 686' (Department of Environmental Protection, 1993). Using this questionnaire it proved difficult for palusplains in very good condition to record a high score as they lack permanent water and are not a refuge for birds.

Table 3. Categories assigned to wetlands

Category (Department of Environmental Protection, 1993).	**Management Category** (Water and Rivers Commission, 2001)	**General Description**	**Management Objectives**
H – High conservation C - Conservation	C - Conservation	Wetland support high level of ecological attributes and functions.	Highest priority. These are the most valuable wetlands. No development.
O – Conservation and recreation R – Resource enhancement	R - Resource enhancement	Wetlands, which may have been partially modified but still support substantial ecological attributes and functions.	Priority wetland. Ultimate objective is for management, restoration and protection to improve conservation category. Protection recommended.
M – Multiple Use	M - Multiple use	Wetlands with few important ecological attributes and functions remaining.	Use, development and management should be considered in the context of ecologically sustainable development.

Assessing the wetlands within the study area resulted in the following scores that are then interpreted using the Environmental Protection Authority (1993) questionnaire and then placed into the Management Categories of Water and Rivers Commission (2001). The assessment is divided into 2 sections, the natural and human attributes of the wetland. If Declared Rare Flora are recorded, the wetland is automatically considered to be category H, high conservation.

This classification does not take into account the higher ground, which at Kemerton is an extension of the wetlands. Several of the individual wetlands discussed in Section 3.2.4 should be combined into one wetland complex (WC). These are listed below and mapped in Appendix C, Map 2.

- Wetland F is a distinctive wetland. The dune to the north is much higher, a ridge, above the wetland. (WC1)
- Wetlands D1, D2, E, I, K, P with the intervening higher ground of *Kunzea glabrescens* and *Banksia ilicifolia* make up one large wetland complex. (WC2)
- Due to the drain to the north of the stockpile area there is a changed wetland section bounded by the drain, stockpile area and office/loading area. This consists of wetland Q, an EPP wetland, and a section of wetland B. (WC3)
- Wetlands R, A and C make up a complex. (WC4)
- Wetlands J, H, S and remainder of B. This complex includes sumplands as well as palusplains. (WC5)
- Wetland K is unique in this area as it was the only area where clay soils and floodplain were recorded. Although this area is to the north of the proposed conservation area it is recommended that it be included in the conservation area. Wetland G on the western side is also a part of this wetland complex. (WC6)
- Wetland U is a small portion of a larger wetland south of the current approved conservation area west of the Muchea limestone area. (WC7)
- Wetland M and N together with other wetlands not surveyed to the east of the project area. (WC8)
- Wetland L is a small wetland surrounded by a pine plantation so is for this report considered as a separate wetland. (WC9)
- Wetland T is a section of a much larger wetland extending beyond this survey to the east but will for this report be considered as a separate wetland. (WC10)

Table 4. Wetland Assessments using Environmental Protection Authority (1993)

Wetland	Attributes Score		Category (EPA)	Management Category
	Natural	Human		
WC1	41	7	C - Conservation	C - Conservation
WC2	49	7	C - Conservation	C - Conservation
WC3	41	6	C - Conservation	C - Conservation
WC4	38	6	C - Conservation	C - Conservation
WC5	44	8	C - Conservation	C - Conservation
WC6	46	7	C - Conservation	C - Conservation
WC7	38	5	C - Conservation	C - Conservation
WC8	44	7	C - Conservation	C - Conservation
WC9	40	5	C - Conservation	C - Conservation
WC10	35	5	R - Resource enhancement	R – Resource enhancement

Considering all the above most of the wetlands complexes within the area surveyed, can be considered to be of Conservation category. This was also identified in 'Greater Bunbury Region Scheme – EPA Bulletin 1108' (Environmental Protection Authority, 2003).

4. DISCUSSION

Several botanical surveys have been undertaken of the Kemerton area, including Kemerton Silica Sand. However a detailed search specifically for Declared Rare and Priority Flora and assessment of the wetlands had not been undertaken previously. This current survey resulted in the following significant species being recorded.

- *Boronia juncea* subsp. *juncea* a Priority 1 species. This species occurred typically associated with *Astartea scoparia* or with other species where there was water on the surface during the September 2003 survey.
- *Boronia capitata* subsp. *gracilis* a Priority 2 species was only recorded along the powerline track that traverses the northern section from SW to NE. Previously this species had been recorded from an area to the east of this location but although a search was undertaken it was not relocated.
- *Acacia semitrullata* a Priority 3 species was common in the higher ground associated with *Kunzea glabrescens, Banksia ilicifolia, Banksia attenuata* and/or *Eucalyptus marginata* subsp. *marginata*.
- *Eucalyptus rudis* subsp. *cratyantha* a Priority 3 species was the only subspecies of *Eucalyptus rudis* recorded during the survey. It occurred as individual trees but more commonly as a clump of a few to stands of several trees with a dense canopy.
- *Dillwynia dillwynioides* a Priority 3 species was common in the damp areas where water was on the surface in the September and October surveys but where it was drier in November.
- *Acacia flagelliformis* a Priority 4 species was only recorded in the southern section of the survey area but was common where it did occur. This species occurs in the drier soils on the edge of the wetland proper and is readily overlooked when not in flower.
- *Caladenia speciosa* a Priority 4 species was only recorded from 2 locations. Unless in flower this species is readily overlooked as the leaves are hairy, typical of many of the 'spider orchids'.
- *Jacksonia sparsa* a Priority 4 species was very common through the survey area in the higher ground. It is a spindly shrub up to 1.5m tall.
- *Evandra pauciflora* is a species restricted to the damplands of the Swan Coastal Plain. It was relatively common in the area occurring on the edge of the wetlands as scattered plants or as the dominant species.
- *Verticordia nitens* is a species at its most southern range extension. It was only located in the south eastern section of the survey area.

- *Banksia menziesii,* recorded by Mattiske Consulting Pty Ltd (2003), is a species at the southern most end of its distribution. One plant was sighted along the fence line at the south west of the property.

The wetlands present at the site were assessed by recording the different vegetation units present in each wetland. The wetlands varied between sumplands, damplands, floodplains and palusplains depending on the soil, shape and standing water. As the land had been grazed previously the vegetation condition was recorded as very good for most of the wetlands, some as good but none were degraded or completely degraded. Each of the wetlands was a complex of vegetation units and, apart from areas of *Melaleuca rhaphiophylla* or *Melaleuca viminea* in standing water during the September and October surveys, was impossible to detail map from an aerial photograph. Each wetland was therefore allocated a letter and the vegetation units present in each described.

The wetland suites, a combination of one or more of the wetlands, were assessed using the questionnaire in 'A Guide to Wetland Management in the Perth and Near Perth Swan Coastal Plain Area – EPA Bulletin 686' (Environmental Protection Authority, 1993). This resulted in all being classified as Conservation (Environmental Protection Authority, 1993 and Water and Rivers Commission, 2001). This indicates that the wetlands at the site are of conservation importance although there is an area in wetland suite WC3 which already has infrastructures, including a drain at the wetland. Wetland Suite WC3 also includes EPP wetland 4.

The Environmental Protection Authority (2002) provides selection criteria for the identification of regionally significant natural areas on the southern Swan Coastal Plain. Below the different selection criteria are listed and related to the area of Kemerton Silica Sand:

- Retain at least 30% of the pre-clearing extent of the ecological communities – Bassendean Complex – Central and South, 27% remains;
- Size and shape – a large area is preferable to a small one the lower size limit being 20ha – area is in excess of 20ha;
- Vegetation condition – the vegetation is recorded as vegetation condition 3, very good, due to the area having been grazed previously;
- Uplands and wetlands – natural areas supporting both ecological community groups support the highest diversity, apparent at Kemerton Silica Sand;
- Relationship to other areas – importance for linkage corridors is given the highest priority, forms an important link with the Spearwood system to the west and the Guildford system to the east;
- Ownership – publically preferred lands are preferred to privately owned land – Kemerton Silica Sand is privately owned.

Careful consideration will therefore need to be given to any proposed development and a management plan prepared to ensure that the remnant and conservation wetlands are not compromised with any proposed development. Areas for development will need to be considered in conjunction with the fauna survey and any water research undertaken for the site.

5. SURVEY TEAM

Three qualified botanists undertook the survey, Dr Eleanor Bennett of Bennett Environmental Consulting Pty Ltd., Ms Cate Tauss of Catherine Tauss Botanist and Ms Kirsty Stratford and Ms Kate George of Martinick Bosch Sell Pty Ltd. Dr Bennett identified the plants and wrote the report.

6. ACKNOWLEDGEMENTS

Mr Paul Wilson is thanked for his comments on the *Boronia* species, Mr Leigh Sage for information on *Goodenia filifolia* and Mr Andrew Brown for confirming the identification of the orchid species.

7. REFERENCES

Department of Agriculture. Western Australia (2003). Declared Plant List. http://agspsrv38.agric.wa.gov.au/servlet/page?_pageid=449&_dad=portal30&_schema=PORTAL30

Department of Environmental Protection (2000). *Bush Forever*. Government of Western Australia

Environment Australia (2001). http://www.erin.gov.au

Environmental Protection Authority (1993). *A Guide to Wetland Management in the Perth and Near Perth Swan Coastal Plain Area – EPA Bulletin 686*. EPA, Perth

Environmental Protection Authority (2002). *A Strategy for the EPA to Identify Regionally Significant Natural Areas in its Consideration of the Greater Bunbury Region Scheme Portion of the Swan Coastal Plain.* EPA, Perth

Environmental Protection Authority (2003). *Greater Bunbury Region Scheme – EPA Bulletin 1108.* EPA, Perth

Keighery, B. (1998). *Vegetation and Flora Conservation Values of the Kemerton Silica Sand Project Area.* Unpublished Report to Department of Conservation and Environment

Mattiske E.M. and Associates (1993a). *Gwalia Consolidated Limited – Kemerton Sand Project. Flora and Vegetation Studies. Report One – February 1993*. Unpublished report prepared for John Consulting Services

Mattiske E.M. and Associates (1993b). *Gwalia Consolidated Limited – Kemerton Sand Project. Flora and Vegetation Studies. Report Two – June 1993*. Unpublished report prepared for John Consulting Services

Mattiske E.M. and Associates (1993c). *Gwalia Consolidated Limited – Kemerton Sand Project. Flora and Vegetation Studies. Report Three – November 1993*. Unpublished report prepared for John Consulting Services

Mattiske E.M. and Associates (1993d). *Gwalia Consolidated Limited – Kemerton Sand Project. Vegetation Mapping of Proposed Transport Corridor. Report Four – November 1993*. Unpublished report prepared for John Consulting Services

Mattiske Consulting Pty Ltd (2003). *Kemerton Silica Sand. Review of Flora, Vegetation and Conservation Values on Kemerton Project Area*. Unpublished report for Kemerton Silica Sand

Muir Environmental (1999). *Report of Biological Survey – Phase 1: Kemerton Industrial Estate. Volume 1 – Report and Volume 2 – Appendices*. Unpublished report for Landcorp

Semeniuk, C.A. (1987). *Wetlands of the Darling System – A geomorphic approach to habitat classification.* J. Roy. Soc. W. Aust. 69 (3) 95-111

Semeniuk, C.A. (1988). *Consanguineous* wetlands *and their distribution in the Darling System Southwestern Australia.* J. Roy. Soc. W. Aust. 70 (3) 69-87

Water and Rivers Commission (2001). Position Statement: Wetlands.

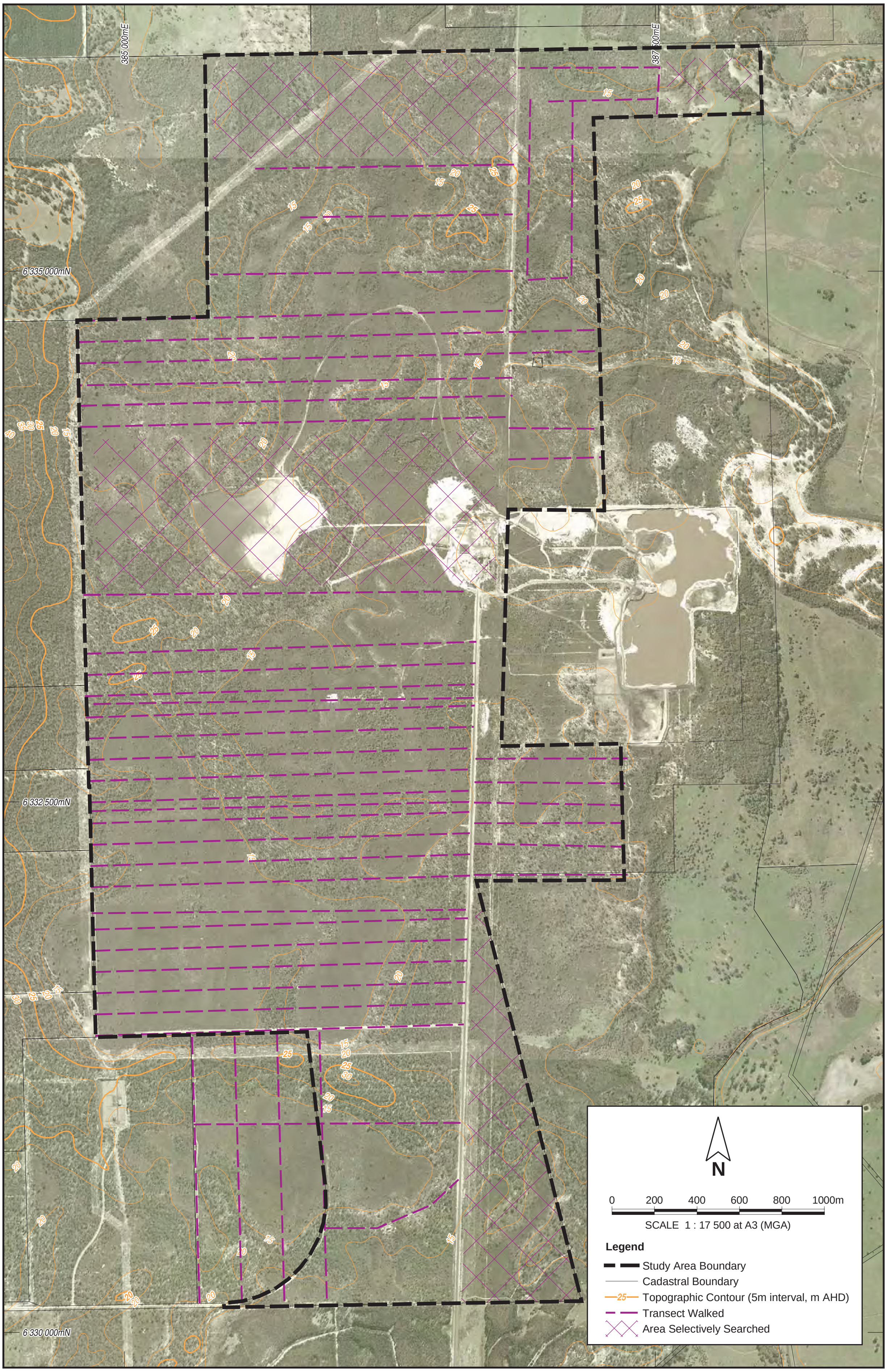
Western Australian Herbarium (2003a). *Florabase*. Department of Conservation and Land Management. http://www.calm.wa.gov.au/science/florabase.html

Western Australian Herbarium (2003b). *Max*. Department of Conservation and Land Management.

Wheeler, J., Marchant, N. Lewington, M. (2002). *Flora of the South West Bunbury – Augusta – Denmark*. Australian Biological Resources Study and University of Western Australia Press

APPENDIX A

Location of transects



MBS Environmental
KEMERTON SILICA SAND

LOCATION OF TRANSECTS

BENNETT ENVIRONMENTAL CONSULTING

Figure 4

Drawn: EB

Date: 06/04

APPENDIX B

Location of Declared Rare and Priority Flora

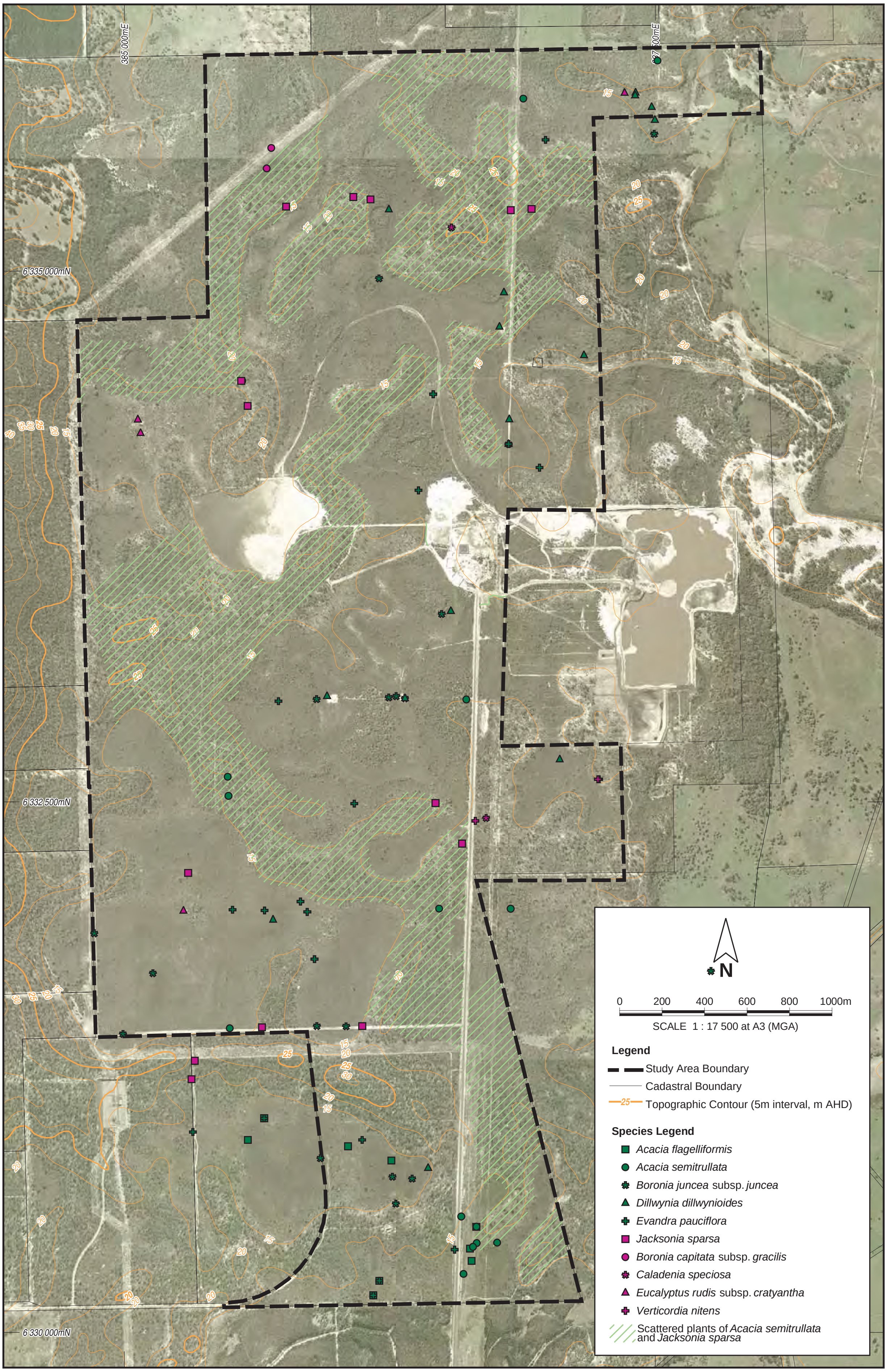
1: Field information
2: Map of locations

SPECIES	NO. PLANTS	NORTHING	EASTING	FIELD NOTES - VEGETATION
Acacia flagelliformis	9+			
Acacia flagelliformis	Ca 50	6330877	386053	*Pericalymma ellipticum* shrubland
Acacia flagelliformis	2	6330175	386172	*Pericalymma ellipticum, Hypocalymma angustifolium, Evandra pauciflora*
Acacia flagelliformis	6+	6330243	386200	*Pericalymma ellipticum, Hypocalymma angustifolium, Evandra pauciflora*
Acacia flagelliformis	1	6330337	386635	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia flagelliformis	4	6330395	386627	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia flagelliformis	5	6330498	386657	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia flagelliformis	2	6330810	386257	*Pericalymma ellipticum, Hypocalymma angustifolium*
Acacia flagelliformis	100	6330907	385581	*Pericalymma ellipticum* wetland
Acacia flagelliformis	100+	6331009	385658	Edge of *Pericalymma ellipticum* wetland
Acacia semitrullata	100++			*Kunzea glabrescens, Banksia ilicifolia* Woodland
Acacia semitrullata	50+			*Kunzea glabrescens* over *Hypocalymma angustifolium*
Acacia semitrullata	2	6330276	386597	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia semitrullata	8	6330403	386641	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia semitrullata	1	6330421	386659	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia semitrullata	8	6330423	386755	Area burnt - *Kunzea glabrescens, Corymbia calophylla, Melaleuca preissiana*
Acacia semitrullata	2	6330498	386657	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia semitrullata	8	6330546	386586	Regrowth *Kunzea glabrescens*
Acacia semitrullata	common	6331193	385316	*Eucalyptus marginata, Banksia attenuata* woodland
Acacia semitrullata	3	6331280	385331	*Eucalyptus marginata, Banksia attenuata* woodland
Acacia semitrullata	3	6331433	385496	Wetland edge
Acacia semitrullata	scattered	6331996	386819	*Banksia ilicifolia* and *Kunzea glabrescens* Shrubland
Acacia semitrullata	5	6331997	386482	*Banksia ilicifolia* and *Kunzea glabrescens* Shrubland
Acacia semitrullata	5	6332528	385490	*Kunzea glabrescens, Banksia ilicifolia, Eucalyptus marginata* over *Dasypogon bromeliifolius*
Acacia semitrullata	scattered thro	6332618	385486	*Kunzea glabrescens, Banksia ilicifolia, Eucalyptus marginata* over *Dasypogon bromeliifolius*
Acacia semitrullata	3	6332982	386610	*Melaleuca preissiana, Hypocalymma angustifolium*
Acacia semitrullata	10	6334365	385580	*Eucalyptus marginata, Banksia attenuata, Kunzea glabrescens*
Acacia semitrullata	2	6334483	385550	*Eucalyptus marginata, Kunzea glabrescens*, few *Banksia ilicifolia*
Acacia semitrullata	5	6334483	385555	*Eucalyptus marginata, Kunzea glabrescens*
Acacia semitrullata	20	6335304	385761	*Kunzea glabrescens, Banksia ilicifolia, Eucalyptus marginata*
Acacia semitrullata	20	6335349	386078	*Kunzea glabrescens, Banksia attenuata* over *Calytrix fraseri*
Acacia semitrullata	1	6335813	386878	*Kunzea glabrescens* over *Hypocalymma angustifolium*
Acacia semitrullata	scattered	6335991	387510	*Kunzea glabrescens, Corymbia calophylla*
Acacia semitrullata	20+	High ground D2		
Boronia capitata subsp. *gracilis*	1	6335484	385670	*Kunzea glabrescens* thicket

Boronia capitata subsp. *gracilis*	1000++	6335580	385691	Powerline NE-SW in with *Euchilops linearis* and *Hypocalymma angustifolium*
Boronia juncea subsp. *juncea*	50+	6332991	386245	*Melaleuca rhaphiophylla, Lepidosperma longitudinale*
Boronia juncea subsp. *juncea*	50+	6330733	386262	*Astartea scoparia* over *Lepidosperma longitudinale*
Boronia juncea subsp. *juncea*	10	6332987	386321	*Pericalymma ellipticum* shrubland
Boronia juncea subsp. *juncea*	50+	6330724	386355	*Astartea scoparia* over *Lepidosperma longitudinale*
Boronia juncea subsp. *juncea*	Ca 70	6333384	386494	*Melaleuca rhaphiophylla* over *Lepidosperma longitudinale*
Boronia juncea subsp. *juncea*	20	6335646	387495	*Astartea scoparia* shrubland
Boronia juncea subsp. *juncea*	20+			*Hypocalymma angustifolium, Hypolaena exsulca*
Boronia juncea subsp. *juncea*	20+			*Astartea scoparia* closed heath over *Meeboldina coangustata, M. tephrina*
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* closed heath over *Meeboldina coangustata, M. tephrina*
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* closed heath over *Meeboldina coangustata, M. tephrina*
Boronia juncea subsp. *juncea*	4+			*Astartea scoparia*, *Hakea varia* closed heath
Boronia juncea subsp. *juncea*	scattered			*Astartea scoparia*, *Pericalymma ellipticum, Meeboldina coangustata, M. tephrina*
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* heath with *Melaleuca lateritia*
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* closed heath
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* heath
Boronia juncea subsp. *juncea*	100+	6330606	386278	*Astartea scoparia*, *Calothamnus lateralis*, sparse *Melaleuca viminea, M. teretifolia, M. lateritia*, M. pre
Boronia juncea subsp. *juncea*	100+	6330820	385923	
Boronia juncea subsp. *juncea*	100	6331406	384993	Wetland edge
Boronia juncea subsp. *juncea*	10+	6331442	386044	Wetland edge
Boronia juncea subsp. *juncea*	30	6331443	385906	Wetland edge
Boronia juncea subsp. *juncea*	5	6331692	385134	*Astartea scoparia*, *Pericalymma ellipticum* closed heath
Boronia juncea subsp. *juncea*	ca 50	6331702	387762	*Astartea scoparia*, *Pericalymma ellipticum* closed heath
Boronia juncea subsp. *juncea*	ca 20	6331880	384858	*Astartea scoparia* thicket
Boronia juncea subsp. *juncea*	100+	6332983	385905	*Pericalymma ellipticum*, *Astartea scoparia*, *Meeboldina coangustata* wet area
Boronia juncea subsp. *juncea*	100++	6332997	386280	*Melaleuca lateritia*
Boronia juncea subsp. *juncea*	10	6334185	386809	*Astartea scoparia*, *Meeboldina coangustata* wetland
Boronia juncea subsp. *juncea*	100+	6334965	386199	*Astartea scoparia*, *Meeboldina coangustata* wetland
Boronia juncea subsp. *juncea*	Ca 25	Wetland N		
Caladenia speciosa	2	6332423	386703	*Banksia ilicifolia, Banksia attenuata, Eucalyptus marginata, Melaleuca thymoides, Stirlingia latifolia*
Caladenia speciosa	1	6335205	386540	*Kunzea glabrescens, Banksia attenuata* and Jarrah community
Dillwynia dillwynioides	1			*Astartea scoparia*, *Pericalymma ellipticum* heath
Dillwynia dillwynioides	2			Very low *Pericalymma ellipticum* heath with *Hakea varia* - waterlogged
Dillwynia dillwynioides	50	6332997	385954	Edge of wetland
Dillwynia dillwynioides	Ca 20	6332987	386321	*Pericalymma ellipticum* shrubland
Dillwynia dillwynioides	Ca 40	6330774	386430	*Astartea scoparia* over *Lepidosperma longitudinale*

Dillwynia dillwynioides	Ca 50	6333398	386537	*Melaleuca preissiana* over *Pericalymma ellipticum*
Dillwynia dillwynioides	Ca20	6334737	386766	*Astartea scoparia, Pericalymma ellipticum* wetland
Dillwynia dillwynioides	1	6334899	386787	*Astartea scoparia* thicket
Dillwynia dillwynioides	5	6334301	386812	*Astartea scoparia, Pericalymma ellipticum* wetland
Dillwynia dillwynioides	10	6334603	387164	*Astartea scoparia* thicket
Dillwynia dillwynioides	10+	6335290	386245	
Dillwynia dillwynioides	10 plants	6335827	387405	*Melaleuca cuticularis* thicket
Dillwynia dillwynioides	100+	6331944	385700	*Calothamnus lateralis, Astartea scoparia* wet area
Dillwynia dillwynioides	20	6332699	387050	*Astartea scoparia* over *Lepidosperma longitudinale*
Dillwynia dillwynioides	5	6332998	385948	On edge of dam
Dillwynia dillwynioides	3	6334185	386809	*Astartea scoparia, Meeboldina coangustata* wetland
Dillwynia dillwynioides	3	6335840	387407	*Kunzea glabrescens* shrubland
Dillwynia dillwynioides	Ca 50	6335772	387483	*Astartea scoparia, Melaleuca viminea* shrubland
Dillwynia dillywnioides	20	6335711	387498	*Kunzea glabrescens* thicket
Dillwynia dillywnioides		Wetland D2		
Dillwynia dillywnioides		Between wetlands D and E		
Dillwynia dillwynioides	100++	Wetland P		
Dillwynia dillwynioides	50+	Wetland U		
Eucalyptus rudis subsp. *cratyantha*	100+			*Melaleuca preissiana, Hypocalymma angustifolium*
Eucalyptus rudis subsp. *cratyantha*	10	6331986	385278	*Eucalyptus rudis, Banksia ilicifolia, Hypocalymma angustifolium*
Eucalyptus rudis subsp. *cratyantha*	11	6334236	385076	Wetland fringe
Eucalyptus rudis subsp. *cratyantha*	6	6334300	385063	*Eucalyptus rudis, Melaleuca preissiana, Hypocalymma angustifolium*
Eucalyptus rudis subsp. *cratyantha*	15	6335839	387355	*Eucalyptus rudis, Melaleuca rhaphiophylla*
Evandra pauciflora	ca 20			*Hypocalymma angustifolium, Hypolaena exsulca*
Evandra pauciflora	50+			*Hypocalymma angustifolium, Pericalymma ellipticum* heath
Evandra pauciflora	Ca 20	6330907	386119	*Pericalymma ellipticum* shrubland
Evandra pauciflora	50+	6330390	386555	Edge of road
Evandra pauciflora	Many	6330175	386172	*Pericalymma ellipticum, Hypocalymma angustifolium, Evandra pauciflora*
Evandra pauciflora	many	6330243	386200	*Pericalymma ellipticum, Hypocalymma angustifolium, Evandra pauciflora*
Evandra pauciflora	2	6330944	385322	Edge of *Pericalymma ellipticum* wetland
Evandra pauciflora	100+++	6331009	385658	Edge of *Pericalymma ellipticum* wetland
Evandra pauciflora	2	6331759	385895	*Pericalymma ellipticum* wetland
Evandra pauciflora	50+	6331981	385861	*Hypocalymma angustifolium, Adenanthos meisneri, Kunzea glabrescens*
Evandra pauciflora	100+	6331988	385660	*Hypocalymma angustifolium, Adenanthos meisneri, Kunzea glabrescens*
Evandra pauciflora	100+	6331991	385509	*Hypocalymma angustifolium, Adenanthos meisneri, Kunzea glabrescens*
Evandra pauciflora	ca 50	6332030	385829	Wetland edge

Evandra pauciflora	50+	6332974	385725	*Pericalymma ellipticum, Xanthorrhoea brunonis* wetland
Evandra pauciflora	>>1000	6332491	386082	Wetland edge
Evandra pauciflora	50+	6333967	386385	*Pericalymma ellipticum, Hypocalymma angustifolium*
Evandra pauciflora	100+	6334074	386955	
Evandra pauciflora	50+	6334185	386809	*Astartea* scoparia, *Meeboldina coangustata* wetland
Evandra pauciflora	20	6334420	386454	*Hypocalymma angustifolium, Pericalymma ellipticum*
Evandra pauciflora	2	6335618	386983	*Kunzea glabrescens* over *Hypocalymma angustifolium*
Evandra pauciflora	100+	Wetland F		
Evandra pauciflora	100+	Wetland D2		
Evandra pauciflora	100+	Wetland P		
Jacksonia sparsa	common	6331193	385316	*Eucalyptus marginata, Banksia attenuata* woodland
Jacksonia sparsa	ca 50	6331280	385331	*Eucalyptus marginata, Banksia attenuata* woodland
Jacksonia sparsa	common	6331438	385648	*Eucalyptus marginata, Banksia attenuata* woodland
Jacksonia sparsa	5	6331443	386120	*Banksia ilicifolia* wetland interzone
Jacksonia sparsa	common	6332165	385300	*Banksia ilicifolia* and *Kunzea glabrescens* Shrubland
Jacksonia sparsa	100++	6332303	386590	*Banksia attenuata, Eucalyptus marginata* Woodland
Jacksonia sparsa	20	6332494	386465	*Kunzea glabrescens* thicket
Jacksonia sparsa	common	6334365	385580	*Eucalyptus marginata, Banksia attenuata, Kunzea glabrescens*
Jacksonia sparsa	10	6334483	385550	*Eucalyptus marginata, Kunzea glabrescens*, few *Banksia ilicifolia*
Jacksonia sparsa	common	6335287	386819	Regrowth *Kunzea glabrescens*
Jacksonia sparsa	common	6335293	386917	Regrowth *Kunzea glabrescens*
Jacksonia sparsa	100++	6335304	385761	*Kunzea glabrescens, Banksia ilicifolia, Eucalyptus marginata*
Jacksonia sparsa	common	6335338	386159	*Kunzea glabrescens* thicket
Jacksonia sparsa	many	6335349	386078	*Kunzea glabrescens, Banksia attenuata* over *Calytrix fraseri*
Jacksonia sparsa	many	Wetland D2		
Jacksonia sparsa	many	Wetland S		
Jacksonia sparsa	many	Wetland U		
Verticordia nitens	20+	6332410	386652	*Eucalyptus marginata, Banksia ilicifolia, Melaleuca thymoides, Calytrix fraseri*
Verticordia nitens	100+	6332606	387230	*Banksia ilicifolia, Banksia attenuata, Eucalyptus marginata, Melaleuca thymoides*
Verticordia nitens	100++	6332606	387235	*Banksia ilicifolia, Banksia attenuata* over *Melaleuca thymoides*



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LOCATIONS OF PRIORITY SPECIES

BENNETT ENVIRONMENTAL CONSULTING

Figure 2

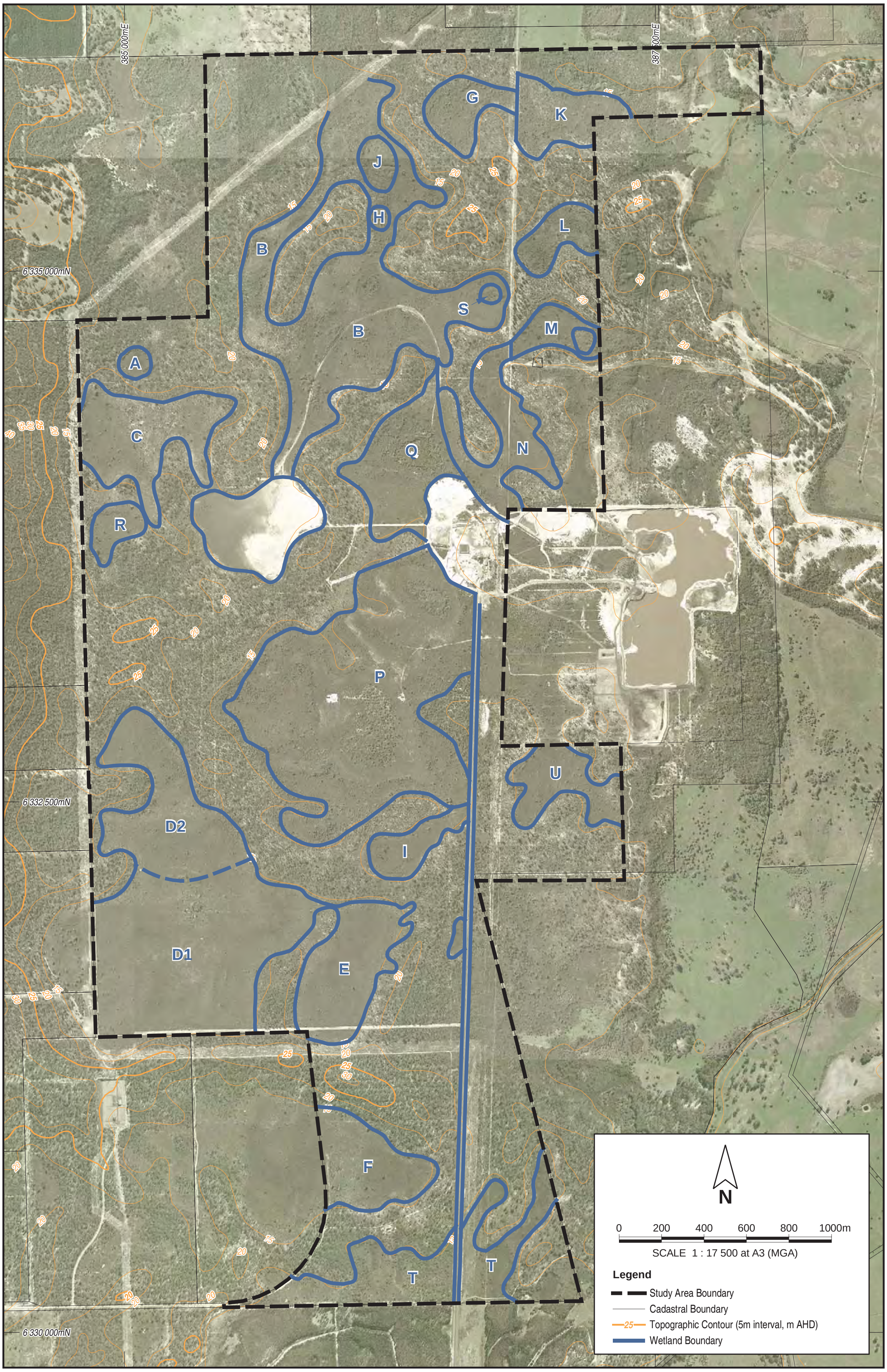
Drawn: EB

Date: 02/04

APPENDIX C

Wetland Locations

Map 1: Wetland locations
Map 2: Wetland complexes



MBS Environmental
KEMERTON SILICA SAND

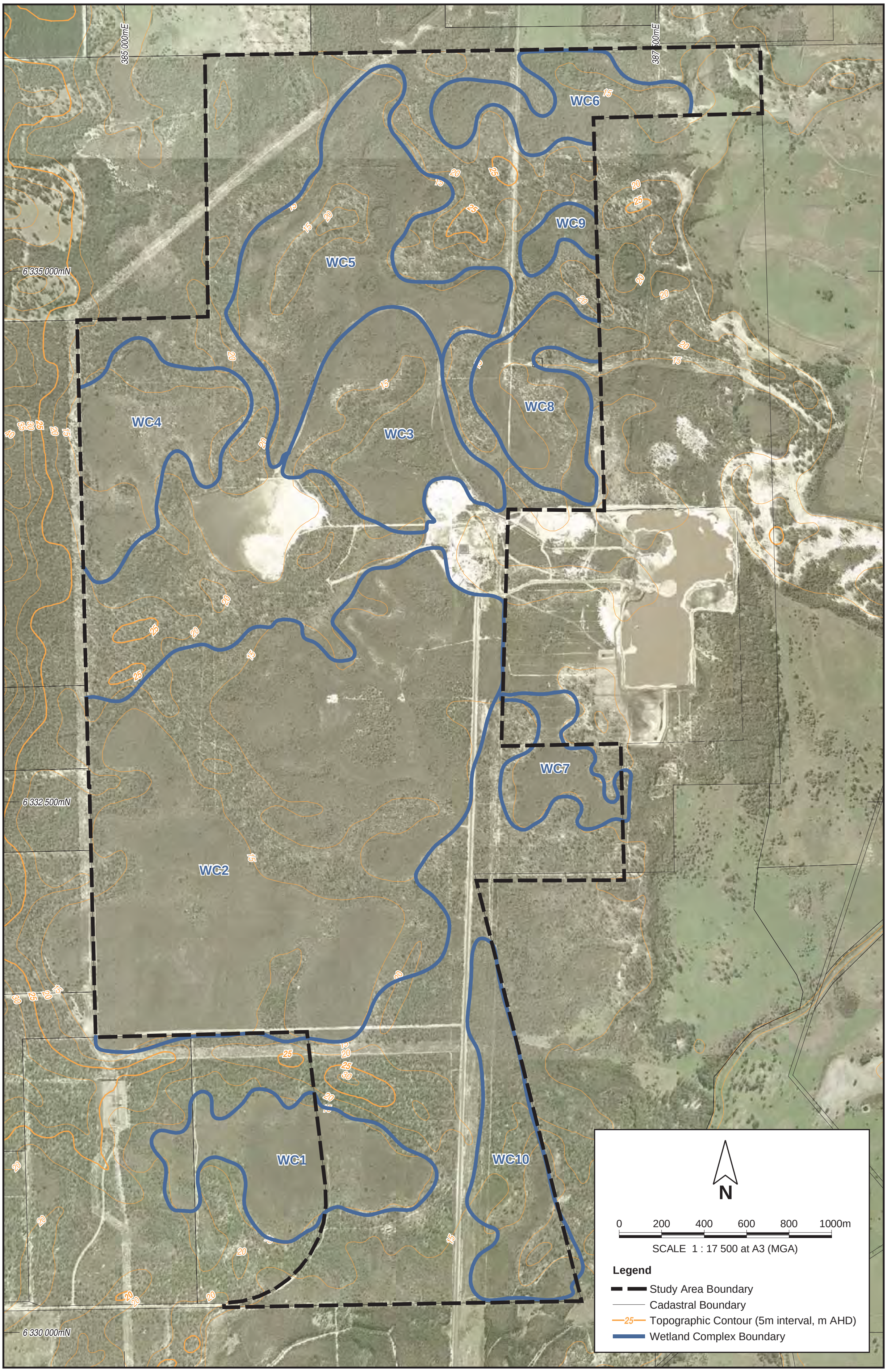
LOCATION OF WETLANDS

BENNETT ENVIRONMENTAL CONSULTING

Figure 1

Drawn: EB

Date: 06/04



MBS Environmental
KEMERTON SILICA SAND

WETLAND COMPLEXES

BENNETT ENVIRONMENTAL CONSULTING

Figure 3

Drawn: EB

Date: 02/04

APPENDIX D

Wetland Assessment

APPENDIX 6:
UPDATED REVIEW OF VEGETATION COMMUNITIES – KEMERTON SILICA SAND PTY LTD
FEBRUARY 2009
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UPDATED REVIEW OF VEGETATION COMMUNITIES - KEMERTON SILICA SAND PTY LTD

This brief report provides an updated assessment of the plant communities at the Kemerton Silica Sand Pty Ltd (KSS) property in relation to the Threatened Ecological Communities and the Priority Ecological Communities.

The initial mapping project was undertaken in 1993 by qualified botanists on a grid system. The area was assessed along east-west grid lines spaced 250 metres apart. Regular recordings were taken along these gridlines. The location of the recordings along the gridlines was based on the variation in the communities, but tended to be between 50m and 150m apart. At each recording site the trees were recorded in a 20m radius and understorey in a 5m radius.

The vegetation was mapped at a detailed level by E.M.Mattiske and Associates (1993a,b,c, d) which defined a total of 24 plant communities and 27 vegetation mapping units for the KSS survey area, with three of the mapping units comprising disturbed stages of plant communities (E.M. Mattiske and Associates 1993a; 1993b; 1993c; 1993d; Mattiske Consulting Pty Ltd 2002; 2003).

The similarities were calculated using both all species and only native species data. The Sorenson Index of Similarity is based on qualitative (Presence/absence) data:

$$ISs = \frac{2a}{2a + b + c}$$

Where:

a = number of species common to both sites
b = number of species found in the first site only
c = number of species found in the second site only

The species by site data was analysed utilising the association measures (Austin and Belbin 1982, Belbin 1995) and flexible UPGMA technique with the PATN program (Blatant Fabrications Pty Ltd 2006). The PATN clustering analysis (Belbin 1995) on all species by sites and native species by sites, see Tables 3 and 4.

$$D = \sum [D_{ik} - D_{jk}] / \sum \{D_{ik} + D_{jk}\}$$

The attached Tables and the Dendrograms indicate that there are very low similarities between the communities as defined by Mattiske in the previous mapping. This is a pattern repeated and appears to relate to the continuum nature of many species across the landscape and the need to rely on presence/absence data only (rather than quantitative and structural dominance).

The Sorenson Similarity analysis reflected very low similarities (less than 0.4 in most cases) and the latter is supported by the lack of Mattiske mapping units clustering with those of Gibson et al. (1994). In the analysis of the native species only the majority of the Mattiske sites did not cluster with the Gibson sites, with the exception of F3 with 14, F2 with 18 and 13 and G4 with 12. The latter in part results from the presence of species that prefer wetter or moister sites on low lying depressions. In the analysis of all species, C1, C3, D1 and G2 were clustered broadly with 14 and D3 was clustered broadly with 15, 12, 13, 18, 16, 17 and 19. These once again reflect the presence of species that prefer wetter or moister sites on low lying depressions or swales.

Therefore it appears that the analyses as undertaken indicate a lack of similarity. Therefore comparisons are based on more subjective interpretations of the dominant species, the general descriptions of the communities and the site/landform considerations. The latter is not surprising as there may be differences in survey techniques. The latter more subjective approach leaves interpretation open to mis-leading summaries on relationships. This was indicated in the 2003 report (see Table 3 and associated text of Mattiske Consulting Pty Ltd 2003). At this stage it was noted that there were some similarities between the communities but are not necessarily direct comparability.

The differences noted during the previous assessments was based on comparisons on dominant species, rather than structural components and in view of the lack of quantitative data it is not surprising that there was some confusion in the various interpretations. The Sorensons Similarity Index and the clustering techniques have been used on a variety of projects with little success and the latter may in part reflect the continuum nature of the communities (with species occurring in a range of environments and the determinant factors in their distributions differing across the Coastal Plain. Therefore there is a need to be subjective in its interpretation and this then leads to different opinions placed on the significance of floristics, dominance, indicator species and structure. Hence the confusion that occurs in these interpretations.

In relation to the potential for the Muchea Limestone community, this matter has always been one of debate between the various parties and whilst the *Eucalyptus decipiens* was recorded in the reserve area (south east of any proposed disturbance), it should also be noted that the communities in this area are not reliant on this one species for definition and that previous reports (Mattiske Consulting Pty Ltd 2003) have indicated that this species is relatively widespread (based on Florabase, Department of Environment and Conservation 2009). Keighery (1998) reported that the project area also contains *Eucalyptus decipiens* Closed Tree Mallee populations associated with Muchea Limestone communities within plant communities D2, F1 and F3. Based on interpretations from geological records limestone was not recorded within these areas at Kemerton and therefore the issue of whether the *Eucalyptus decipiens* reflects a particular community or not is still open to interpretation. After reviewing the distribution of this mallee species on FloraBase it appears that although it is associated with the limestone it is not confined to these Muchea limestone areas.

In conclusion, it appears that there is little evidence to indicate a strong similarity with the Gibson *et al.* (1994) communities as defined utilizing the Sorenson's Similarity Index or the PATN analyses (Belbin 1995). The presence of some dominant species or species that reflect seasonal swamps do not necessarily indicate a presence of the respective TEC or PEC's. Therefore there is some subjectivity on this matter and it really relies on the significance of the remnant areas within the Kemerton area.

Mattiske Vegetation Community	Comparison with Floristic Community Type			Comments
	Mattiske comparison with Gibson 2009	EPASU comments to Draft PER	TEC/PEC status	
A1	21a			Some similarity with dominants
A2	21a			Some similarity with dominants
A3	21a			Some similarity with dominants
B1		1b	TEC Vulnerable	Not 1b as 1b on Pinjarra Plain
C1		21b	PEC - Priority 3	Not 21b as 21b on Ridge Hill and Pinjarra Plain
C2		21b	PEC - Priority 3	Not 21b as 21b on Ridge Hill and Pinjarra Plain
C3	11	1b	TEC Vulnerable	Not 1b as 1b on Pinjarra Plain, some overlap with dominants
D1	11			Some similarity with dominants
D2	4	Muchea Limestone	TEC Endangered State & Federal	Some similarity with dominants, question over significance
D3	12			Some similarity with dominants
E1	4			Some similarity with dominants
E2	4			Some similarity with dominants
E3	4			Some similarity with dominants
E4	4			Some similarity with dominants
F1	12	Muchea Limestone	TEC Endangered State & Federal	Some similarity with dominants
F2		7	TEC Vulnerable	7 on Pinjarra Plain, some similarity with dominants
F3	13	Muchea Limestone	TEC Endangered State & Federal	7 on Pinjarra Plain, 13 due to dominance of Melaleuca
G1	5/11			Differences based on dominance of shrubs or tree species
G2	5/11			Differences based on dominance of shrubs or tree species
G3	5/13			Differences based on dominance of shrubs or tree species
G4		7	TEC Vulnerable	7 on Pinjarra Plain
H1	5/11			Differences based on dominance of shrubs or tree species
H2	5/11			Differences based on dominance of shrubs or tree species
H3	5/12			Some similarities with 5 and 12 based on dominants only
I1	21a	21b	PEC - Priority 3	Disturbed and Degraded 21a, 21b on Ridge Hill/Pinjarra Plain
I2	21a	21b	PEC - Priority 3	Disturbed and Degraded 21a, 21b on Ridge Hill/Pinjarra Plain
I3	Disturbed 21a			Disturbed and Degraded

Note: Only low similarities and unclear associations were observed in analyses and therefore the re has been variable interpretations on the PEC and TEC's. This largely relates to the reliance on different qualitative measures.

REFERENCES

Austin, M. P. and Belbin, L. (1982)
A new approach to the species classification problem in floristic analysis. *Australian Journal of Ecology*, 7: 75-89.

Belbin L. (1995) *PATN Pattern Analysis Package*. CSIRO Division of Wildlife and Ecology, Lyneham ACT.

Blatant Publications Pty Ltd (2006)
PATN version 3.11

English, V. and Blyth, J. 1997. *Identifying and Conserving Threatened Ecological Communities (TECS) in the South West Botanical Province.* Department of Conservation and Land Management.

Department of Environment and Conservation (2009). *Florabase – Information on the Western Australian Flora*. Department of Conservation and Land Management. http://www.calm.wa.gov.au/science/florabase.html

Gibson, N, Keighery, B., Keighery, G., Burbidge, A. and Lyons, M. 1994. *A Floristic Survey of the Swan Coastal Plain.* Unpublished Report for the Australian Heritage Commission prepared by the Department of Conservation and Land Management and the Conservation Council of Western Australia.

Keighery, B 1998. *Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area*. Unpublished report to Department of Conservation and Environment.

Keighery, G.J. and Keighery, B.J., and Bibson. 1997. Floristics of Reserves and Bushland Areas in the Perth Region (System 6) Part XIII: In: *Floristics of Reserves and Bushland Areas of the Perth Region (System 6)* Parts V-IX.

Keighery, G.J. and Keighery, B.J. 1995. *Muchea Limestones - Floristics.* Unpublished report to Australian Nature Conservation Authority Natural Reserves Network and Department of Conservation and Environment.

Mattiske, E.M. and Associates 1993a. *Gwalia Consolidated Limited - Kemerton Sand Project: Flora and Vegetation Studies. Report One - February 1993.* Unpublished report prepared for John Consulting Services.

Mattiske, E.M. and Associates 1993b. *Gwalia Consolidated Limited - Kemerton Sand Project: Flora and Vegetation. Report Two - June 1993.* Unpublished report prepared for John Consulting Services.

Mattiske, E.M. and Associates 1993c. *Gwalia Consolidated Limited - Kemerton Sand Project: Updated Flora and Vegetation Report. Report Three - November 1993.* Unpublished report prepared for John Consulting Services.

Mattiske, E.M. and Associates 1993d. *Gwalia Consolidated Limited - Kemerton Sand Project: Vegetation Mapping of Proposed Transport Corridor. Report Four - November 1993.* Unpublished report prepared for John Consulting Services.

Mattiske Consulting Pty Ltd (2003). *Kemerton Silica Sands. Review of Flora, Vegetation and Conservation Values on Kemerton Project Area.* Prepared for Kemerton Silica Sands, February 2003.

Table 1: All Species Sorenson's Similarity

	A1	A2	A3	B1	C1	C2	C3	D1	D2	D3	E1	E2	E3	E4	F1	F2	F3	G1	G2	G3	G4	H1	H2	H3	1a	1b	2	3a	3b	3c	4	5	6	7	8	9	10a	10b	11	12	13	14	15	16	17	18	19	20a	20b	20c	21a	21b	21c	22	23a	23b	24	25	26a	26b	27	28	29a	29b	30a	30b
A2	0.64																																																																	
A3	0.66	0.49																																																															
B1	0.35	0.30	0.34																																																													
C1	0.14	0.20	0.09	0.12																																																											
C2	0.28	0.29	0.23	0.35	0.24																																																								
C3	0.24	0.23	0.18	0.27	0.20	0.24																																																						
D1	0.21	0.23	0.20	0.36	0.25	0.30	0.24																																																					
D2	0.25	0.20	0.28	0.32	0.14	0.25	0.38	0.29																																																			
D3	0.07	0.10	0.08	0.09	0.07	0.20	0.26	0.21	0.24																																																		
E1	0.40	0.38	0.35	0.58	0.09	0.31	0.19	0.36	0.37	0.24																																																	
E2	0.40	0.37	0.35	0.58	0.26	0.38	0.21	0.43	0.38	0.14	0.61																																															
E3	0.05	0.04	0.10	0.13	0.00	0.14	0.16	0.07	0.18	0.32	0.20	0.14																																														
E4	0.03	0.00	0.03	0.10	0.00	0.08	0.18	0.08	0.16	0.29	0.17	0.05	0.40																																													
F1	0.12	0.13	0.20	0.22	0.03	0.12	0.16	0.18	0.45	0.19	0.31	0.25	0.20	0.21																																												
F2	0.05	0.04	0.06	0.04	0.00	0.07	0.16	0.07	0.24	0.16	0.10	0.05	0.25	0.20	0.33																																											
F3	0.03	0.04	0.03	0.10	0.00	0.17	0.06	0.09	0.13	0.20	0.11	0.11	0.32	0.40	0.14	0.32																																										
G1	0.60	0.54	0.59	0.45	0.14	0.30	0.30	0.28	0.39	0.15	0.49	0.46	0.10	0.10	0.24	0.07	0.05																																									
G2	0.19	0.16	0.16	0.36	0.25	0.12	0.34	0.38	0.14	0.14	0.27	0.26	0.29	0.33	0.09	0.07	0.09	0.19																																								
G3	0.05	0.06	0.16	0.19	0.00	0.17	0.23	0.18	0.39	0.19	0.35	0.29	0.27	0.23	0.39	0.27	0.24	0.23	0.06																																							
G4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.15	0.25	0.00	0.00	0.11																																						
H1	0.42	0.31	0.41	0.36	0.10	0.18	0.26	0.20	0.46	0.21	0.41	0.42	0.13	0.11	0.29	0.08	0.09	0.47	0.20	0.25	0.00																																					
H2	0.16	0.20	0.19	0.25	0.03	0.19	0.20	0.19	0.46	0.20	0.32	0.26	0.17	0.22	0.38	0.10	0.11	0.35	0.13	0.38	0.04	0.37																																				
H3	0.05	0.07	0.08	0.13	0.00	0.19	0.21	0.07	0.29	0.22	0.24	0.18	0.46	0.55	0.32	0.23	0.38	0.14	0.13	0.44	0.13	0.20	0.40																																			
1a	0.25	0.24	0.33	0.19	0.07	0.10	0.11	0.07	0.12	0.06	0.15	0.12	0.04	0.02	0.08	0.00	0.00	0.28	0.10	0.04	0.00	0.22	0.11	0.01																																										
1b	0.27	0.26	0.32	0.21	0.08	0.11	0.14	0.11	0.16	0.07	0.15	0.14	0.05	0.01	0.10	0.00	0.00	0.29	0.09	0.07	0.00	0.23	0.13	0.03	0.75																																									
2	0.12	0.14	0.21	0.23	0.02	0.08	0.11	0.10	0.19	0.06	0.20	0.16	0.07	0.05	0.20	0.02	0.02	0.21	0.08	0.12	0.00	0.23	0.22	0.09	0.50	0.54																																								
3a	0.19	0.16	0.28	0.19	0.07	0.06	0.10	0.08	0.13	0.04	0.12	0.14	0.06	0.03	0.15	0.01	0.01	0.22	0.10	0.07	0.02	0.23	0.16	0.07	0.55	0.56	0.56																																							
3b	0.27	0.23	0.35	0.20	0.10	0.08	0.15	0.11	0.14	0.04	0.12	0.11	0.03	0.01	0.08	0.00	0.00	0.28	0.11	0.03	0.00	0.22	0.09	0.01	0.66	0.67	0.46	0.65																																						
3c	0.14	0.11	0.21	0.18	0.07	0.05	0.11	0.10	0.11	0.05	0.09	0.10	0.05	0.02	0.12	0.02	0.00	0.17	0.08	0.03	0.00	0.18	0.12	0.03	0.48	0.51	0.43	0.66	0.65																																					
4	0.29	0.24	0.37	0.28	0.09	0.14	0.16	0.15	0.24	0.09	0.28	0.20	0.08	0.05	0.16	0.03	0.03	0.36	0.14	0.13	0.00	0.32	0.19	0.09	0.49	0.58	0.52	0.58	0.62	0.48																																				
5	0.24	0.17	0.35	0.21	0.04	0.12	0.15	0.13	0.24	0.09	0.17	0.16	0.07	0.06	0.20	0.09	0.06	0.34	0.09	0.16	0.02	0.29	0.19	0.13	0.44	0.45	0.46	0.57	0.56	0.52	0.63																																			
6	0.22	0.15	0.27	0.22	0.04	0.10	0.14	0.14	0.19	0.08	0.18	0.15	0.08	0.06	0.15	0.06	0.06	0.26	0.10	0.10	0.02	0.22	0.15	0.10	0.34	0.33	0.33	0.51	0.44	0.49	0.49	0.56																																		
7	0.08	0.03	0.19	0.11	0.05	0.02	0.08	0.05	0.13	0.07	0.08	0.08	0.09	0.06	0.20	0.11	0.04	0.12	0.11	0.10	0.02	0.20	0.13	0.13	0.25	0.26	0.33	0.48	0.42	0.52	0.45	0.63	0.52																																	
8	0.08	0.04	0.16	0.12	0.04	0.01	0.10	0.09	0.15	0.06	0.08	0.09	0.06	0.05	0.13	0.06	0.02	0.15	0.07	0.07	0.02	0.20	0.15	0.08	0.37	0.41	0.46	0.64	0.51	0.64	0.48	0.58	0.52	0.69																																
9	0.11	0.08	0.23	0.19	0.08	0.08	0.15	0.10	0.20	0.06	0.20	0.14	0.13	0.09	0.24	0.08	0.04	0.24	0.14	0.20	0.02	0.24	0.26	0.16	0.40	0.41	0.55	0.55	0.40	0.46	0.50	0.55	0.41	0.59	0.60																															
10a	0.08	0.09	0.16	0.15	0.06	0.04	0.09	0.10	0.18	0.06	0.10	0.15	0.08	0.00	0.17	0.06	0.02	0.15	0.08	0.11	0.02	0.17	0.18	0.10	0.37	0.38	0.57	0.57	0.42	0.48	0.44	0.55	0.46	0.60	0.66	0.65																														
10b	0.16	0.17	0.20	0.20	0.05	0.08	0.15	0.11	0.12	0.07	0.15	0.13	0.07	0.02	0.13	0.02	0.02	0.24	0.08	0.08	0.00	0.21	0.18	0.07	0.45	0.51	0.63	0.60	0.51	0.56	0.56	0.57	0.45	0.53	0.62	0.58	0.62																													
11	0.18	0.17	0.32	0.22	0.10	0.07	0.16	0.16	0.23	0.12	0.19	0.18	0.11	0.09	0.30	0.13	0.07	0.25	0.16	0.15	0.02	0.27	0.22	0.14	0.33	0.37	0.38	0.47	0.43	0.47	0.46	0.60	0.46	0.58	0.51	0.47	0.41	0.44																												
12	0.09	0.11	0.17	0.15	0.06	0.03	0.11	0.13	0.22	0.17	0.19	0.16	0.14	0.07	0.27	0.14	0.15	0.17	0.16	0.22	0.04	0.23	0.24	0.23	0.20	0.18	0.22	0.25	0.21	0.21	0.32	0.40	0.33	0.42	0.32	0.34	0.36	0.35	0.44																											
13	0.03	0.02	0.15	0.14	0.03	0.06	0.14	0.12	0.23	0.16	0.13	0.13	0.20	0.11	0.24	0.13	0.11	0.15	0.09	0.24	0.04	0.20	0.25	0.25	0.15	0.21	0.29	0.29	0.15	0.26	0.25	0.39	0.31	0.46	0.38	0.48	0.41	0.35	0.40	0.40																										
14	0.11	0.09	0.12	0.19	0.17	0.11	0.18	0.34	0.16	0.13	0.17	0.20	0.13	0.22	0.18	0.19	0.23	0.14	0.23	0.11	0.00	0.16	0.09	0.18	0.07	0.09	0.08	0.11	0.15	0.20	0.18	0.21	0.19	0.17	0.15	0.14	0.07	0.11	0.25	0.15	0.26																									
15	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.08	0.09	0.06	0.08	0.19	0.02	0.00	0.00	0.00	0.04	0.07	0.07	0.00	0.01	0.00	0.01	0.01	0.03	0.00	0.04	0.08	0.14	0.05	0.04	0.06	0.05	0.16	0.27	0.22	0.06																								
16	0.00	0.00	0.03	0.00	0.11	0.00	0.00	0.00	0.05	0.06	0.00	0.00	0.06	0.07	0.11	0.18	0.14	0.00	0.00	0.10	0.09	0.02	0.03	0.11	0.00	0.01	0.02	0.07	0.04	0.06	0.06	0.10	0.17	0.25	0.11	0.08	0.09	0.05	0.23	0.18	0.17	0.10	0.33																							
17	0.00	0.00	0.08	0.03	0.12	0.08	0.13	0.04	0.20	0.24	0.06	0.06	0.17	0.09	0.21	0.17	0.05	0.08	0.08	0.15	0.00	0.13	0.12	0.16	0.05	0.08	0.05	0.09	0.05	0.10	0.09	0.16	0.16	0.25	0.18	0.18	0.16	0.13	0.31	0.22	0.38	0.22	0.20	0.41																						
18	0.06	0.07	0.13	0.05	0.07	0.00	0.12	0.07	0.17	0.15	0.12	0.08	0.08	0.04	0.20	0.19	0.04	0.11	0.11	0.10	0.05	0.16	0.12	0.11	0.17	0.13	0.18	0.23	0.14	0.25	0.19	0.28	0.19	0.33	0.32	0.28	0.26	0.23	0.34	0.26	0.31	0.17	0.07	0.16	0.29																					
19	0.02	0.03	0.07	0.03	0.16	0.04	0.07	0.04	0.11	0.09	0.06	0.06	0.04	0.05	0.14	0.13	0.00	0.06	0.04	0.08	0.00	0.07	0.08	0.04	0.05	0.06	0.05	0.09	0.08	0.13	0.08	0.09	0.13	0.18	0.20	0.10	0.13	0.11	0.27	0.10	0.17	0.11	0.08	0.32	0.43	0.30																				
20a	0.27	0.23	0.33	0.14	0.03	0.08	0.09	0.03	0.09	0.05	0.09	0.09	0.03	0.00	0.04	0.00	0.00	0.27	0.05	0.02	0.00	0.20	0.09	0.03	0.58	0.53	0.34	0.51	0.51	0.39	0.45	0.40	0.34	0.23	0.27	0.23	0.28	0.37	0.26	0.13	0.11	0.03	0.00	0.00	0.07	0.17	0.07																			
20b	0.27	0.23	0.32	0.18	0.04	0.07	0.11	0.06	0.09	0.03	0.10	0.08	0.01	0.01	0.05	0.00	0.00	0.27	0.07	0.01	0.00	0.20	0.08	0.01	0.63	0.63	0.37	0.57	0.67	0.51	0.51	0.41	0.44	0.28	0.37	0.29	0.27	0.38	0.28	0.13	0.08	0.08	0.00	0.04	0.05	0.12	0.04	0.68																		
20c	0.28	0.24	0.31	0.18	0.05	0.08	0.10	0.09	0.10	0.03	0.09	0.11	0.02	0.02	0.06	0.00	0.00	0.25	0.08	0.00	0.00	0.16	0.11	0.02	0.54	0.53	0.36	0.58	0.55	0.54	0.53	0.46	0.46	0.30	0.38	0.32	0.34	0.45	0.33	0.16	0.16	0.11	0.00	0.03	0.07	0.14	0.05	0.68	0.68																	
21a	0.31	0.24	0.41	0.19	0.09	0.11	0.13	0.10	0.18	0.07	0.17	0.14	0.04	0.02	0.10	0.03	0.01	0.34	0.09	0.07	0.00	0.27	0.13	0.03	0.62	0.64	0.37	0.56	0.67	0.53	0.62	0.56	0.49	0.37	0.46	0.37	0.33	0.43	0.47	0.23	0.18	0.13	0.03	0.08	0.15	0.25	0.17	0.63	0.67	0.62																
21b	0.38	0.33	0.40	0.20	0.11	0.15	0.17	0.11	0.18	0.08	0.18	0.14	0.05	0.02	0.10	0.02	0.02	0.37	0.11	0.05	0.00	0.28	0.13	0.03	0.65	0.66	0.36	0.51	0.61	0.44	0.62	0.51	0.41	0.28	0.32	0.33	0.28	0.45	0.33	0.24	0.15	0.12	0.00	0.01	0.07	0.16	0.04	0.64	0.67	0.63	0.70															
21c	0.37	0.30	0.42	0.24	0.08	0.14	0.17	0.15	0.17	0.06	0.19	0.17	0.03	0.03	0.10	0.01	0.03	0.40	0.11	0.08	0.00	0.29	0.14	0.03	0.50	0.53	0.34	0.55	0.58	0.50	0.66	0.61	0.54	0.38	0.43	0.36	0.33	0.48	0.47	0.23	0.22	0.17	0.01	0.08	0.11	0.16	0.12	0.62	0.61	0.69	0.71	0.66														
22	0.29	0.23	0.37	0.22	0.00	0.16	0.11	0.14	0.17	0.04	0.19	0.17	0.02	0.02	0.10	0.02	0.04	0.36	0.04	0.13	0.00	0.28	0.14	0.04	0.43	0.43	0.40	0.42	0.42	0.30	0.58	0.55	0.42	0.26	0.28	0.32	0.32	0.34	0.34	0.23	0.22	0.13	0.00	0.04	0.08	0.16	0.07	0.54	0.43	0.48	0.50	0.54	0.58													
23a	0.36	0.28	0.41	0.24	0.08	0.14	0.15	0.12	0.16	0.06	0.20	0.17	0.04	0.03	0.12	0.01	0.03	0.39	0.11	0.08	0.00	0.30	0.14	0.04	0.53	0.53	0.32	0.53	0.55	0.44	0.65	0.56	0.43	0.35	0.36	0.31	0.30	0.45	0.42	0.25	0.20	0.13	0.01	0.05	0.08	0.18	0.08	0.72	0.63	0.67	0.76	0.71	0.78	0.65												
23b	0.34	0.26	0.36	0.18	0.03	0.10	0.12	0.08	0.12	0.05	0.15	0.10	0.03	0.00	0.05	0.00	0.00	0.35	0.06	0.03	0.00	0.23	0.12	0.03	0.48	0.45	0.29	0.47	0.45	0.35	0.51	0.47	0.41	0.24	0.25	0.26	0.25	0.35	0.29	0.19	0.15	0.06	0.00	0.02	0.06	0.12	0.06	0.74	0.60	0.64	0.66	0.65	0.67	0.70	0.79											
24	0.27	0.23	0.33	0.13	0.11	0.07	0.12	0.07	0.10	0.04	0.09	0.12	0.03	0.00	0.07	0.01	0.00	0.23	0.09	0.02	0.00	0.21	0.07	0.03	0.42	0.44	0.23	0.45	0.52	0.44	0.45	0.46	0.41	0.34	0.39	0.24	0.28	0.36	0.42	0.15	0.18	0.15	0.03	0.11	0.21	0.23	0.31	0.53	0.44	0.52	0.68	0.52	0.57	0.38	0.60	0.53										
25	0.23	0.18	0.29	0.16	0.13	0.07	0.15	0.10	0.09	0.05	0.12	0.12	0.03	0.03	0.08	0.02	0.00	0.23	0.13	0.03	0.00	0.20	0.06	0.01	0.41	0.42	0.18	0.35	0.52	0.46	0.44	0.42	0.39	0.38	0.37	0.27	0.22	0.31	0.49	0.17	0.17	0.16	0.04	0.13	0.22	0.26	0.25	0.43	0.41	0.42	0.65	0.47	0.53	0.29	0.53	0.40	0.71									
26a	0.13	0.10	0.17	0.14	0.09	0.03	0.10	0.05	0.11	0.04	0.10	0.09	0.04	0.00	0.07	0.00	0.00	0.13	0.07	0.02	0.00	0.13	0.07	0.02	0.29	0.28	0.17	0.35	0.35	0.41	0.36	0.37	0.34	0.34	0.37	0.25	0.26	0.35	0.35	0.22	0.15	0.10	0.05	0.10	0.19	0.29	0.33	0.35	0.32	0.37	0.49	0.40	0.42	0.27	0.45	0.40	0.67	0.61								
26b	0.23	0.19	0.28	0.11	0.10	0.06	0.10	0.06	0.11	0.05	0.08	0.09	0.01	0.00	0.06	0.01	0.00	0.23	0.06	0.03	0.00	0.17	0.06	0.01	0.42	0.42	0.22	0.44	0.48	0.45	0.40	0.45	0.40	0.34	0.38	0.27	0.27	0.35	0.41	0.19	0.17	0.13	0.04	0.07	0.19	0.28	0.25	0.49	0.43	0.50	0.67	0.51	0.55	0.33	0.56	0.49	0.79	0.70	0.72							
27	0.16	0.14	0.18	0.10	0.02	0.05	0.09	0.05	0.08	0.02	0.08	0.08	0.00	0.00	0.02	0.00	0.00	0.15	0.02	0.00	0.00	0.12	0.04	0.00	0.31	0.31	0.19	0.33	0.34	0.28	0.27	0.27	0.23	0.16	0.24	0.16	0.17	0.25	0.23	0.11	0.09	0.07	0.00	0.00	0.08	0.22	0.22	0.38	0.33	0.30	0.40	0.40	0.34	0.29	0.37	0.36	0.53	0.44	0.61	0.56						
28	0.27	0.20	0.34	0.15	0.07	0.08	0.09	0.09	0.12	0.04	0.11	0.12	0.02	0.01	0.09	0.02	0.01	0.27	0.08	0.03	0.00	0.23	0.09	0.02	0.52	0.52	0.30	0.57	0.60	0.53	0.53	0.53	0.46	0.34	0.43	0.30	0.31	0.41	0.43	0.17	0.15	0.13	0.02	0.07	0.14	0.20	0.17	0.66	0.65	0.67	0.80	0.63	0.70	0.50	0.75	0.69	0.74	0.64	0.55	0.70	0.43					
29a	0.08	0.05	0.13	0.05	0.09	0.02	0.04	0.02	0.09	0.02	0.04	0.04	0.04	0.00	0.06	0.02	0.00	0.08	0.04	0.02	0.00	0.11	0.03	0.02	0.18	0.20	0.11	0.21	0.23	0.28	0.25	0.28	0.27	0.27	0.27	0.17	0.17	0.25	0.34	0.16	0.16	0.10	0.02	0.18	0.30	0.34	0.39	0.21	0.17	0.21	0.36	0.27	0.27	0.15	0.28	0.22	0.59	0.51	0.65	0.59	0.48	0.42				
29b	0.11	0.05	0.16	0.03	0.10	0.04	0.06	0.04	0.10	0.04	0.06	0.05	0.02	0.00	0.05	0.02	0.00	0.07	0.04	0.02	0.00	0.11	0.03	0.02	0.20	0.19	0.07	0.23	0.26	0.27	0.25	0.29	0.30	0.26	0.23	0.18	0.19	0.22	0.31	0.11	0.15	0.14	0.04	0.12	0.24	0.25	0.33	0.25	0.21	0.25	0.42	0.26	0.29	0.18	0.32	0.28	0.62	0.55	0.70	0.63	0.52	0.46	0.72			
30a	0.02	0.02	0.05	0.03	0.11	0.03	0.00	0.00	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.07	0.09	0.08	0.12	0.13	0.21	0.10	0.15	0.19	0.16	0.16	0.08	0.08	0.11	0.23	0.07	0.04	0.07	0.04	0.29	0.26	0.17	0.29	0.08	0.10	0.09	0.17	0.10	0.16	0.11	0.10	0.09	0.37	0.34	0.39	0.35	0.29	0.26	0.55	0.39		
30b	0.05	0.05	0.13	0.04	0.12	0.05	0.07	0.00	0.05	0.05	0.04	0.02	0.05	0.00	0.05	0.00	0.00	0.04	0.02	0.02	0.00	0.08	0.02	0.03	0.17	0.20	0.11	0.19	0.23	0.29	0.25	0.26	0.25	0.25	0.25	0.18	0.13	0.22	0.35	0.14	0.14	0.07	0.05	0.16	0.34	0.25	0.34	0.16	0.14	0.17	0.33	0.24	0.26	0.13	0.22	0.19	0.52	0.59	0.54	0.52	0.32	0.37	0.64	0.56	0.51	
30c	0.07	0.07	0.09	0.13	0.07	0.10	0.12	0.04	0.06	0.04	0.03	0.06	0.04	0.00	0.02	0.00	0.00	0.07	0.07	0.03	0.00	0.06	0.05	0.00	0.17	0.16	0.13	0.15	0.14	0.19	0.14	0.20	0.27	0.20	0.18	0.11	0.14	0.22	0.27	0.09	0.18	0.07	0.04	0.16	0.34	0.17	0.27	0.15	0.12	0.16	0.24	0.17	0.22	0.13	0.21	0.16	0.37	0.35	0.39	0.37	0.31	0.28	0.49	0.38	0.41	0.49

Table 2: Native Species Sorenson's Similarity

	A1	A2	A3	B1	C1	C2	C3	D1	D2	D3	E1	E2	E3	E4	F1	F2	F3	G1	G2	G3	G4	H1	H2	H3	1a	1b	2	3a	3b	3c	4	5	6	7	8	9	10a	10b	11	12	13	14	15	16	17	18	19	20a	20b	20c	21a	21b	21c	22	23a	23b	24	25	26a	26b	27	28	29a	29b	30a	30b
A2	0.64																																																																		
A3	0.67	0.50																																																																	
B1	0.38	0.33	0.36																																																																
C1	0.13	0.19	0.09	0.16																																																															
C2	0.29	0.30	0.25	0.39	0.31																																																														
C3	0.23	0.22	0.16	0.24	0.21	0.27																																																													
D1	0.20	0.20	0.20	0.41	0.25	0.31	0.23																																																												
D2	0.26	0.21	0.29	0.33	0.17	0.26	0.39	0.30																																																											
D3	0.08	0.11	0.08	0.10	0.09	0.20	0.30	0.21	0.25																																																										
E1	0.41	0.39	0.36	0.64	0.11	0.32	0.21	0.38	0.38	0.25																																																									
E2	0.40	0.36	0.34	0.66	0.26	0.39	0.20	0.41	0.40	0.14	0.64																																																								
E3	0.05	0.04	0.09	0.10	0.00	0.14	0.13	0.08	0.19	0.33	0.21	0.15																																																							
E4	0.03	0.00	0.04	0.11	0.00	0.08	0.21	0.09	0.17	0.29	0.17	0.05	0.42																																																						
F1	0.13	0.13	0.20	0.24	0.04	0.13	0.18	0.20	0.48	0.21	0.33	0.24	0.21	0.23																																																					
F2	0.05	0.04	0.07	0.05	0.00	0.07	0.19	0.08	0.26	0.17	0.11	0.05	0.27	0.21	0.36																																																				
F3	0.03	0.04	0.04	0.11	0.00	0.17	0.07	0.09	0.14	0.20	0.12	0.11	0.33	0.40	0.15	0.33																																																			
G1	0.60	0.54	0.60	0.48	0.13	0.31	0.30	0.27	0.41	0.15	0.51	0.46	0.10	0.11	0.25	0.08	0.05																																																		
G2	0.18	0.14	0.14	0.34	0.29	0.14	0.19	0.37	0.13	0.16	0.31	0.24	0.26	0.40	0.11	0.09	0.11	0.18																																																	
G3	0.05	0.07	0.16	0.22	0.00	0.18	0.27	0.19	0.41	0.20	0.36	0.30	0.29	0.24	0.42	0.29	0.25	0.24	0.07																																																
G4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.17	0.25	0.00	0.00	0.11																																															
H1	0.42	0.31	0.40	0.37	0.09	0.19	0.24	0.19	0.48	0.22	0.44	0.41	0.13	0.12	0.29	0.09	0.09	0.48	0.18	0.27	0.00																																														
H2	0.17	0.21	0.20	0.28	0.04	0.20	0.23	0.21	0.47	0.22	0.35	0.28	0.19	0.24	0.41	0.11	0.12	0.37	0.15	0.41	0.05	0.38																																													
H3	0.05	0.07	0.08	0.14	0.00	0.19	0.24	0.07	0.31	0.22	0.24	0.19	0.48	0.55	0.34	0.24	0.38	0.15	0.15	0.45	0.13	0.22	0.43																																												
1a	0.20	0.23	0.19	0.19	0.19	0.12	0.08	0.13	0.07	0.04	0.13	0.23	0.00	0.00	0.05	0.00	0.00	0.22	0.09	0.04	0.00	0.13	0.05	0.00																																											
1b	0.12	0.13	0.13	0.13	0.07	0.17	0.05	0.00	0.00	0.00	0.09	0.09	0.00	0.00	0.03	0.00	0.00	0.14	0.00	0.00	0.00	0.02	0.03	0.00	0.24																																										
2	0.03	0.04	0.02	0.06	0.00	0.00	0.08	0.10	0.07	0.11	0.13	0.06	0.00	0.00	0.08	0.00	0.00	0.06	0.00	0.09	0.00	0.07	0.13	0.21	0.00	0.00																																									
3a	0.11	0.03	0.13	0.10	0.00	0.09	0.04	0.05	0.05	0.05	0.04	0.07	0.00	0.00	0.05	0.00	0.00	0.08	0.00	0.04	0.00	0.04	0.08	0.05	0.13	0.09	0.00																																								
3b	0.23	0.24	0.23	0.21	0.14	0.18	0.17	0.13	0.20	0.10	0.16	0.18	0.03	0.00	0.09	0.00	0.00	0.24	0.07	0.06	0.00	0.14	0.13	0.03	0.20	0.24	0.04	0.26																																							
3c	0.04	0.06	0.08	0.04	0.00	0.05	0.04	0.05	0.05	0.05	0.04	0.04	0.11	0.00	0.06	0.00	0.00	0.09	0.00	0.05	0.00	0.06	0.06	0.10	0.13	0.13	0.06	0.21	0.18																																						
4	0.17	0.14	0.16	0.28	0.11	0.22	0.04	0.32	0.20	0.10	0.32	0.21	0.05	0.05	0.16	0.05	0.06	0.23	0.10	0.17	0.00	0.22	0.20	0.09	0.29	0.17	0.06	0.17	0.15	0.18																																					
5	0.11	0.06	0.13	0.04	0.07	0.05	0.05	0.06	0.03	0.00	0.04	0.04	0.00	0.07	0.06	0.06	0.07	0.14	0.00	0.05	0.09	0.06	0.10	0.11	0.11	0.10	0.00	0.28	0.17	0.17	0.16																																				
6	0.23	0.17	0.23	0.17	0.00	0.11	0.17	0.18	0.13	0.08	0.21	0.12	0.08	0.13	0.07	0.04	0.09	0.24	0.12	0.07	0.00	0.14	0.12	0.11	0.03	0.03	0.00	0.17	0.07	0.12	0.20	0.13																																			
7	0.00	0.00	0.06	0.00	0.00	0.00	0.05	0.00	0.11	0.13	0.09	0.00	0.13	0.15	0.16	0.20	0.00	0.05	0.06	0.11	0.00	0.06	0.10	0.18	0.04	0.05	0.00	0.08	0.00	0.13	0.08	0.15	0.10																																		
8	0.02	0.03	0.07	0.07	0.00	0.00	0.00	0.00	0.10	0.00	0.04	0.03	0.00	0.00	0.05	0.10	0.05	0.04	0.00	0.04	0.06	0.07	0.06	0.05	0.16	0.04	0.00	0.20	0.13	0.11	0.20	0.12	0.11	0.24																																	
9	0.08	0.05	0.17	0.18	0.04	0.11	0.14	0.04	0.07	0.00	0.13	0.09	0.04	0.13	0.17	0.08	0.05	0.15	0.08	0.11	0.00	0.09	0.18	0.08	0.14	0.11	0.00	0.24	0.09	0.09	0.18	0.21	0.21	0.21	0.30																																
10a	0.06	0.07	0.11	0.09	0.04	0.04	0.03	0.11	0.18	0.12	0.12	0.15	0.08	0.00	0.24	0.12	0.04	0.11	0.04	0.15	0.05	0.12	0.23	0.15	0.20	0.11	0.14	0.15	0.23	0.18	0.33	0.07	0.15	0.21	0.29	0.21																															
10b	0.12	0.15	0.13	0.15	0.00	0.11	0.11	0.08	0.07	0.12	0.16	0.12	0.08	0.04	0.07	0.00	0.05	0.15	0.04	0.07	0.00	0.12	0.18	0.08	0.17	0.18	0.10	0.18	0.19	0.13	0.12	0.07	0.16	0.11	0.15	0.24	0.24																														
11	0.13	0.15	0.19	0.23	0.19	0.10	0.14	0.21	0.19	0.17	0.24	0.27	0.12	0.06	0.24	0.06	0.00	0.20	0.17	0.15	0.00	0.20	0.22	0.11	0.21	0.10	0.14	0.15	0.17	0.12	0.19	0.14	0.13	0.38	0.23	0.20	0.33	0.17																													
12	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.04	0.13	0.07	0.00	0.15	0.20	0.04	0.15	0.00	0.03	0.14	0.11	0.00	0.03	0.05	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00	0.00																												
13	0.02	0.00	0.08	0.04	0.00	0.05	0.00	0.05	0.16	0.11	0.08	0.04	0.06	0.00	0.17	0.17	0.06	0.09	0.00	0.15	0.08	0.10	0.15	0.11	0.11	0.05	0.07	0.23	0.08	0.04	0.19	0.22	0.13	0.14	0.19	0.20	0.23	0.13	0.09	0.00																											
14	0.06	0.04	0.06	0.18	0.00	0.19	0.08	0.21	0.07	0.00	0.19	0.18	0.13	0.17	0.08	0.13	0.36	0.06	0.13	0.19	0.00	0.07	0.04	0.11	0.00	0.00	0.00	0.00	0.04	0.00	0.06	0.08	0.09	0.00	0.00	0.05	0.00	0.05	0.00	0.00	0.00																										
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																									
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																								
17	0.00	0.00	0.02	0.00	0.17	0.13	0.11	0.07	0.09	0.21	0.00	0.00	0.08	0.09	0.03	0.08	0.09	0.02	0.00	0.00	0.00	0.02	0.00	0.07	0.00	0.00	0.00	0.00	0.06	0.00	0.05	0.00	0.11	0.06	0.09	0.04	0.08	0.12	0.05	0.00	0.10	0.00	0.00	0.00																							
18	0.02	0.03	0.08	0.04	0.00	0.00	0.11	0.06	0.18	0.20	0.09	0.04	0.07	0.08	0.23	0.36	0.08	0.07	0.07	0.12	0.11	0.11	0.14	0.13	0.04	0.00	0.09	0.09	0.03	0.05	0.04	0.05	0.04	0.17	0.17	0.04	0.15	0.00	0.10	0.11	0.34	0.00	0.00	0.00	0.00																						
19	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																					
20a	0.16	0.16	0.17	0.11	0.04	0.13	0.06	0.00	0.08	0.07	0.05	0.05	0.04	0.00	0.04	0.00	0.00	0.18	0.00	0.03	0.00	0.06	0.09	0.07	0.15	0.19	0.04	0.19	0.25	0.25	0.19	0.09	0.21	0.09	0.13	0.17	0.24	0.17	0.09	0.00	0.11	0.00	0.00	0.00	0.07	0.06	0.00																				
20b	0.13	0.09	0.13	0.14	0.04	0.10	0.06	0.03	0.06	0.00	0.08	0.08	0.00	0.04	0.02	0.00	0.00	0.09	0.04	0.00	0.00	0.11	0.07	0.03	0.21	0.16	0.00	0.25	0.24	0.08	0.25	0.09	0.14	0.06	0.11	0.17	0.12	0.17	0.09	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.16																			
20c	0.11	0.09	0.13	0.08	0.06	0.00	0.05	0.11	0.08	0.00	0.08	0.08	0.00	0.06	0.06	0.00	0.00	0.07	0.11	0.00	0.00	0.06	0.06	0.00	0.18	0.20	0.00	0.15	0.11	0.12	0.15	0.09	0.16	0.19	0.15	0.13	0.07	0.10	0.17	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.09																		
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21b	0.15	0.10	0.10	0.19	0.09	0.19	0.18	0.14	0.06	0.07	0.15	0.09	0.00	0.09	0.07	0.00	0.00	0.15	0.08	0.00	0.00	0.07	0.11	0.00	0.09	0.25	0.11	0.09	0.16	0.00	0.19	0.06	0.15	0.06	0.05	0.16	0.08	0.04	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.17	0.24	0.05	0.23																
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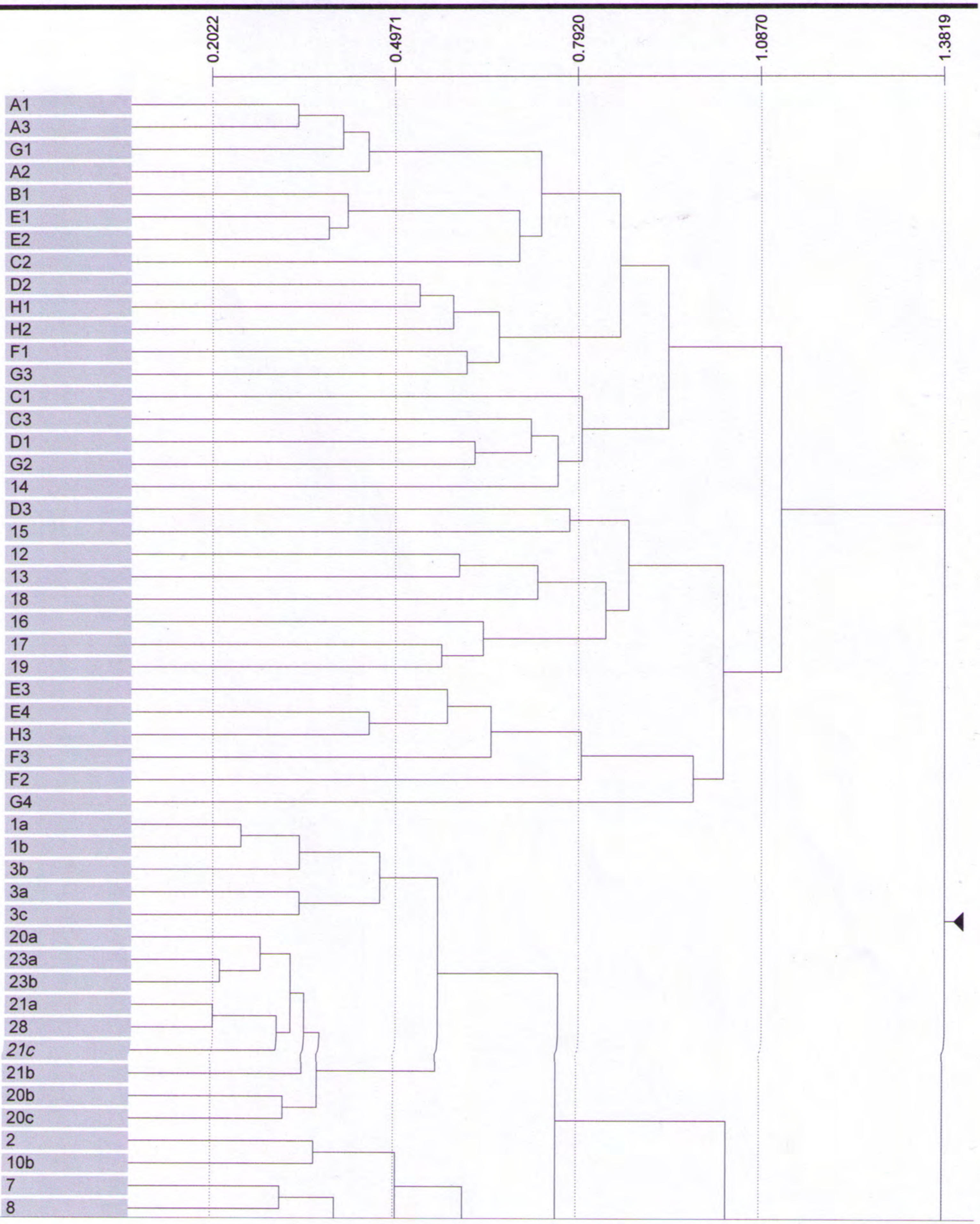

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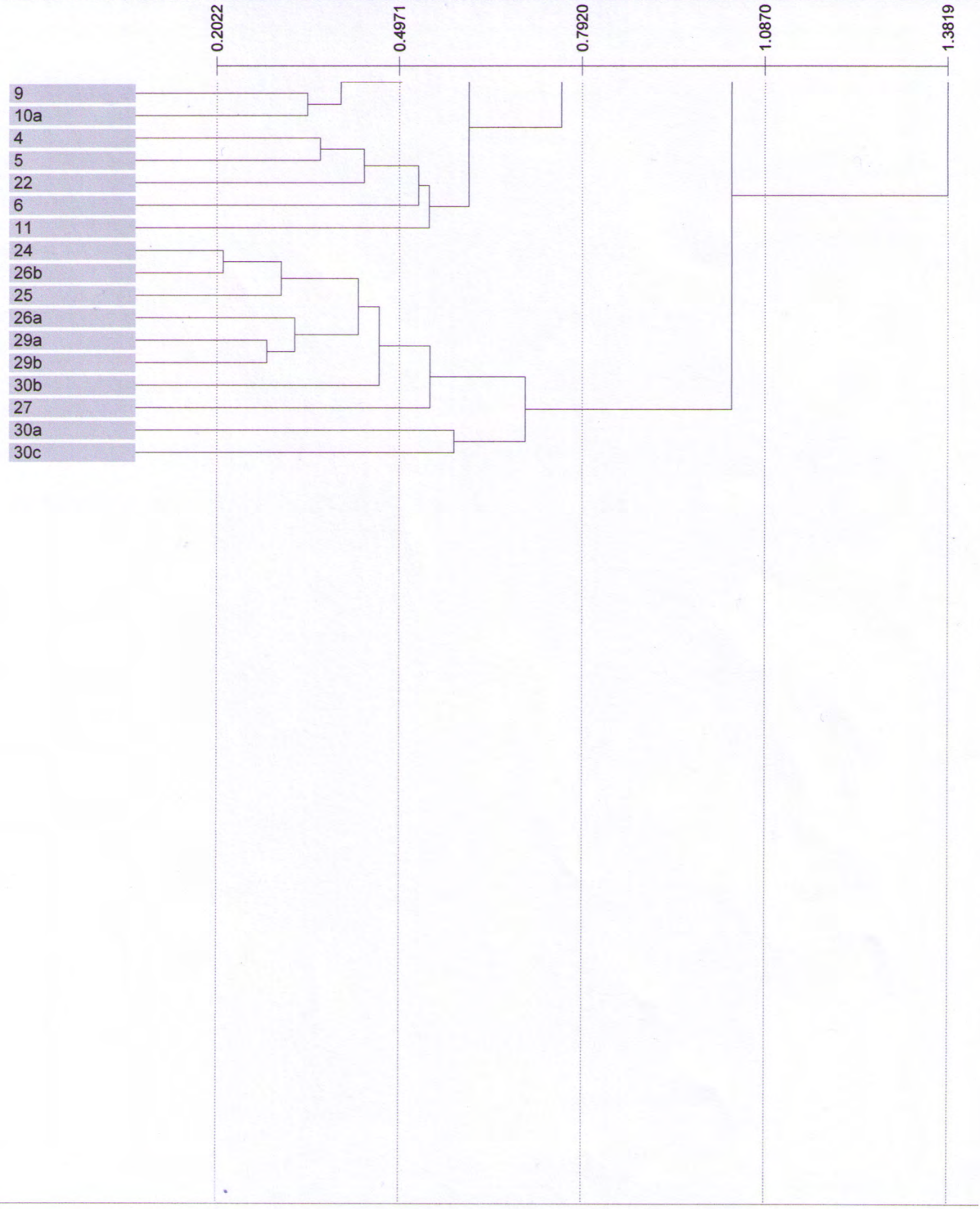

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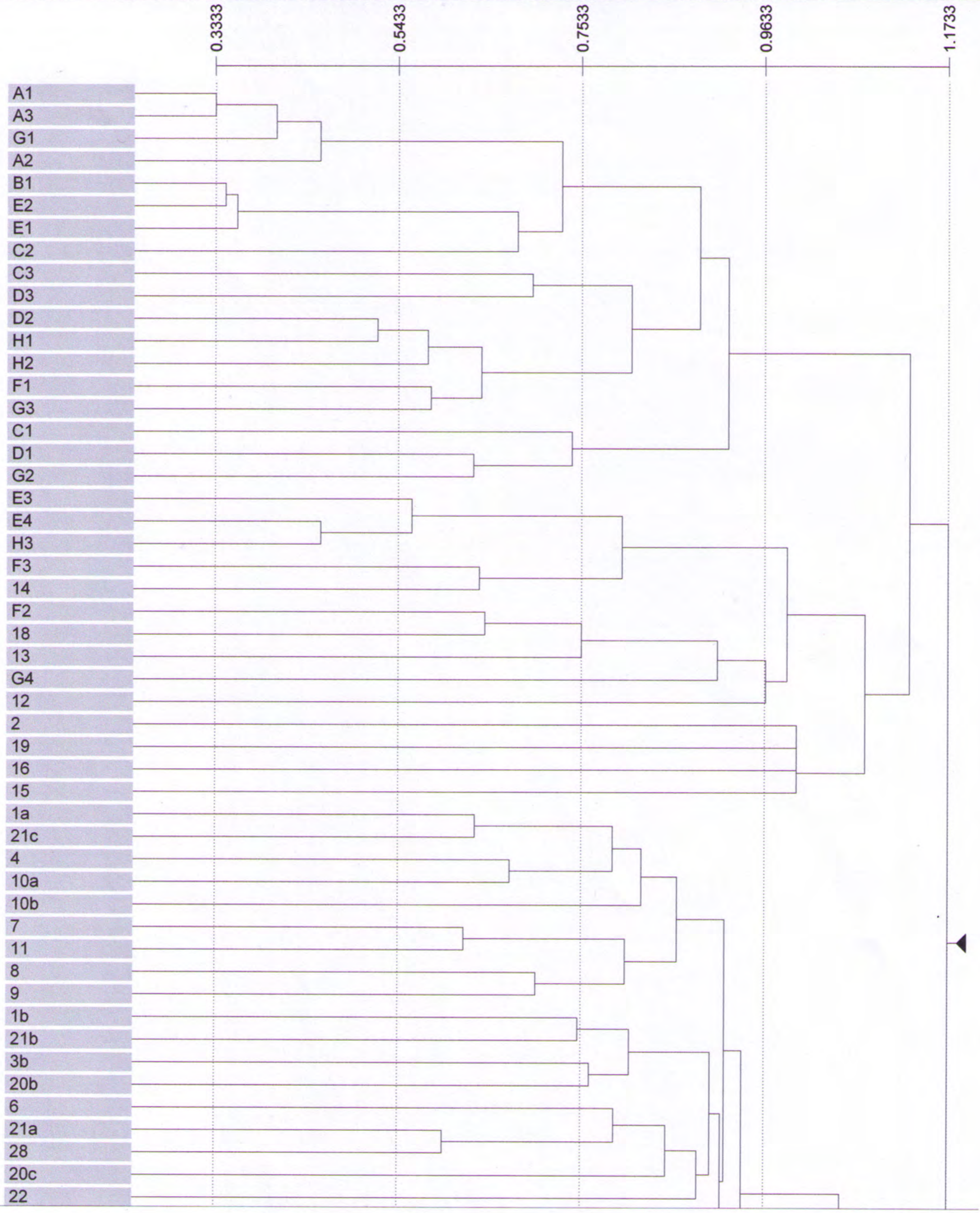

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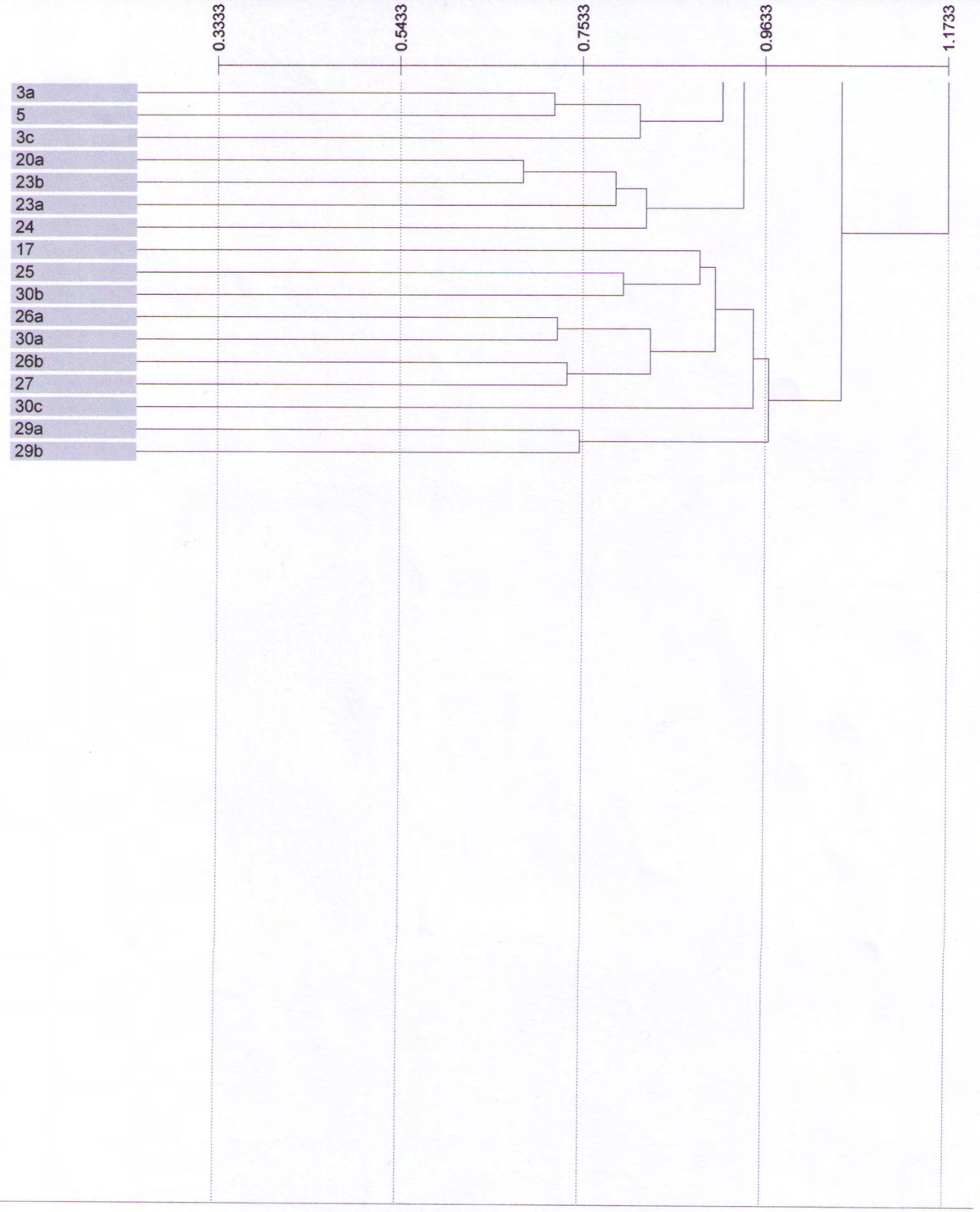
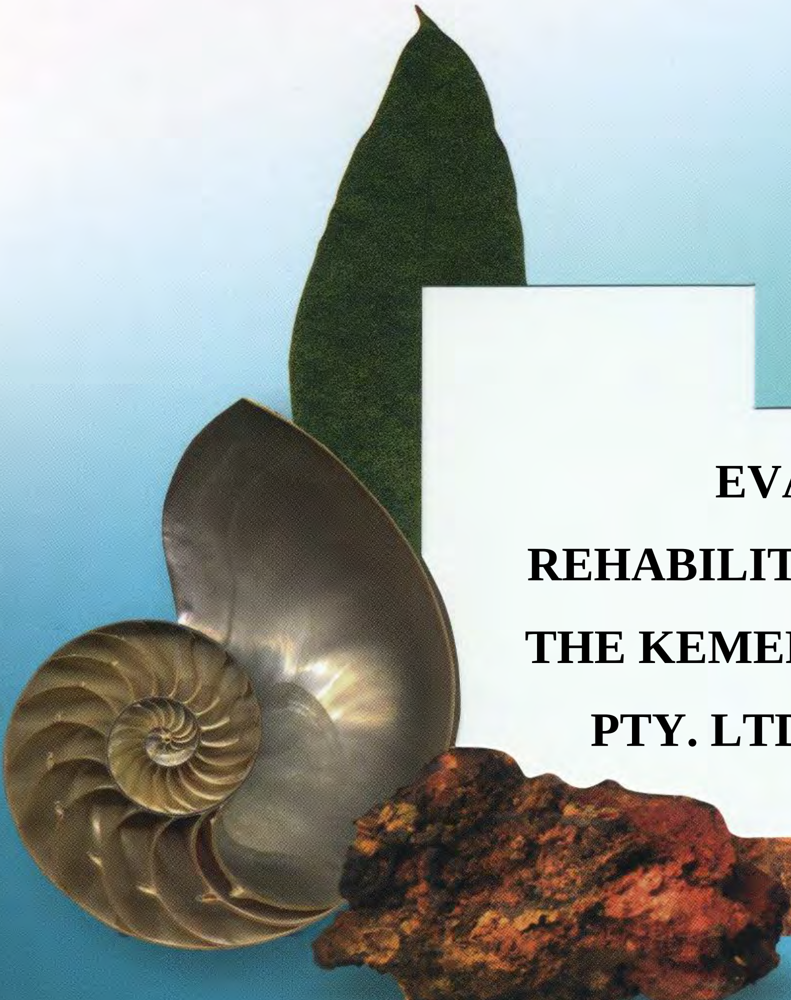


APPENDIX 7:
EVALUATION OF REHABILITATION EFFORTS AT THE KEMERTON SILICA SAND PROJECT AREA
JUNE 2007
CENTRE FOR ECOSYSTEM MANAGEMENT
EDITH COWAN UNIVERSITY

Centre for ecosystem management

EDITH COWAN UNIVERSITY
PERTH WESTERN AUSTRALIA



EVALUATION OF REHABILITATION EFFORTS AT THE KEMERTON SILICA SANDS PTY. LTD. PROJECT AREA

CENTRE FOR ECOSYSTEM MANAGEMENT

CENTRE *for* ECOSYSTEM MANAGEMENT

EDITH COWAN UNIVERSITY

EVALUATION OF REHABILITATION EFFORTS AT THE KEMERTON SILICA SANDS PTY. LTD. PROJECT AREA.

June 2007

By **Dr. Eddie van Etten**
Dr. Clint McCullough
A/Prof. Mark Lund

Centre for Ecosystem Management Report No. 2008-10

Prepared for:

Kemerton Silica Sand Pty Ltd

Dr. Eddie van Etten BSc (Hons), MAppSc, PhD (Vegetation Scientist),

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1 Executive Summary

1. The Kemerton Silica Sand Pty Ltd (KSS) mine is located on a 1,600 ha block of land at the northern end of Kemerton Industrial Park. The company mines silica sands following mechanical removal of topsoil, and then extracts the ore from below the water table by dredging.

2. The Kemerton Industrial Park consists of large areas of remnant or regenerating bushland, with areas of lakes and wetlands, surrounded by cleared farmland. The presence of ecological significant flora, fauna and ecosystems heightens the environmental importance of the area. Lakes with more than 1 000 m^2 of standing water on 1/12/91 are protected by the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992. A number of lakes on the project area are protected under this EPP, which restricts mining, discharge to, filling, and other forms of degrading activities without approval.

3. Currently KSS wishes to ensure the longevity of operations by expanding the area that can be mined and is preparing a Public Environmental Review (PER). Given the ecological value of the area, it is important for KSS to be able to adequately demonstrate an ability and commitment to rehabilitate the area post-mining, however no areas around the dredge ponds, have been completely rehabilitated to date.

4. In 2007, KSS commissioned a desktop study to review available literature for the site and develop a rehabilitation strategy. The study recommended a staged approach to the eventual production of a rehabilitation plan for the site. As part of Stage 2 of it was recommended to study why previous rehabilitation efforts had not been successful. This study aims to answer this question.

5. This study includes a survey and critical assessment of existing rehabilitation efforts around the northern most dredge pond where the bulk of rehabilitation has occurred to date. The objectives of the study were to: assess previous rehabilitation practices; identify key soil and hydrological processes which influence revegetation; and recommend improvements to current rehabilitation practices and techniques to improve existing rehabilitation.

6. Annual rainfall since the commencement of rehabilitation in 2001 has been below long- and short–term averages, with 2006 being one of the lowest on record. Such low rainfall is likely to have been a major influence on revegetation success.

7. Existing permanent monitoring transects (established by Mattiske Consulting 2003, 2004) and new transects (this study) monitored in each area of different rehabilitation practice around the northern dredge pond between 19th to 21st June 2007. In another study (van Etten *et al*. in prep) transects were taken in natural wetlands at the KSS site over the same time period as this study, permitting comparison to local natural wetland vegetation. Data analysis include comparisons between transects and previous monitoring in terms of average plant cover, density and species richness. Species composition was compared between transects and with natural wetland vegetation using ordination and other multivariate statistics in Primer v6 (PRIMER-E Ltd, 2006). Soil profiles, topsoil characteristics and micro-topography were also measured and compared.

8. Six distinct areas of rehabilitation (‘Sectors’) were identified around the dredge pond, each with an unique rehabilitation history. The current condition of the rehabilitation within each sector and recommendations for future remedial treatment (if required) are outlined below:

a. Sector 1, in the north-east corner, has improved slightly due to ripping, weed control, fertiliser and seeding the previous year (although which was most influential is difficult to determine) in terms of plant density, cover and diversity. It is too early to tell whether or not ripping has alleviated postulated soil compaction problems.

b. Sector 2, lowlands on the east side, are considered to be the most successful revegetation on the site with cover and composition similar to some natural wetland communities. Low topographic position and reasonably shallow depth to groundwater are believed to have promoted plant survival and growth. It is recommended to leave this area alone over the next few years.

c. Sector 3 received the same initial revegetation treatment as Sector 2, but remains very poor in terms of plant cover, diversity and density (although very high in weed cover). This is believed to be due to higher elevation, which means greater depth to groundwater. Seeding, weed control and fertiliser treatment in 2006 appear to have had little beneficial effect. Planting and seeding of species more typical of uplands is recommended.

d. Sector 4 which occupies an extensive area on the west bank of the dredge pond has seen reasonable success in terms of plant cover, but species richness is poor and declining over time. Targeted re-seeding in bare patches is recommended.

e. Sectors 5 & 6, north and south slopes respectively, were only ~1 year post-revegetation (using topsoil) at time of assessment. Despite this, early growth and diversity are promising. Areas treated with fresher topsoil (Sector 6) were superior in terms of species diversity.

9. Sectors differed significantly from one another and to natural wetlands in terms of plant species composition, dominance, diversity and structure. Generally, wetlands had higher cover of fringing paperbark (*Melaleuca* species) and lower cover of sedges and rushes than rehabilitation. There were many examples of species found only in rehabilitation or in natural wetlands.

Therefore considerable improvement is possible in rehabilitating around the dredge pond so they more closely resemble analogue wetland vegetation.

10. Soils from the rehabilitation areas were also clearly different to those from natural wetland with substantially lower nutrient concentrations and organic matter in rehab. Topographic profiles of slopes around the dredge pond varied considerably with undercutting by wave action particularly evident on the steeper eastern slopes. Vegetation characteristics and general rehabilitation success appeared to change around 2 m above lake water levels.

11. Rehabilitation guidelines recommended to improve future rehabilitation were outlined in detail and include:

    - Direct or otherwise rapid return of topsoil to site as main revegetation method;
    - Avoid spreading topsoil too thinly or thickly (10–30 cm is best)
    - Dividing slopes to be rehabilitated in three zones: Flooded (within seasonal lake fluctuations), Fringing (within 2 m of lake levels) and Upland (>2 m above lake levels);
    - Topsoil for ‘Fringing’ and ‘Upland’ zones should be sourced from different vegetation (dampland and upland margins respectively), whereas revegetation of ‘Flooded’ zone should focus on planting, sandbanking, woody debris and brushing;
    - Litter, mulch and slow-release fertiliser should be spread on soil surface after topsoil placement;
    - Vegetation goals for each zone in terms of structure, dominance and key species are outlined, together with recommended method for species re-establishment;
    - Weed and herbivore management programs should be improved.
    - Gradual slopes seems to be more stable and easier to revegetate than steeper slopes.

17. A series of research projects to address gaps in our knowledge and key factors likely to influence revegetation success are recommended. Generally an adaptive management approach is recommended to trial new revegetation approaches and to improve revegetation success over time.

Frontispiece

Figure 1. Dr. Eddie van Etten developing a voucher collection in a rehabilitation trial Area of Lake 1.

This document should be referenced as follows.

van Etten, E. J. B., McCullough, C. D. & Lund, M. A. (2008). *Evaluation of rehabilitation efforts at the Kemerton Silica Sands Pty. Ltd. project area, June 2007*. Report number 2008-10 Centre for Ecosystem Management, Edith Cowan University, Perth, Australia. 88pp. Unpublished commercial-in-confidence report to Kemerton Silica Sand Pty Ltd.

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3 Background

The Kemerton Silica Sand Pty Ltd (KSS) project area occupies some 1,600 ha of land at the northern end of Kemerton Industrial Park, 20 km north of Bunbury. The KSS Project Area is located on the Swan Coastal Plain, primarily on gently undulating Bassendean Sands, with vegetation comprising eucalypt-banksia woodland on uplands and wetlands on lower parts of the landscape.

Feldspathic silica sands are extracted from below the water table using dredge ponds. The resource generally lies beneath <1 m of topsoil and 4 to 7 m of overburden (which generally contains a band of coffee rock at the inter-phase between high and low groundwater levels). The overburden is removed by earth moving equipment. The resource is then extracted from a 30 m deep superficial aquifer using a surface floating dredge to a maximum permitted depth of 15 m. Once extraction is complete, the dredge pond is approximately 10 m deep. As the dredge pond is essentially an expression of the groundwater, the results are permanently inundated lakes. Fines, overburden and topsoil are available for sculpting and landscaping of the dredge ponds and surrounds.

The shallow depth to groundwater in the inter-dunal depressions results in numerous areas of palusplain, damplands, sumplands and lakes (as per the definitions of Semeniuk, 1987) within the project area. These become inundated from rainfall or the rising groundwater table, typically from July to November. Some of the wetlands are perched above the water table and so are dependant on rainfall for inundation. Six EPP wetlands (one crosses the boundary) located across 200 ha of the project area have now been vested with the Department of Environment and Conservation (DEC) as the Kemerton (formerly Gwalia) Nature Reserve. One and part of another EPP lake remain in the project area, but are away from the current operations. One EPP lake has been lost in previous KSS mining activities. The KSS project area contains examples of remnant and regrowth native vegetation following selective logging and stocking in the past (GHD, 2005). Some of these vegetation communities have been identified as threatened. A threatened ecological community (“Shrublands and

Woodlands on Muchea Limestone" (English & Blyth 2000)) listed as endangered by the DEC and endangered under the Commonwealth Environment and Biodiversity Conservation Act 1999 has been reported as occurring on the eastern side of the existing dredge ponds (Environmental Protection Authority 2005). Ownership of this land (13 ha in total) was transferred from KSS to the conservation estate in 2006 to help protect this Threatened Ecological Community (TEC).

Rehabilitation efforts to date have centred around the slopes of a large dredge pond situated north of current mining operations (hereafter called 'North Lake' – see Figure 2) which was extracted in the late 1990's, with rehabilitation commencing on the eastern side in 2001. Revegetation has been patchy in cover and, overall, rehabilitation has had mixed success (Mattiske & Havel 1998; Mattiske Consulting Pty Ltd 2004, 2005; McCullough et al. 2007). State government has yet to decide what completion criteria for most mining operations should be, therefore they can provide little guidance for companies in this regard. There are currently many unknowns in rehabilitation (i.e., what can achieved, the cost and the success), therefore companies have little choice but to be proactive and commence rehabilitation as soon as possible, making sure that they develop proven rehabilitation strategies for their site (McCullough *et al.*, 2007). Nevertheless, with the current public perception of mining, current KSS management is also now more focused on triple-bottom-line sustainability of the operation, with a view to maintaining and improving stakeholder perception of the operation. Consequently, autumn 2006 saw more rehabilitation and rehabilitation planning than in the preceding 10 years of operation. Current mine management is also now more committed to improving post-mining revegetation through research and learning from previous attempts at rehabilitation, as well as further investigating the possible reasons for lack of plant growth in some areas.

In late 2006, Kemerton Silica Sand Pty Ltd contracted Associate Professor Mark Lund, and Drs Clint McCullough and Eddie van Etten of Edith Cowan University's Centre for Ecosystem Management as Consulting Ecologists. These researchers visited the site on 31st August 2006 and 24th January 2007. The primary purpose of this first contract was to start the rehabilitation planning process, by identifying realistic and achievable outcomes of any rehabilitation plan. A focus of this work was on nature of final pit lake environs formed from dredging of silica sand below the water table and how best to merge these with the natural pristine wetlands of the region. The consultancy proposed development of an effective rehabilitation plan along the following stages:

Stage 1: To determine realistic goals for the rehabilitation of the site.

Stage 2: Implementation of enhanced monitoring program.

Stage 3: Studies commenced to fill in identified knowledge gaps.

Stage 4: Development of the rehabilitation plan.

Stage 1 was completed in 2007 with a report entitled "Synthesis of Existing Data & Knowledge Gaps for the Rehabilitation of Kemerton Silica Sand Mine Dredge Ponds" published in February 2007 (McCullough *et al.*, 2007). Stage 1 comprised:

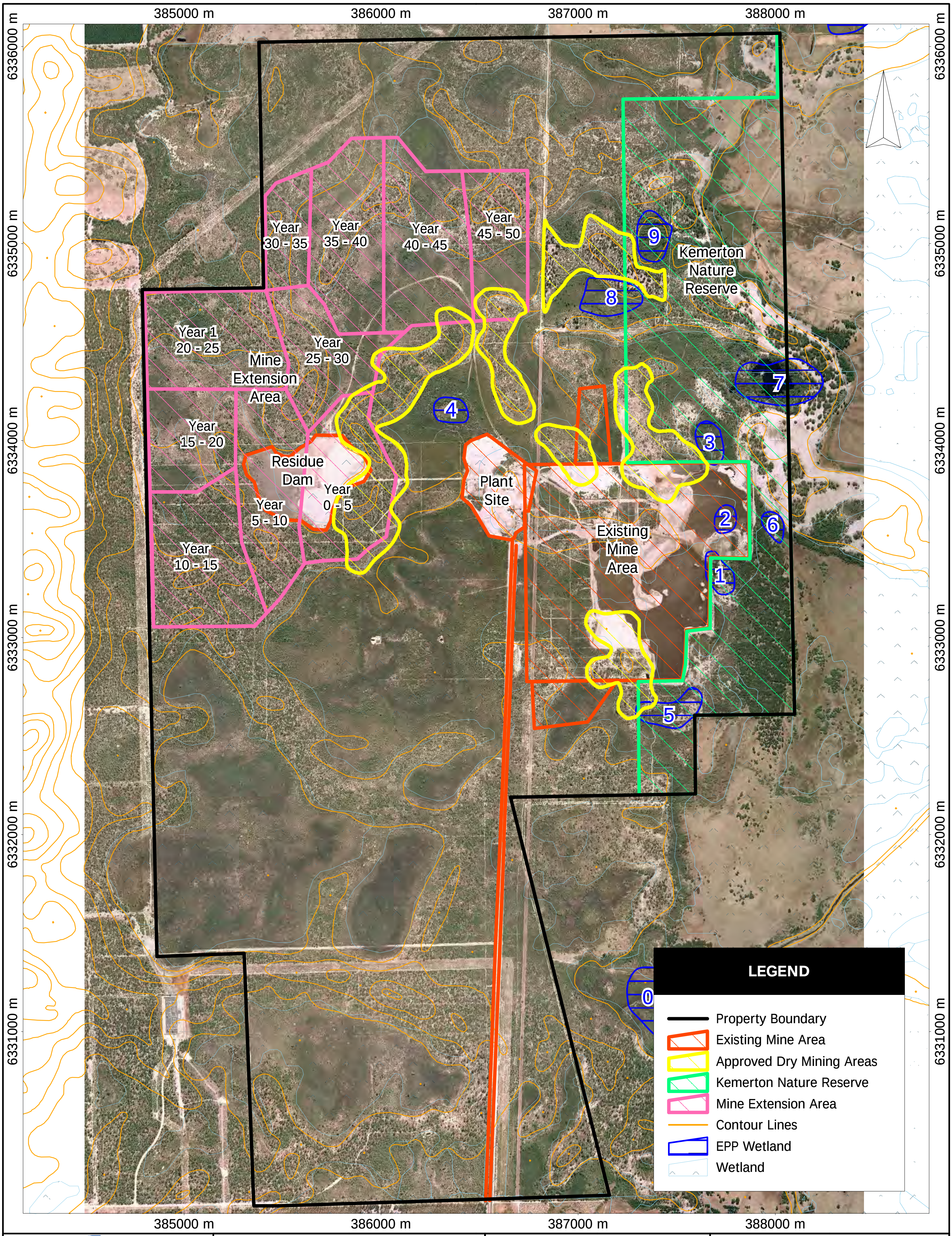
- a review, collation and synthesis of existing data required to establish clearly what is known and what knowledge gaps remain,
- a series of realistic goals for the rehabilitation of the site from consultation with key stakeholders across a range of goals and with an assessment of their ecological feasibility,
- a recommended series of projects/consultancies to fill current knowledge gaps,
- a recommended realistic and cost effective monitoring program that can compliment and enhance existing data collection.

This current report contributes to Stage 2 – the implementation of enhanced monitoring. Specifically it assesses the state of vegetation rehabilitation efforts to date around the slopes of North Lake, and provides recommendations for improvement in rehabilitation where necessary, both of existing rehabilitation and for future attempts. It is based on field visit to the site by the authors on June 18th - 20th 2007. Other projects contributing to Stage 2 include water quality monitoring and aquatic macro-invertebrate monitoring.

A supplementary report commissioned by KSS to address Stage 3 research examines the patterns and processes of the natural wetland systems of the project Area. This 'Natural Wetland Characterisation Project' report will be submitted separately (McCullough, van Etten *et al* in prep.).

3.1 Objectives

- To assess current rehabilitation practices in terms of species diversity and vegetation cover as indicators of rehabilitation success;
- To examine key soil and hydrological parameters as drivers of rehabilitation success;
- To recommend improvements in rehabilitation practices, particularly in regard to improved topsoil protocols and specific methods for returning key plant species absent from existing revegetation.



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Scale: 1:24000
Original Size: A4
Air Photo: 2006
Datum: Australian Geocentric 1994 (GDA94
0 500 m

Kemerton
Silica Sand Pty Ltd

Site Layout

Figure 1

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4 Study Sites and Methodology

4.1 Location & Study Area

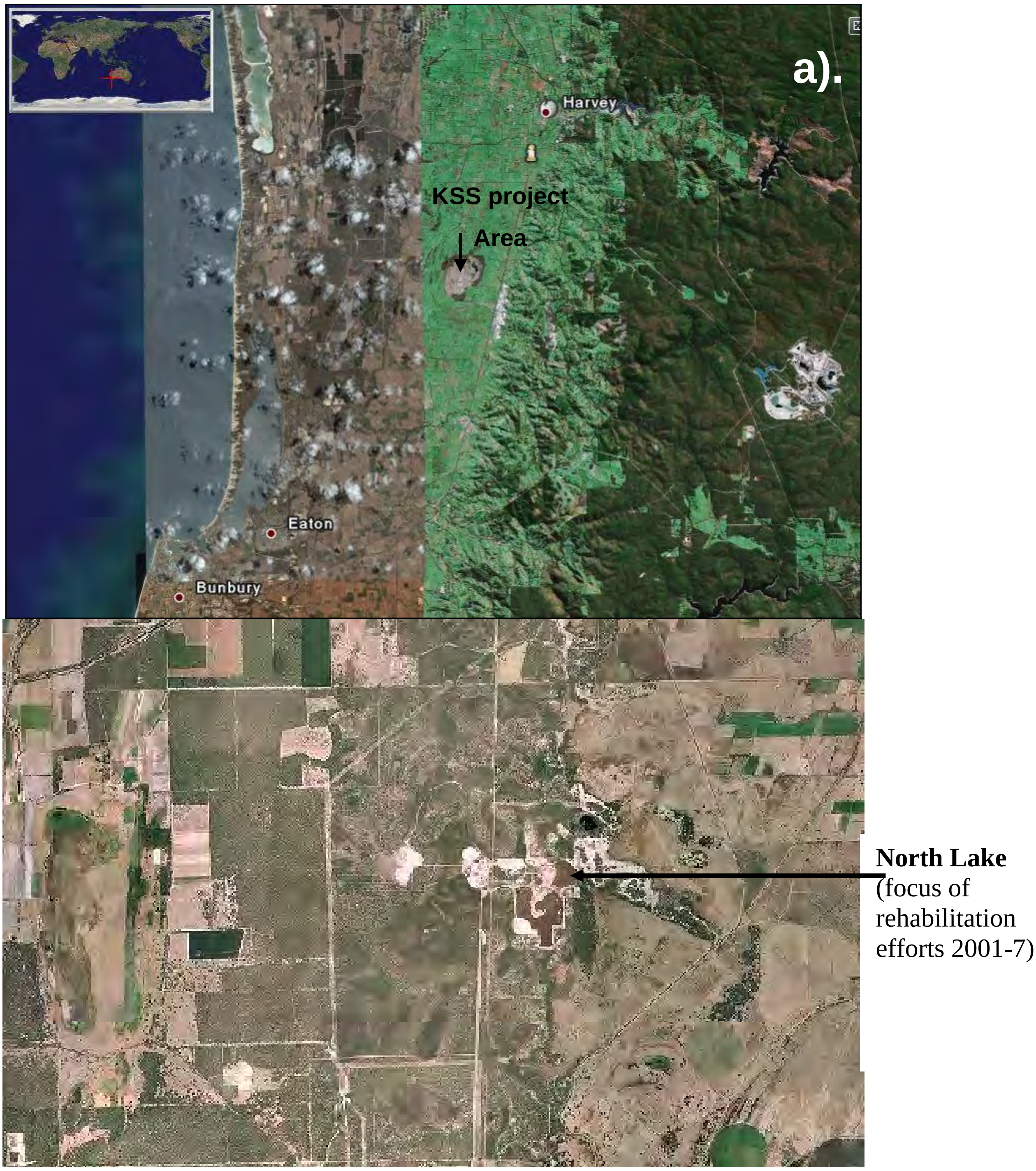


Figure 2. a). Location of KSS project Area in South West Australia, and b). aerial photograph of Kemerton Area showing Kemerton and dredge ponds as at 2007. North Lake, is shown with arrow.

The study has focussed on the main rehabilitation area around the northern most dredge pond of the Kemerton active mining area, hereafter referred to as "North Lake" (Figure 2). This area was mined and the pond created in the late 1990's. Rehabilitation of the surrounding slopes commenced in 2001 and is continuing. Active mining is currently occurring in dredge ponds to the south but little rehabilitation has occurred on the surrounding slopes, although rehabilitation occurred at the southern edge of the dredge ponds in 2007.

4.2 Rehabilitation History & Sectors

The slopes of North Lake have been progressively rehabilitated between 2001 and 2007. We have identified six distinct rehabilitation areas or 'sectors' delineated by different histories of soil treatments and revegetation techniques, as well as fundamental environmental differences. These are described in Table 1 and are mapped in Figure 3.

Table 1. Summary of rehabilitation history and monitoring around North Lake.

Sector	Monitoring Transect	Area (ha)	Treatment(s)	Monitoring History
1 (north-east)	Mattiske #1	~2	**Feb 2001**: contoured and spread with topsoil (and understorey debris) **Autumn/winter 2002**: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags **Autumn 2006:** ripped, hand-seeded, brushed, herbicide and fertilised/limed	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM (this report)
2 (east)	Mattiske #4	~2	**Feb 2001**: contoured and spread with topsoil (and understorey debris) **Autumn/winter 2002**: minor ripping on contour, herbicide treatment and planting of seedlings (in gaps only); fertilised and covered with tree bags	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM (this report)
3 (south-east)	Mattiske #5	~1	**Feb 2001**: contoured and spread with topsoil (and understorey debris) **Autumn/winter 2002**: major ripping on contour, herbicide treatment, planting of seedlings' fertilised and covered with tree	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM (this

Sector	Monitoring Transect	Area (ha)	Treatment(s)	Monitoring History
			bags **Autumn 2006:** hand-seeded and fertilised/limed	report)
4 (west)	Mattiske #7	~4	**April 2003**: contoured and spread with 20cm topsoil (and understorey debris)	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM (this report)
5 (north)	New Transect (#10)	~2	**Autumn 2006**: contoured and spread with 10 year old, stored topsoil (with some understorey debris)	**June 2007**: CEM (this report)
6 (south)	New Transect (#9)	~2	**Autumn 2006:** contoured and spread with direct fresh topsoil return (understorey debris). Most topsoil from dampland Area. Upland soil placed on higher ground	**June 2007**: CEM (this report)

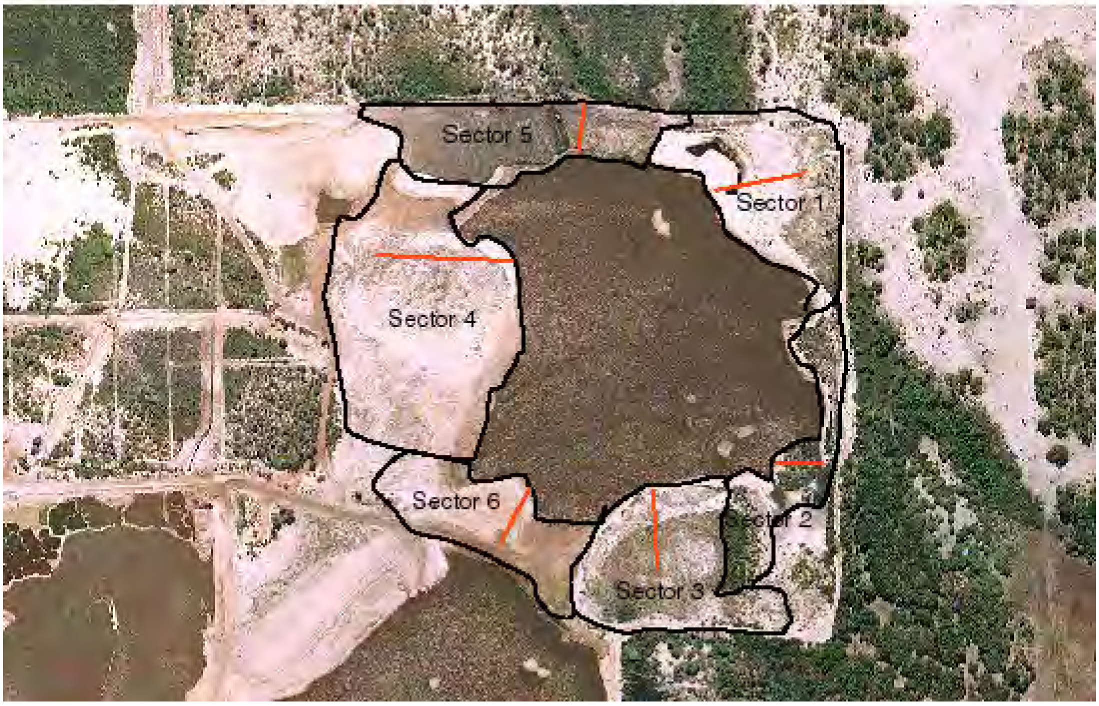


Figure 3. Aerial photograph from 2006 showing Sectors around North Lake. Topsoil has been recently applied to Sector 5 in the photo. Position of monitoring transects are shown by red lines.

4.3 Climate

Average rainfall in the Kemerton Area is around 900 mm per year (based on interpolation of Bureau of Meteorology records from Bunbury, some 20 km to the south, and Wokalup, some 10 km to the north-east). Rainfall is distinctly mediterranean in distribution, with the vast majority of precipitation falling in winter and spring (Figure 4). Summers are typically very dry and warm to hot, whereas winters are cool and wet (Figure 5). Frosts are rare, with an average of 1 day per year with minimum ground temperatures below -1^{o}C recorded at Wokalup, although this seems to be increasing with dry winters.

The rehabilitation period 2001–2006 was one of the driest periods on record (Figure 6). With the exception of 2005, each year was not only substantially below the long term average, but also less than the recent (1996–2006) average. The year 2006 was very close to the lowest annual rainfall on record.

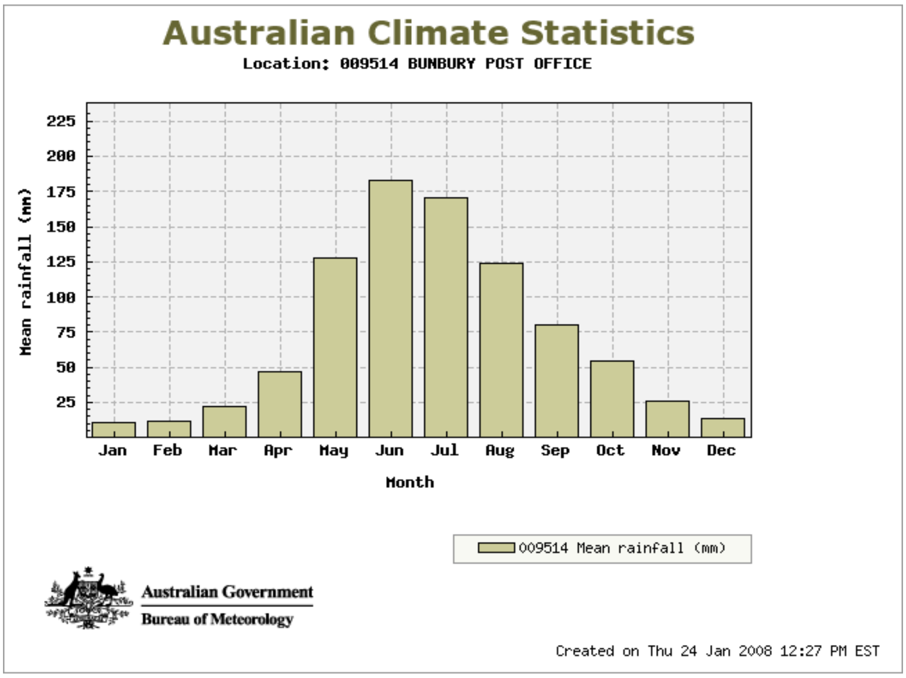


Figure 4. Average monthly rainfall for Bunbury P.O. (1880-1985) (Source: Bureau of Meteorology 2008).

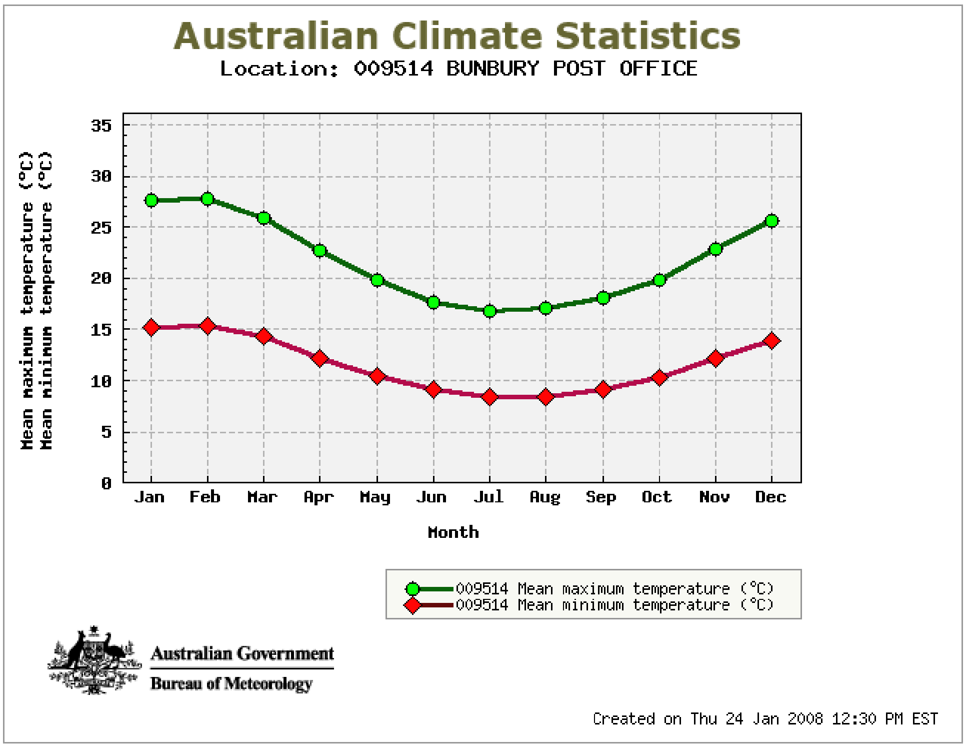


Figure 5. Average monthly maximum and minimum temperatures for Bunbury P.O. (1880-1985). (Source: Bureau of Meteorology 2008).

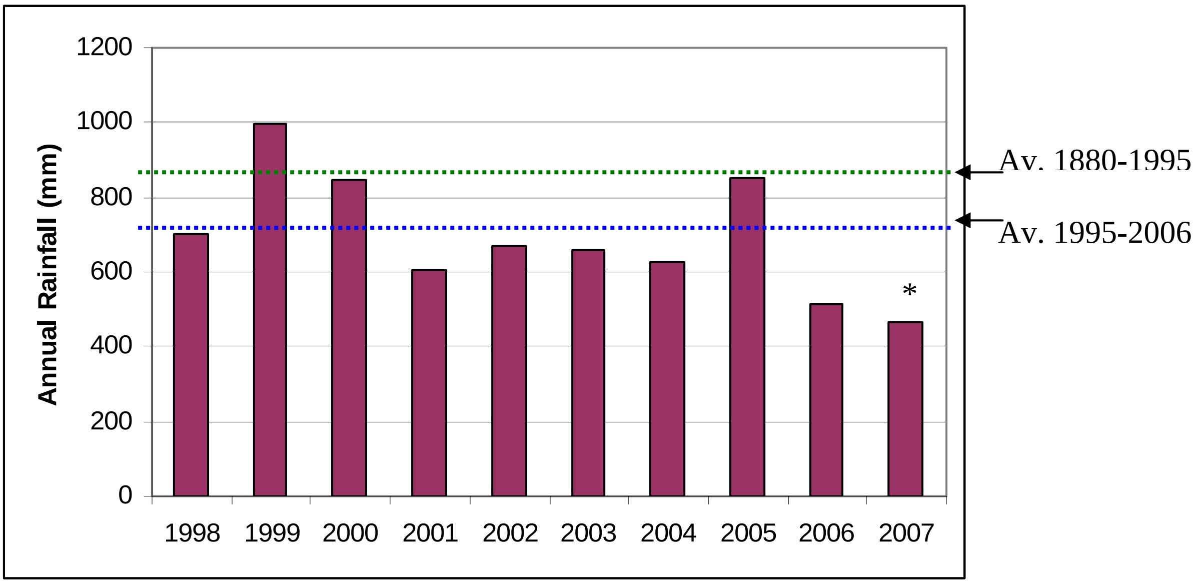


Figure 6. Annual rainfall for Bunbury for the period 1998-2007 compared against average annual rainfall for 1880-1995 (long-term; green broken line) and 1995-2006 (recent; blue broken line). (* rainfall for 2007 up to and including June when assessment was carried out).

4.4 Current Rehabilitation Practices Assessment

Assessment of success of current rehabilitation practices and results to date were made through measurement of existing permanent monitoring transects, established by Mattiske Consulting P/L, and the establishment and measurement of additional permanent monitoring transects which captured 2005-2006 rehabilitation efforts. One monitoring transect was measured in each of the six distinct rehabilitation sectors (as defined below). Field measurements took place on 19th to 21st June 2007.

Each monitoring transect commenced at the lake shoreline, was orientated more-or-less perpendicular to the shoreline and the contours of the slope, and finished at the end of the rehabilitation at the top of the slope. They varied in length from 80 to 200 m. At each 5 m interval along transects a 2 m x 2 m sampling quadrat was established and the cover and abundance of each plant species was recorded. Notes on plant size, particularly the number of seedlings, and condition were made. Plant species were identified using a combination of prior experience, published keys, Florabase (DEC website), herbarium records and other resources. Nomenclature follows that of Florabase as of October 2007.

Data analysis involved calculating the mean and standard error of quadrat cover, density (number of plants per quadrat) and richness (number of species per quadrat) for each transect. Ordination techniques attempt to arrange surveyed sites so that the degree of similarity in plant species composition is represented in the physical spacing of the sites when the data are plotted i.e., similar sites sit close to one another. Differences between sites can then be tested using ANOSIM which can be considered to be similar to analysis of variance (ANOVA) for this type of analysis (Clarke & Gorley, 2001). Similarities were determined using the Bray-Curtis measure (based on square root transformed cover values of species). Ordination and ANOSIM were then performed using the Primer (v6) software (PRIMER-E Ltd, 2006).

4.5 Soil and Topographic Profiling

A theodolite was used to assess vertical slope height and angle variation along each transect perpendicular to the shore of North Lake. GPS coordinates at each theodolite measuring station and a tape measure were used to assess horizontal slope with distance along the transect.

Soil profile measurements were completed to help establish reasons for lack of growth and cover across much of the rehabilitated sites. Different vegetation zones were identified along the transects of each sector. A sampling trench was then dug and different soil horizons to 0.50 m depth were identified. A soil sample was then collected from three different sites to form a pooled sample for the area. In the laboratory, the soil sample was dried, ground and analysed for the following parameters: Texture, Colour, Nitrate-N, (mg/kg), Ammonium, (mg/kg), Phosphate, (mg/kg), Potassium, (mg/kg), Sulphur, (mg/kg), Carbon, (%), Iron, (mg/kg), Conductivity, (dS/cm) and pH.

4.6 Comparison of Rehabilitated Areas with Local Wetland Vegetation Parameters

Transects were also established across several natural wetlands in the Kemerton area. These were to characterise the biotic patterns of such wetlands, identify likely processes which drive or influence such patterns and to examine likely dynamics in vegetation. (These findings are outlined in a complementary report: van Etten *et al.,* in prep.). These measurements of natural wetlands also facilitated comparisons to rehabilitation. This was achieved through comparing: 1) structural attributes of the vegetation; 2) plant composition using the multivariate techniques of ordination; 3) comparing dominance and diversity patterns within plant communities (Grant & Loneragan, 2003); and 4) soil and topographic features.

A review of existing information (literature, expert opinion, practices at other south-west Australian mines) on seed ecology and revegetation techniques was made in order to recommend the most appropriate methods for returning key species to rehabilitated areas was made. Categories for species return were: topsoil, direct seeding, planting tubestock, recalcitrant species needing cuttings or tissue culture, and poorly known species requiring further research. Mining companies renown for successful rehabilitation of mine sites in the south-west (e.g., Alcoa) were consulted and information gained on best practice and recommended revegetation methods for return of plant species. These companies were mostly involved in mining uplands, rather than wetlands and surrounding dampland vegetation.

5 RESULTS

The considerable variation in rehabilitation history (Table 1) and environmental conditions has contributed to markedly divergent revegetation around North Lake. Six Sectors have been delineated around the lake (see Figure 3) each with a particular history of rehabilitation techniques, timing, environmental features and vegetative characteristics. Each of these Sectors are discussed separately in sections below in terms of vegetative characteristics, rehabilitation success (or otherwise), our prognosis for their future development, and our recommendations to improve the standard of rehabilitation, where required.

General trends in rehabilitation success or otherwise, as well as formal comparisons with natural wetlands then follow.

5.1 The Rehabilitation Sectors

5.1.1 Sector 1: North-East Corner

5.1.1.1 History:

- February 2001: contoured and spread with topsoil (and understorey debris);
- Autumn/winter 2002: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags;
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- Autumn 2006: Ripping between existing plants with 3 tyne ripper to 30 cm depth. handseeded (with ~9 common understorey species), limed

(2t/ha) and fertilised (incl. trace elements). Also hand spread with brush to avoid re-compacting the area;

- June 2007: 3rd monitoring by CEM (this report).

Plate 1. Rehabilitation in Sector 1. The foreground shows a mostly bare area believed to the result of recent soil deposition via wind. The background shows typical revegetation within Sector 1 with sedges dominating at low elevations and shrubs and small trees on higher ground.

5.1.1.2 Results

Sector 1 has experienced steady and statistically significant increases in plant cover, plant density and number of native plant species over time (Figure 7). However plant species richness and cover remain relatively low (i.e., less than 10% native plant cover on average, and only 4.5 plant species per 4 m^2quadrat, on average).

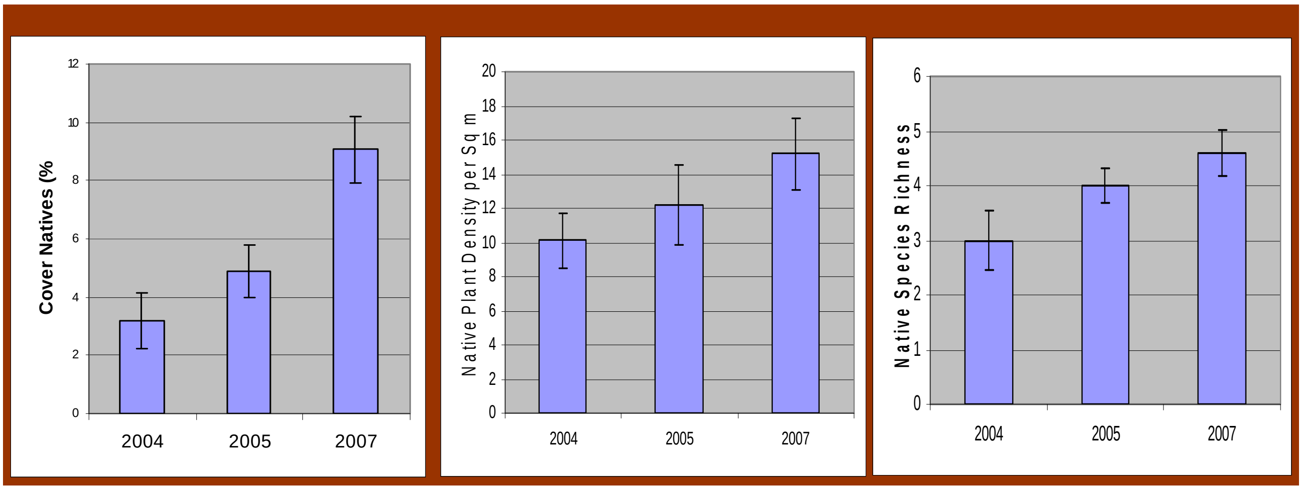


Figure 7. Graphs of % native cover, plant density and mean species richness for 2004 and 2005 Mattiske studies (Mattiske Consulting Pty Ltd, 2004, 2005) and this study (June 2007) for Sector 1.

Much of the increase in plant numbers between 2005 and 2007 can be attributed to seed germination following 2006 hand-seeding treatment, with most monitoring quadrats having some seedlings. The most commonly found seedlings were *Hypocalymma angustifolium, Kunzea ericifolia, Acacia pulchella, Acacia saligna* and *Viminaria juncea.* A small number of eucalypt seedlings were also found. Interestingly, the eucalypt and legume seedlings have come from seed already in topsoil as these weren't amongst those species sown in 2006. The legume seedlings are particularly fast growing (up to 60 cm wide and high in one year). This rapid growth of seedlings, in combination with resprouting of many shrubs from rootstock, has more than compensated for the physical disturbance of established plants during the ripping and fertilising treatments. In fact the cover, on average, has almost doubled following treatment.

The most widespread plant species in terms of cover was *Hypocalymma angustifolium* (average of around 3% cover per quadrat), followed by *Baumea articulata* and *Melaleuca preissiana* (around 1% mean cover for each), and then *Euchilopsis linearis* and *Acacia pulchella* (both 0.7% mean cover). These averages belie the uneven spatial distribution of species with some clear zonation observable with distance from lake shore. Common upland species were *Hypocalymma angustifolium, Kunzea ericifolia, Acacia pulchella* and *Eucalyptus marginata*, whereas *Melaleuca* species increased in cover on the bottom section of the slope. *Baumea articulata, Euchilopsis* *linearis* and *Lepidosperma longitudinale* (all sedges and rushes) were most common in the last couple of monitoring quadrats closest to the lake (Plate 1). A number of almost bare patches occur close to lake in the southern parts of this Sector (Plate 1). These areas are likely recent wind blown sand deposits and are only slowly being colonised by sedges.

The lack of tree growth in this Sector, which has concerned mine management for several years, has been attributed to the influence of soil compaction, wind exposure and/or winter water-logging (Mattiske Consulting P/L 2004, 2005). Few trees have exceeded 1 m in height in the 5+ years since planting/seeding, with little growth of monitored trees in the 2004–5 period (Table 2). These three monitoring trees were disturbed by the 2006 ripping, but are resprouting and reasonably healthy. They have yet to recover in terms of height. It is therefore too earlier to evaluate the benefits of this ripping in terms of overcoming tree growth suppression.

Table 2. Tree height in Sector 1 for different paperbark species and years of monitoring.

Species	2004 Height (cm)	2005 Height (cm)	2007 Height (cm)
Melaleuca rhaphiophylla	130	130	80
Melaleuca preissiana	100	110	60
Melaleuca preissiana	80	110	90

Weeds remain prevalent despite the recent ripping treatment. Average cover is 6.6% with less weeds closer to shoreline and lower in the profile. Most are annual and short-lived dicot herbs, but there are also considerable numbers of grasses throughout the Sector. A strong negative correlation occurs between weed cover and native plant cover ($r = -0.80$; $p<0.001$; Figure 8), as well as between weed cover and native species richness ($r = -0.50$), and weed cover and plant density ($r = -0.51$). This relationship implies that high levels of weeds may be restricting native plant establishment and/or growth. Weed cover has recovered rapidly following the 2006 ripping suggesting on-going control is required. Despite this, seedlings had established throughout the Sector, even where weed cover was high, although at low densities.

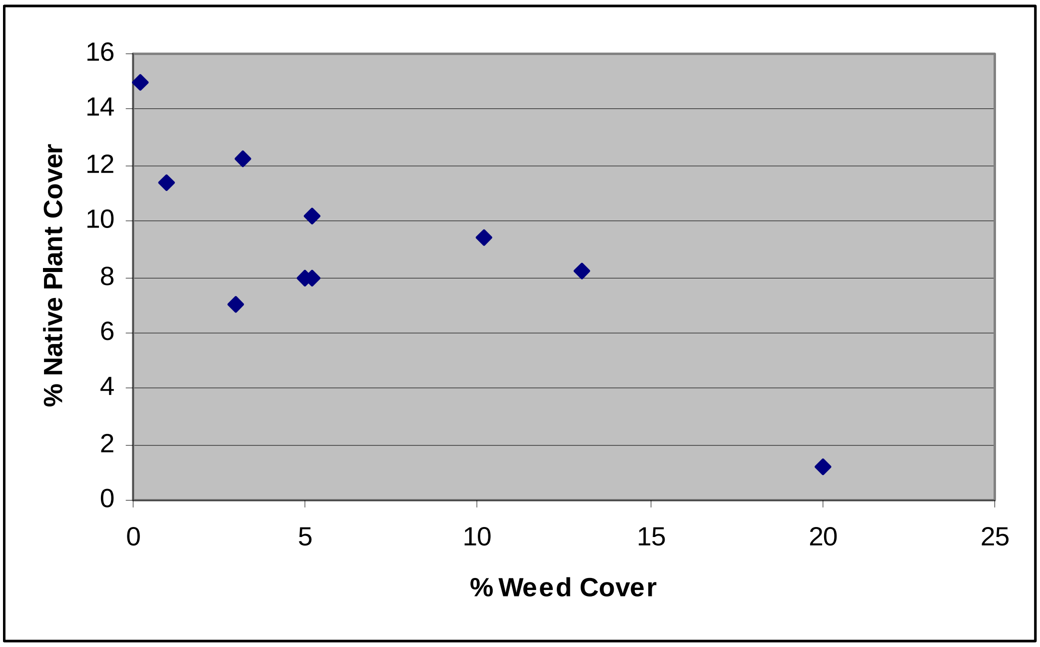


Figure 8. Scatter plot showing relationship between percentage cover of native plants and weeds at Area 1 monitoring quadrats. There is a significant negative linear relationship ($r = -0.80$; $p<0.001$) indicating that weeds generally decrease in line with increasing native plant cover.

5.1.1.3 Conclusions

Signs are that the 2006 ripping-seeding-fertiliser treatment has been somewhat successful in improving diversity, cover and growth of vegetation in this Sector. However the level of improvement per effort/cost of this treatment is, at this early stage of assessment, somewhat disappointing given the current sparse nature of the vegetation and low diversity compared to other rehabilitation sites around the lake.

There remains a reasonable possibility of second and subsequent year germination given that 2006 winter was one of the driest on record. Therefore it would be wise to continue monitoring of this Sector for some years to fully evaluate the success of the recent treatments.

5.1.1.4 Recommendations

1) Monitor annually to fully assess results of recent treatments;
2) Where vegetation cover remains low after 1-2 more years, gap planting and seeding of selected species to improve cover. Species should be selected according to site characteristic rather than a "scattergun" approach of sowing a general seed mix. Guidelines for more precise matching species to site are outlined in section 6.
3) Strategic and on-going weed control is needed to promote native plants (strategic in the sense of focussing on patches where weeds dominate native plants while leaving weeds where native plants are absent to provide a level of cover that will be important in promoting soil stability and minimising wind erosion).
4) Avoid expending high amounts of effort and money in this rehab Sector as its likely to remain a poor return on investment.

5.1.2 Sector 2: East Side Lowlands

5.1.2.1 History

- February 2001: contoured and spread with topsoil (and understorey debris);
- Autumn/winter 2002: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags;
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- June 2007: 3rd monitoring by CEM (this report).

Plate 2. Photos of monitoring quadrats in Sector 2 during June 2007.

5.1.2.2 *Results*

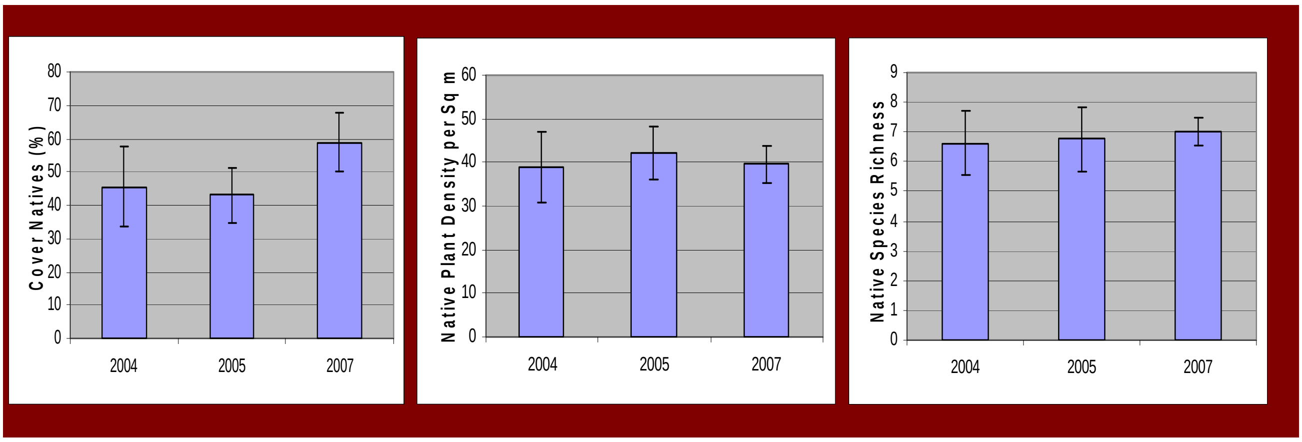


Figure 9. Graphs of % native cover, plant density and mean species richness for 2004 and 2005 Mattiske studies (Mattiske Consulting Pty Ltd, 2004, 2005) and this study (June 2007) for Sector 2.

This is the most successful Sector to date in terms of rehabilitation. It has reasonably stable plant cover, diversity and density over the last few years, although mean cover did increase significantly from 43% in 2005 to almost 60% in 2007. The success of this Sector in comparison the area immediately south (see Sector 3) is probably due to its lower topographic position and presumed access to groundwater (which would be particularly important for plant survival and growth during summer).

The most common species in terms of cover were: *Astartea scoparia* (clear dominant representing almost half the vegetative cover over the transect), *Leptocarpus* sp., *Melaleuca lateriflora*, *Lepidosperma longitudinale* and *Melaleuca rhaphiophylla*. There is however distinct zonation along the transect with *Astartea scoparia* dominating in thickets of shrubs higher in the profile, whereas *Melaleuca* spp. with understorey of sedges such as *Lepidosperma longitudinale*, *Leptocarpus* sp. and *Baumea articulata* occur on the lower slopes close to the lake edge.

There has been a small amount of recent deaths; however these have been more-or-less balanced by seedling recruitment, mainly of *Kunzea recurva* and *Astartea scoparia*, which has occurred primarily in small gaps. These have very likely come from existing rehabilitation which is now reproductively mature. Significant growth of monitored trees has continued over the last two years (Table 3); some individuals now exceed 4 m in height.

Weeds are virtually absent in this Sector. This is most likely due to the dense tree and shrub cover (weeds are typically space and sun loving plants).

Table 3. Tree height in Sector 2 for different paperbark species and years of monitoring.

Tree No.	Species	2004 Height (cm)	2005 Height (cm)	2007 Height (cm)
1	*Melaleuca rhaphiophylla*	50	60	90
2	*Melaleuca rhaphiophylla*	?	60	100
3	*Melaleuca rhaphiophylla*	140	150	180
4	*Melaleuca rhaphiophylla*	120	120	190
5	*Melaleuca rhaphiophylla*	180	180	260

5.1.2.3 Conclusions and Recommendations

This area is probably best left alone for the next few years. Although many of legumes which originally established in this Sector have died out, Myrtaceae shrubs should persist for several more, especially the large paperbark trees such as *Melaleuca rhaphiophylla* and *M. preissiana* which dominate the lower slopes. Smaller shrubs may die after 10 years (although longevity data is generally lacking for south-west species) and it will be interesting to see if recruitment continues to occur in gaps. Also individual shrubs are likely to die due to the intense competition (self-thinning). Although thinning is a slow process, it will give surviving plants more space to grow, as well creating gaps to facilitate recruitment of new plants (and perhaps new species). Many of the species remaining are resprouters, some of which may persist for a very long time through underground root and rhizome systems.

The success in this Sector demonstrates the potential to achieve excellent results in the rehabilitation of Kemerton wetland margins. It also holds much promise in our abilities to improve rehabilitation through more careful and deliberate matching of species to site characteristics. Species in this Sector are generally adapted to waterlogged conditions in winter and early spring. This suits the typical fringing wetland and dampland species which were introduced to this Sector. Areas receiving similar treatment, but higher in the profile with greater distance to groundwater and lake edge, haven’t fared as well.

5.1.3 Sector 3: South-East Side Uplands

5.1.3.1 History

- Feb 2001: contoured and spread with topsoil (and understorey debris);
- Autumn/winter 2002: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags;
- March 2004: monitored by Mattiske Consulting P/L;

- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- Autumn 2006: hand-seeded (with ~9 common species), fertilised (including trace elements), limed (2t/ha) and (apparently) treated with herbicide;
- June 2007: 3rd monitoring by CEM (this report).

5.1.3.2 Results:

In contrast to the adjoining area to the north (see Sector 2) which received the same rehabilitation treatment in 2001, this area continues to show poor success in terms of plant cover, density and species richness. Although cover and plant density have recovered somewhat from the lows of 2005, they remain mediocre at just over 14% mean native cover and an average of 8.1 plants per 4 m^2. Mean native plant species richness has however significantly declined from 2004–2005 and is now only *ca.* 4 species per m^2. Species disappearing from monitoring quadrats over time include: *Acacia stenoptera, Aotus gracillima, Pericalymma ellipticum, Desmocladus flexuosus* and *Drosera* spp. Most of these species are relatively short-lived species.

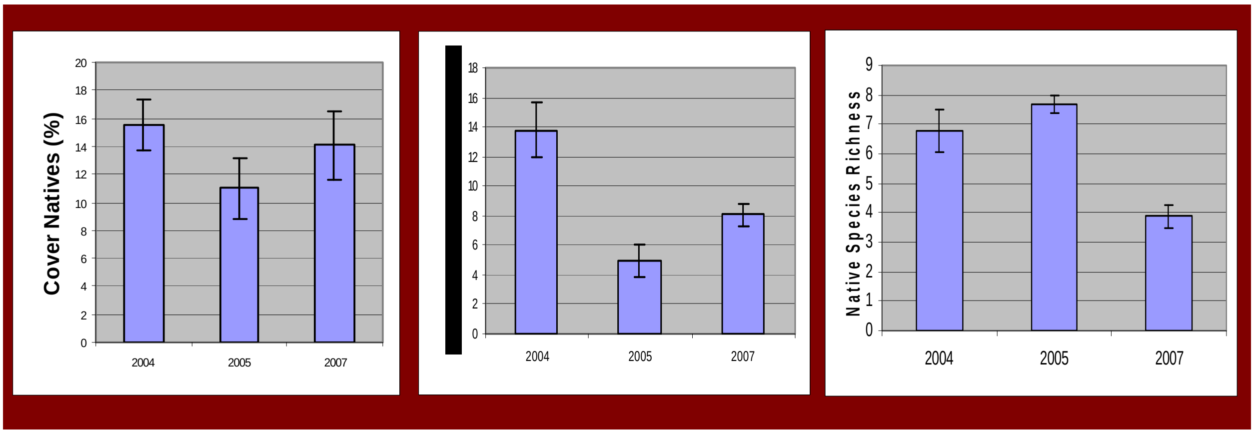


Figure 10. Graphs of % native cover, plant density and mean species richness for 2004 and 2005 Mattiske studies (Mattiske Consulting Pty Ltd, 2004, 2005) and this study (June 2007) for Sector 3.

Despite the reduced species diversity, the increase in plant density can be mainly attributed to small numbers of seedlings becoming established over the last 2 years. This appears to be more the result of seed dispersal from nearby reproductively

Plate 3. Monitoring quadrats of Transect #5 within Rehab Sector 3 taken during June 2007.

mature adults and subsequent germination than from sown seed given the species germinating and the spatial patterns observed in the field. Few seeds sown in autumn 2006 appear to have germinated. Seedlings found in Sector 3 were mostly *Kunzea recurva* (which appears to have been sown), but also some legumes (such as *Acacia*, *Jacksonia*, *Viminea juncea*) which weren't sown.

The clear dominant native species was *Kunzea recurva* (6% mean cover), with small numbers of *Astartea scoparia*, *Corymbia calophylla*, *Viminea juncea* and *Acacia saligna* occurring across the Sector (all >1% cover on average). In contrast to other Sectors, species composition is relatively similar along the transect, with no obvious zonation. The first two monitoring quadrats closest to the lake appear to have been washed away/eroded, with a small cliff face developing where the lake waters have scoured the slope. Almost all of the monitoring transect is now >1m above the lake water level (see topographic profile, Figure 19).

Only two marri trees (*Corymbia calophylla*) have been monitored in terms of height (Table 4). These results, in combination with observations of other trees in this Sector, suggest little growth of trees over the last few years.

Table 4. Marri (*Corymbia calophylla*) height in Sector 3 for different years of monitoring.

Tree No.	Species	2004 Height (cm)	2005 Height (cm)	2007 Height (cm)
1	*Corymbia calophylla*	120	120	105
2	*Corymbia calophylla*	70	60	80

Weeds are prevalent within rehabilitation areas and have been a concern for some time in this Sector (Mattiske Consulting Pty Ltd, 2004, 2005). Current weed cover is 25% on average, but up to 90% in places. There is a weak positive correlation between weed cover and native species cover ($r = 0.42$; $p<0.001$), richness (Figure 11; $r=0.47$; $p<0.001$) and density ($r = 0.23$; $p = 0.01$). This suggests weeds and native species are possibly responding to the same environmental parameters and that high weed cover is not necessarily a barrier to native plant growth in this Sector (contrary to the situation in Sector 1). It is possible that that weeds have filled gaps left as native species died out in this Sector. Also weeds may have responded to fertilising the year before with little evidence that herbicides have been effective (perhaps they weren't actually applied as reported). Weed levels decline towards the lake, suggesting their preference for drier, sandy soils, or avoidance of winter waterlogged sites.

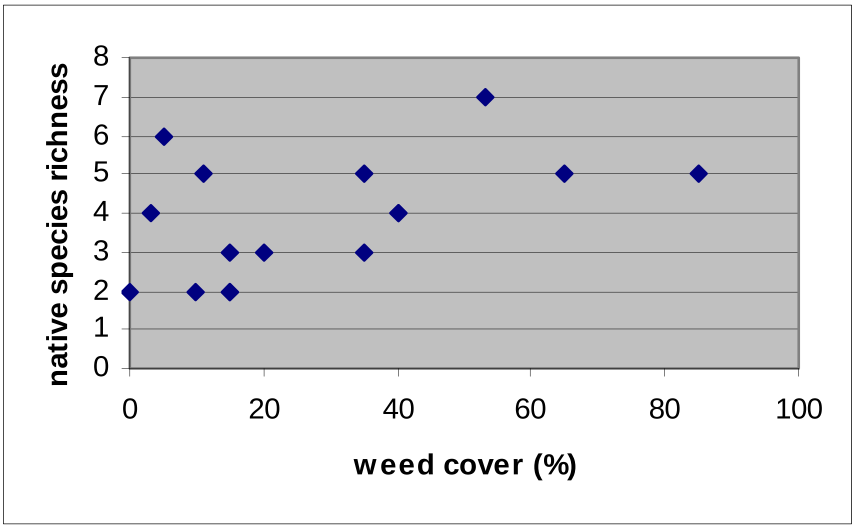


Figure 11. Scatter plot showing relationship between percentage native plant species richness and cover of weeds at Area 3 monitoring quadrats. There is a significant positive correlation ($r = +0.48$; $p<0.001$) indicating that weeds generally decrease in line with the number of native species.

5.1.3.3 Conclusions and Recommendations

This area remains poor in terms of revegetation success with little improvement achieved despite reported fertilising, liming and herbicide treatments conducted the previous year (if indeed they were actually completed). Part of reason for the lack of success may be inappropriate species selection given the raised elevation of most of this Sector (i.e., >2m above the lake water level). More upland 'Zone' species (as defined in Chapter 6) should be targeted for future direct seeding and seedling planting to improve this site. Also fertiliser and herbicide treatment should be more precisely targeted to planting patches rather than general spraying, with grass selective herbicide and slow release fertiliser added in the immediate vicinity of planted seedlings.

5.1.4 Sector 4: West Side

5.1.4.1 History

- April 2003: contoured and spread with topsoil (and understorey debris);
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- June 2007: 3rd monitoring by CEM (this report).

5.1.4.2 Results

Native plant cover in this Sector has significantly increased with current mean cover of 25.6% almost double of what it was in August 2005 and about six times more than 2004 (Figure 12). However there has been no concomitant increase in mean plant density and a significant decline in native species richness has occurred (Figure 12).

Plate 4. Monitoring quadrats of Transect #7 within Sector 4 taken during June 2007.

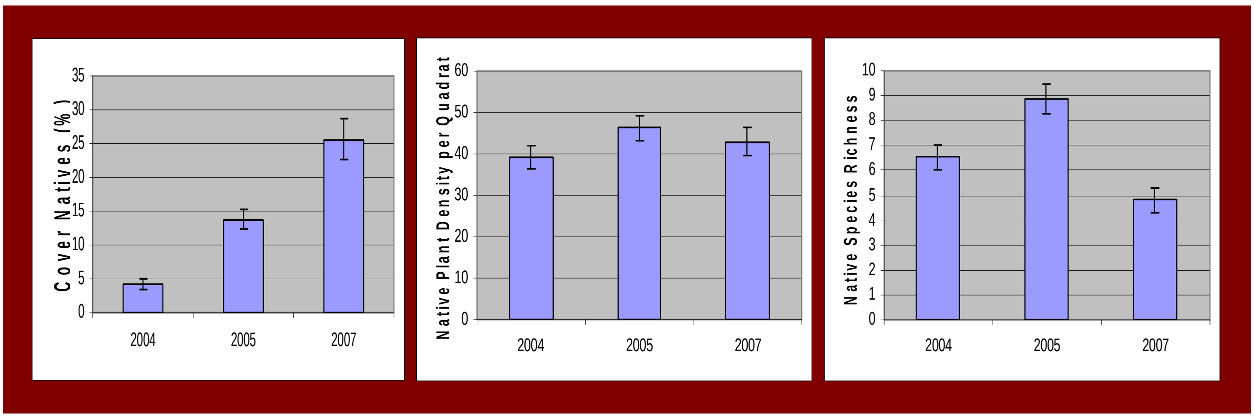


Figure 12. Graphs of % native cover, plant density and mean species richness for 2004 and 2005 Mattiske studies (Mattiske Consulting Pty Ltd, 2004, 2005) and this study (June 2007) for Sector 4.

Species found in Sector 4 in 2005 but not re-recorded in 2007 include *Acacia pulchella, Acacia saligna, Acacia stenoptera,* another unidentified *Acacia* species, *Boronia dichotoma*, *Cyathochaeta teretifolia* (P3), *Dampiera* sp., *Desmocladus flexuosus*, *Drosera gigantea* subsp. *gigantea*, *Drosera glanduligera*, *Hypolaena exsulca*, *Goodenia pulchella*, *Melaleuca rhaphiophylla*, *Schoenus efoliatus*, *Thysanotus multiflorus* and *Viminaria juncea*. A small number of these species are annuals or annually renewed geophytes, such as the *Drosera*, and their absence in 2007 likely reflects differences in sampling season (i.e., early winter in 2007 compared to late winter in 2005). Others differences may be due to inconsistencies in identification and difficulties in taxonomic determination at the seedling stage. Despite this, there has clearly been a reduction in perennial species, particularly amongst legumes. Many legumes, such as *Acacia pulchella* and *Viminaria juncea,* are known to be short-lived (<5 years) and are typically present in younger rehabilitated (such as seen currently in Sectors 5 & 6). It has only been 4 years since this rehabilitation – therefore the reduction in legumes seems to have occurred relatively quickly. Importantly, little recruitment of legumes or other species has been recorded in this Sector, suggesting some barrier to germination and/or early establishment of seedlings (there is little doubt that ample seed has been produced and may well be viable in the soil given the longevity of native legume seed). Current diversity is relatively low in this Sector at just under five native species per 4 m^2 quadrat. This trend in declining diversity is a major concern given the low baseline status. Of interest, *Euchilopsis linearis,* Swamp Pea, was recorded in two quadrats in this Sector, but was previously unrecorded in rehabilitation at Kemerton. This is a positive results as this species is common in seasonally waterlogged areas of the Swan Coastal Plain, and suggests some long-lived seed in the soil.

Lepidosperma longitudinale is the dominant species in Sector 4 and appears to be actively spreading via rhizomes. Average cover is 17%, with a maximum cover of 25% obtained in some quadrats. This species appears to have received little grazing pressure in this Sector, which is in contrast to rehabilitation closer to the remnant bushland to the north and east (e.g., Sectors 1 & 5). Three other species are common in Sector 4: *Kunzea ericifolia*, *Hypocalymma angustifolium* and an unidentified Myrtaceae species (possibly *Taxandria linearfolia*).

Weeds in this Sector are sparse; average weed cover is only around 1%, with highest of 5% recorded in highest/driest part of transect.

5.1.4.3 Conclusions and Recommendations

Although vegetative growth and colonisation is occurring in Sector 4, it is limited to a small number of species (particularly the dominant sedge *Lepidosperma longitudinale).* Declining species diversity in the face of no to limited recruitment of short-lived species is of concern. It is recommended to test seed store and viability to gauge recruitment potential and diversity of soil seed store. If this is poor, reseed in open patches, including with scarified legume seed. Species selection guidelines as outlined in Chapter 6 should be followed, particularly the focus on key species currently missing from the area such as *Melaleuca* trees. Continue annual vegetation monitoring this Sector.

We also recommend monitoring grazing (via measurement of plant herbivory, scat density, etc.) and implement vertebrate control measures if necessary to control grazing pressure (as success of *Leptospermum* in this Sector is likely due to lack of grazing).

5.1.5 Sector 5: North Side New Rehabilitation Area

5.1.5.1 History

- Autumn 2006: contoured and spread with 10 year old, stored topsoil (with some understorey debris);
- June 2007: Initial monitoring by CEM (this report).

Plate 5. Monitoring quadrats of new transect established within Rehab Sector 5 taken during June 2007.

5.1.5.2 Results

Although it has achieved much the same cover of native species, this Sector has significantly fewer native species and lower plant density than the area on the opposite side of the lake (Sector 6; see below) which was rehabilitated about the same time but with fresh topsoil (as opposed to 10 years old topsoil here) (Figure 13). In fact the number of plants established per quadrat is some three times lower in this Sector. Mean species richness is only 6.9 per quadrat compared to 12.7 in Sector 6 (Figure 13). Difference in species composition are mainly *Kunzea ericifolia*, *Calothamnus lateralis* and *Euchilopsis linearis* (all more abundant here in Sector 5), and *Acacia pulchella*, *Lepidosperma longitudinale* and *Hypocalymma angustifolium* (all more abundant in Sector 6). *Pericalymma ellipticum*, *Platysace filiformis*, *Empodisma gracillimum*, *Hypolaena* sp., *Melaleuca preissiana* and *Dasypogon bromeliifolius* occur in Sector 6 but were not recorded in Sector 5. For complete details of species differences see Appendix 1 for results of SIMPER (Similarity Percentages) analyses.

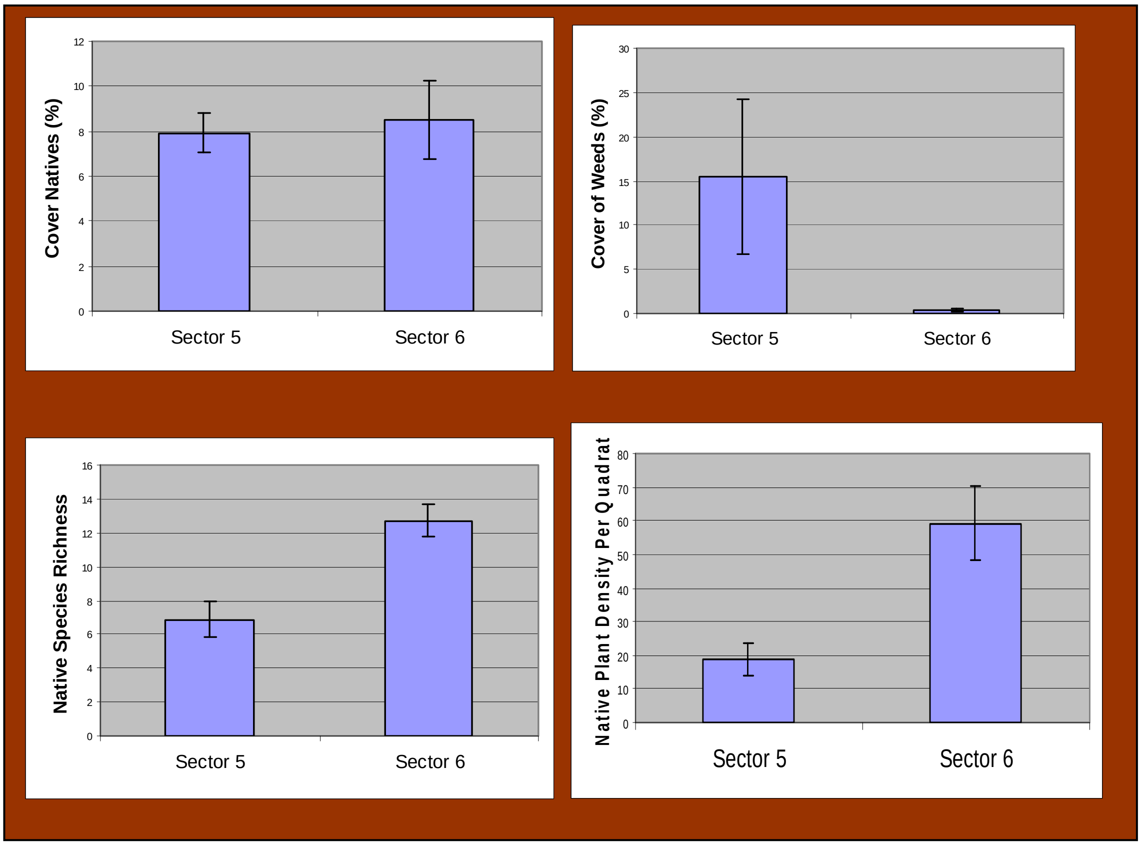


Figure 13. Graphs of % native cover, % weed cover, native species richness and plant density for Sectors 5 and 6 in this study (June 2007).

The most common species, in terms of vegetation cover, in this Sector are: *Kunzea ericifolia*, *Acacia pulchella*, *Hypocalymma angustifolium*, *Viminaria juncea* and *Calothamnus lateralis.*

Weed cover is relatively high, averaging around 16% across the monitoring transect. It is particularly high in the upper part of the transect, which is likely to be due to its close proximity to abundant weed cover around the fire break between the rehabilitation and remnant bushland. This implies that major weed infestations in areas immediately surrounding rehabilitation should be controlled as such infestations are a major source of wind-blown seed into the rehabilitation.

This Sector is subject to high grazing pressure as evident from eaten and damaged leaves (especially *Lepidosperma longitudinale*, an important colonising species in the rehabilitation) and abundant droppings. Again proximity to remnant bushland is likely to be a contributing factor.

5.1.5.3 Conclusions and Recommendations

The lower success in plant establishment when compared to Sector 6 is strong evidence for avoiding storing topsoil for long periods (several years of more), and for the implementation of direct topsoil return where practical. The diversity of Sector 5 now needs to be enhanced via direct seeding, particularly in bare patches – key species to be seeded would differ along the topographic profile according to the guidelines outlined in Chapter 6.

Some weed control is necessary on the upper slopes close to and including the firebreaks, as well as on other disturbed areas surrounding the rehabilitation. Similarly, some means of limiting access to rehabilitation by grazing animals needs to implemented. Some options for herbivore control are outlined in sections below.

5.1.6 Sector 6: South Side New Rehabilitation

5.1.6.1 History

- Autumn 2006: contoured and spread with fresh topsoil (with some understorey debris) - i.e., direct topsoil return. Most topsoil came from a dampland area, whilst upland soil was placed on higher ground;
- June 2007: Initial monitoring by CEM (this report).

Plate 6. Monitoring quadrats of Transect New within Sector 6 taken during June 2007.

5.1.6.2 Results

The more-or-less double species diversity and far greater level of plant establishment in Sector 6 compared to Sector 5 are testament to the importance of using fresh rather than old (stored) topsoil. Vegetation cover is relatively low at 8.5% on average, but greater than that achieved in other rehabilitation Sectors in their first year (e.g., Mattiske Transects 6, 7 & 8 in Sector 4, which all achieved less than 5% cover). This level of cover was achieved despite one of the lowest rainfalls on record.

The most common species in Sector 6 are *Acacia pulchella*, *Hypocalymma angustifolium*, *Lepidosperma longitudinale*, *Pericalymma ellipticum*, *Kunzea* *ericifolia, Platysace filiformis* and *Euchilopsis linearis*. Several species found in this Sector were absent from Sector 5 (including *Pericalymma ellipticum, Platysace filiformis, Empodisma gracillimum, Hypolaena* sp., *Melaleuca preissiana* and *Dasypogon bromeliifolius*). Many of these species were also absent from other areas of rehabilitation, suggesting that they may have relatively short seed longevity in the soil (see Appendix 1).

5.1.6.3 Conclusions and Recommendations

At this early stage (*ca.* one year) Sector 6 is, overall, promising in terms of rehabilitation success. Diversity and cover are relatively high for year one. It is recommended that monitoring continues in this Sector to confirm rehabilitation is continuing on this acceptable trajectory. No other intervention is recommended for the short term.

5.2 Vegetation

5.2.1 Plant Growth

Vegetative cover has increased in all Sectors around North lake since the last monitoring in 2005 (Table 5). However plant density is generally stable (Table 5), and at some sites gradually declining,. Most of the increase in cover can be attributed to growth of existing plants, particularly the more dominant species and individuals, rather than new plants becoming established.

5.2.2 Plant Diversity

The number of plant species in monitoring quadrats increased in some sectors between 2005 and 2007 (e.g., Sectors 1 & 2), whilst declining quite severely at others (e.g., Sectors 3 & 4) (Table 5). Most rehabilitated areas remain very poor in species diversity (i.e., fewer than 5 species per quadrat on average, and fewer than 0.5 species per square metre; Table 6). The most diverse in terms of plant species is Sector 6 which is also the most recently rehabilitated area (in 2006) using fresh (direct return) topsoil (Table 6). Twenty-nine species were found in monitoring quadrats established in Sector 6, with an average of 12.7 of these per monitoring quadrat (Table 6). Species diversity was next highest in Sector 5 (Table 6).

In comparison, plant surveys of natural wetlands in the Kemerton area by the authors demonstrate that diversity of these vegetation complexes is highly variable, varying from 2–3 for some fringing *Melaleuca* vegetation around lakes, through to 20–30 perennial species per relevé (sampling area) in open woodland on winter waterlogged depressions.

Table 5. Mean quadrat cover and density of native plants and weeds for each of the rehabilitation Areas and monitoring periods.

Sector	**Sector 1**			**Sector 2**			**Sector 3**			**Sector 4**			**Sector 5**	**Sector 6**
Transect	R1			R4			R5			R7			R10	R9
Year	2004	2005	2007	2004	2005	2007	2004	2005	2007	2004	2005	2007	2007	2007
Mean Native Cover (%)	3.2±1.0	4.9±0.9	9.1±1.2	46±12.0	43±8.2	59±9.0	16±1.8	11±2.2	14±2.5	4.1±0.8	14±1.4	26±3.0	7.9±0.9	8.5±1.7
Mean Native Density (per 4 m^2)	10±1.7	12±2.3	15±2.1	39±8.1	42±6.1	40±4.2	14±1.9	5.0±1.1	8.1±0.8	39±2.9	46±3.1	43±3.5	19±4.7	59±11.0
Mean Native Species Richness	3.0±0.6	4.0±0.3	4.6±0.4	6.6±1.1	6.8±1.1	7.0±0.5	6.8±0.7	7.7±0.3	3.9±0.4	6.6±0.5	8.9±0.6	4.8±0.5	6.9±1.1	13±1.0
Weed Cover (%)	n.a.	n.a.	6.6±1.9	n.a.	n.a.	0	n.a.	n.a.	28±6.0	n.a.	n.a.	1.2±0.6	16±8.7	0.3±0.2

n.a.= not available

Table 6. Overall diversity measures for each Sector when assessed by this study in June 2007.

Sector	Transect	Quads	S	S/m2	N	J'	H'	R per Quad
1	R1	10	16	0.40	9	0.83	2.29	4.6
2	R4	8	17	0.53	59	0.68	1.92	7.0
3	R5	16	17	0.27	15	0.68	1.94	3.9
4	R7	11	15	0.34	26	0.42	1.14	4.8
5	R10	7	20	0.71	8	0.87	2.59	6.9
6	R9	7	29	1.04	9	0.77	2.61	12.7

Total species: **S** - the total number of species in each Area.
Total individuals: **N** - The number of individuals in each sample.
Pielou's evenness: **J'** - this is a measure of equitability, a measure of how evenly the individuals are distributed among the different species.
Shannon-Wiener diversity index: **H'** (using natural log)
Mean richness per monitoring quadrat: **R per Quad**

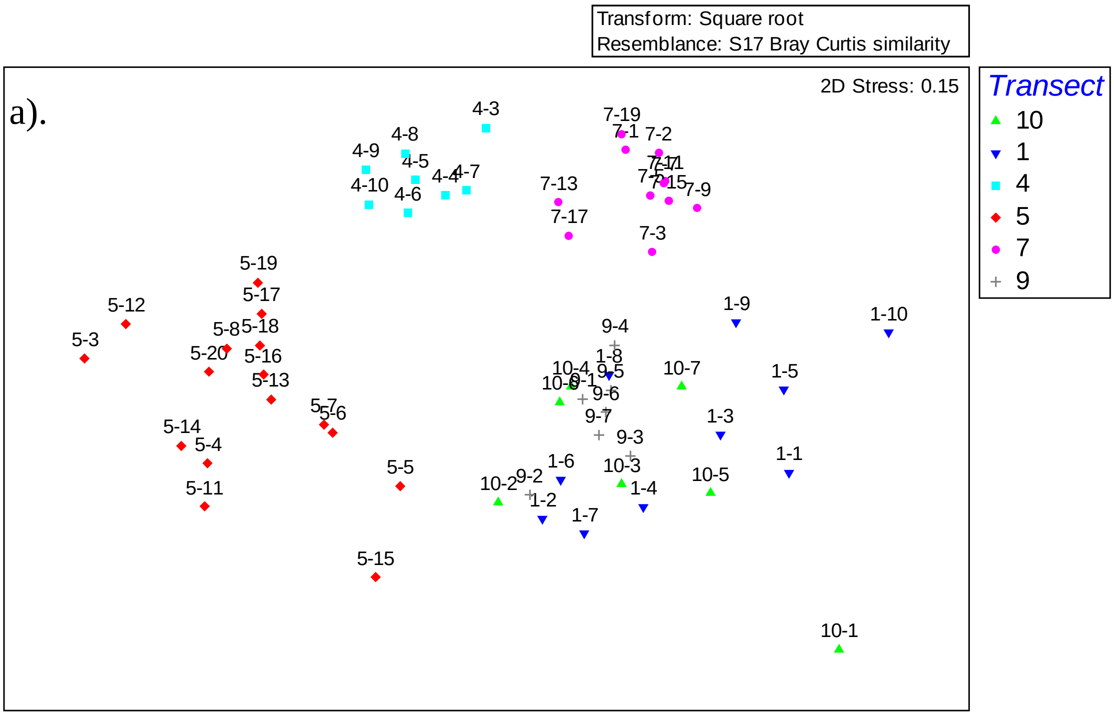


Figure 14. Ordination (MDS) of monitoring quadrats demonstrating similarities in species of monitoring quadrats within transects associated with each sector..

Table 7. Results of ANOSIM 'global' test with 999 permutations for differences in plant species composition between transects and pair-wise comparisons between transects. Global Test: sample statistic (Global R): 0.796, significance level of sample statistic: 0.1%.

Groups	R Statistic	Significance Level %	Possible Permutations	Number >= Observed
10, 1	0.263	1.3	19448	12
10, 4	0.901	0.1	6435	0
10, 5	0.826	0.1	245157	0
10, 7	0.882	0.1	31824	0
10, 9	0.346	0.2	1716	1
1, 4	0.904	0.1	43758	0
1, 5	0.898	0.1	5311735	0
1, 7	0.852	0.1	352716	0
1, 9	0.358	0.4	19448	3
4, 5	0.796	0.1	735471	0
4, 7	0.956	0.1	75582	0
4, 9	1.000	0.1	6435	0
5, 7	0.954	0.1	1.3E+07	0
5, 9	0.886	0.1	245157	0
7, 9	0.997	0.1	31824	0

5.2.3 Floristics

Differences in plant species composition occur within monitoring quadrats of the one transect with zonation evident across transects (see ordinations; Figure 14). The ordination demonstrates quite clearly that community composition was generally more similar within a monitoring transect than between them, with most transects distinct from others (Figure 14a); the only overlap in composition being between monitoring transects 9 & 10 (Sectors 6 & 5 respectively).

Such compositional differences were tested using ANOSIM (Table 7), which demonstrated that each transect is floristically significantly different ($p < 0.05$). to every other transect. These differences extended to transects 1 and 10, which were different to other quadrats in terms of species composition, as well as even to each other

The species which mainly account for the compositional differences between pairs of transects were identified using SIMPER analysis – these results are shown in Appendix 1.

5.2.4 Comparison of Floristics with Natural Wetlands

In terms of species composition, there were general differences between rehabilitation areas and natural wetlands of the Kemerton Area, as demonstrated in the ordination of sites using (square-root) transformed cover values (Figure 15), although there is some overlap in composition with Sector 2 (R4) being quite close in floristics to several natural wetlands. The ordination using presence/absence data shows more overlap between sites with the rehabilitated sites grouping more-or-less in the middle of the ordination (Figure 16). Floristic information for each transect was grouped from the various monitoring quadrats along the transect; hence they represent an overall representation of the floristics of the various Sectors.

There were no significant floristic differences ($p>0.05$) between rehabilitation and natural wetlands when rehabilitation quadrat data was aggregated for each transect, although it was marginally significant ($p=0.047$) for non-transformed species data (Table 8). However when monitoring quadrats are analyses separately, statistically significant differences ($p<0.05$) in species composition are evident between rehabilitation and natural wetlands (Table 7). This suggests that sampling intensity may need to be relatively high to demonstrate such floristic differences. Differences in species composition are more distinct when cover values of species are considered compared to when presence-absence or transformed cover values are used, which suggest that differences are not only due to variation in species occurrences, but are also related to differences in their relative dominance and abundance.

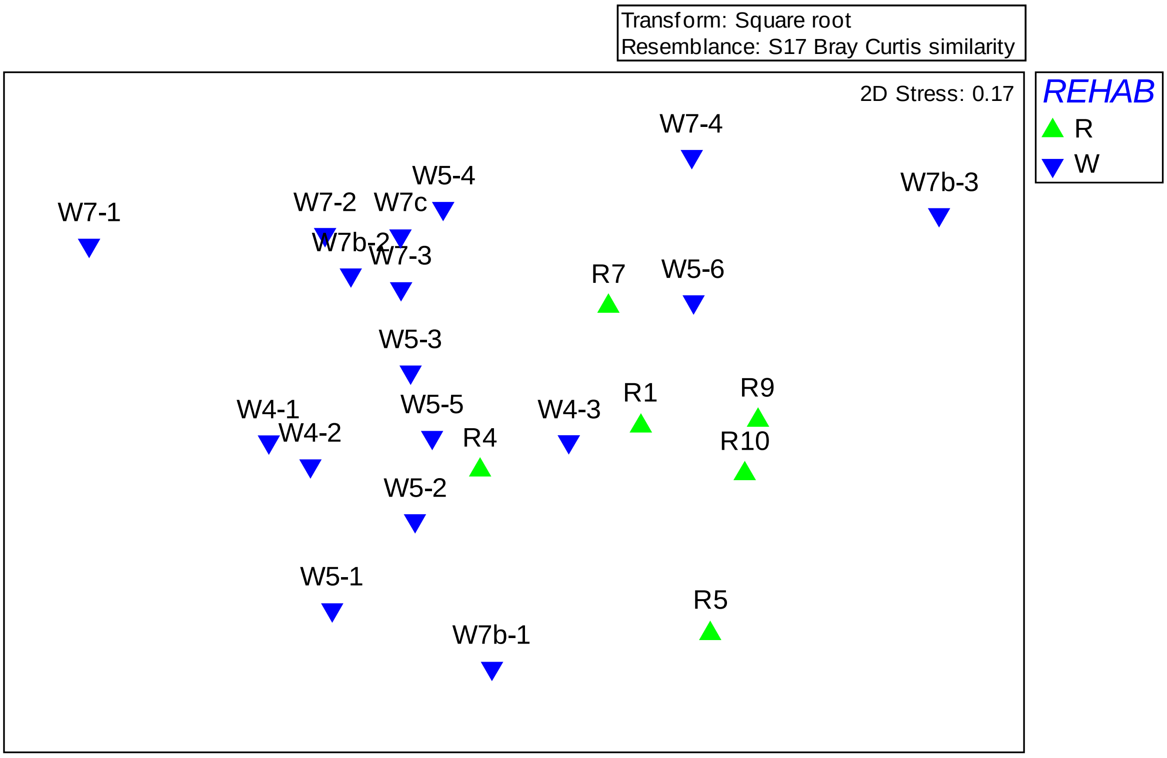


Figure 15. Ordination (MDS) of native species composition of rehabilitation monitoring transects (R1-R10) with natural wetland relevés (W1-W5) based on square root of cover values and Bray-Curtis similarity metric. Second number associated with wetland relevés refers to position along transect through wetland – for instance W5-5 refer to fifth relevé along transect through wetland 5. R1 is from Sector 1; R4=Sector 2; R5=Sector 3; R7= Sector 4; R10 = Sector 5; and R9 = Sector 6.

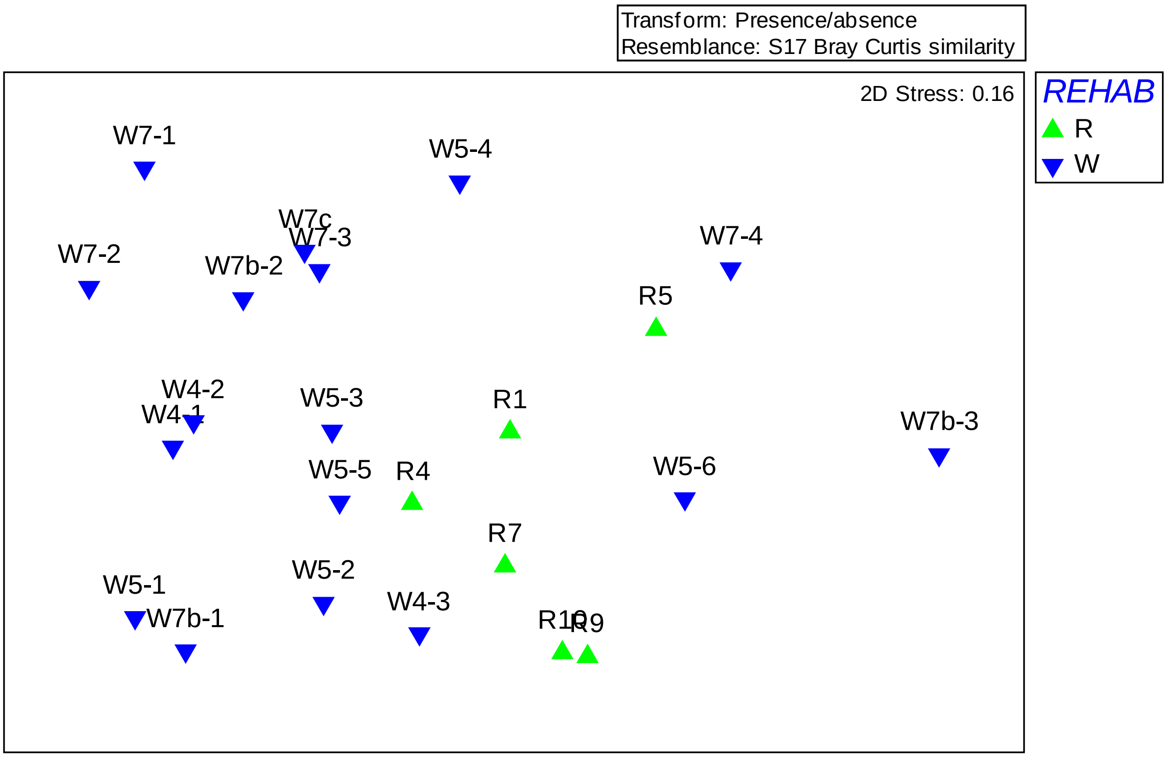


Figure 16. Ordination (MDS) of native species composition of rehabilitation monitoring transects (R1-R10) with natural wetland relevés (W1-W5) using presence-absence data. Second number associated with wetland relevés refers to position along transect through wetland – for instance W5-5 refers to fifth relevé along transect through wetland 5.

Table 8. Summary of ANOSIM (analysis of similarity) tests for differences in species composition between rehabilitation and natural wetlands for various data sets and transformations. 'Transects' refers to aggregated floristic data for monitoring transects, whilst 'Quadrats' refers to analysis with each quadrat considered as separate sample in analysis.

Data	Transects		Quadrats	
Transformation	Global R	p	Global R	P
Presence/Absence	0.185	5.4%	0.247	0.1%
Square Root Transformed Cover	0.179	7.0%	0.263	0.1%
Cover (no transformation)	0.192	4.7%	0.410	0.1%

Species chiefly responsible for floristic differences between rehabilitation and natural wetlands were determined using SIMPER (similarity percentages analysis) – these results are shown in Appendix 2. In terms of plant cover, the main differences were in terms of fringing *Melaleuca* species (*M. rhaphiophylla, M. lateriflora, M. preissiana* and *M. teretifolia*); all were far more common in natural wetlands and often achieving very high cover there. The sedges *Baumea articulata*, *Lepidosperma longitudinale* and *Leptocarpus* sp. were far more common in natural wetlands than rehabilitation areas. In terms of species absent or present, *Euchilopsis linearis*, *Viminaria juncea*, an unidentified species of Restionaceae and *Cytogonidium leptocarpoides* were the most widespread species within the rehabilitated areas but were not recorded at all in natural wetlands during the survey. On the other hand, *Eucalyptus rudis, Xanthorrhoea priessii*, *Pteridium esculentum* and *Pimelea* spp were found in certain parts of natural wetland systems (principally on slightly higher ground), but were not recorded in any monitoring quadrats in the rehabilitation.

5.2.5 Structure and Dominance

Considerable differences in vegetation structure occur between current rehabilitation and natural wetland vegetation. This is not surprising given the rehabilitation was between 1 to 6 years old. However one area of rehabilitation (Sector 2) has achieved high cover approaching that of natural fringing wetland vegetation within approximately 6 years (Table 5, Table 9); this demonstrates the potential for rapid revegetation under the right conditions. It is also worth noting that vegetation of natural wetlands vary greatly in their levels of tree cover, being typically highest in seasonally inundated areas of fringing vegetation and lowest on seasonally waterlogged, heavy soils (which dry out to form extremely hard surfaces in summer). There is considerable variation in the structural complexity of the natural wetlands, with the number of strata (distinct vegetation layers) within natural wetlands varying from one to five. Most rehabilitation currently comprises a single stratum (although this would be expected to change with time).

Table 9. Summary of vegetation relevés in natural wetlands areas showing cover of natives, weeds and tree, and the number of native species per relevé.

EPP Wetland	Relevé	Description	Cover Native (%)	Cover Weeds (%)	Tree Cover (%)	Native Species Richness
7	1	Lake Bed with annuals	40	0	1	2
	2	Fringing *M. rhaphiophylla*	60	2	60	3

	3	Fringing *M. rhaphiophylla* with sedge	100	10	45	5
	4	Fringing Eucalypt woodland	100	1	45	13
7b	1	Wetland Bed	60	0	30	4
	2	Fringing *M. rhaphiophylla* with sedge	60	0	40	4
	3	Fringing Eucalypt woodland	40	0	25	6
7c	1	Fringing *M. rhaphiophylla*	80	0	80	2
5	1	Wetland Bed	40	0	10	5
	2	*Melaleuca* thicket with sedge and rush	70	0	40	8
	3	Fringing *M. rhaphiophylla* with sedge	100+	0	60	10
	4	Fringing *Melaleuca* – Eucalypt Transition	100+	0	60	8
	5	Fringing mixed *Melaleuca*	80	0	60	10
	6	Fringing Eucalypt woodland	100+	0	30	13
4	1	Wetland Bed with *M. laterifolia*	45	0	45	3
	2	Fringing mixed Melaleuca	55	0	55	4
	3	Dampland Community	65	0	13	13

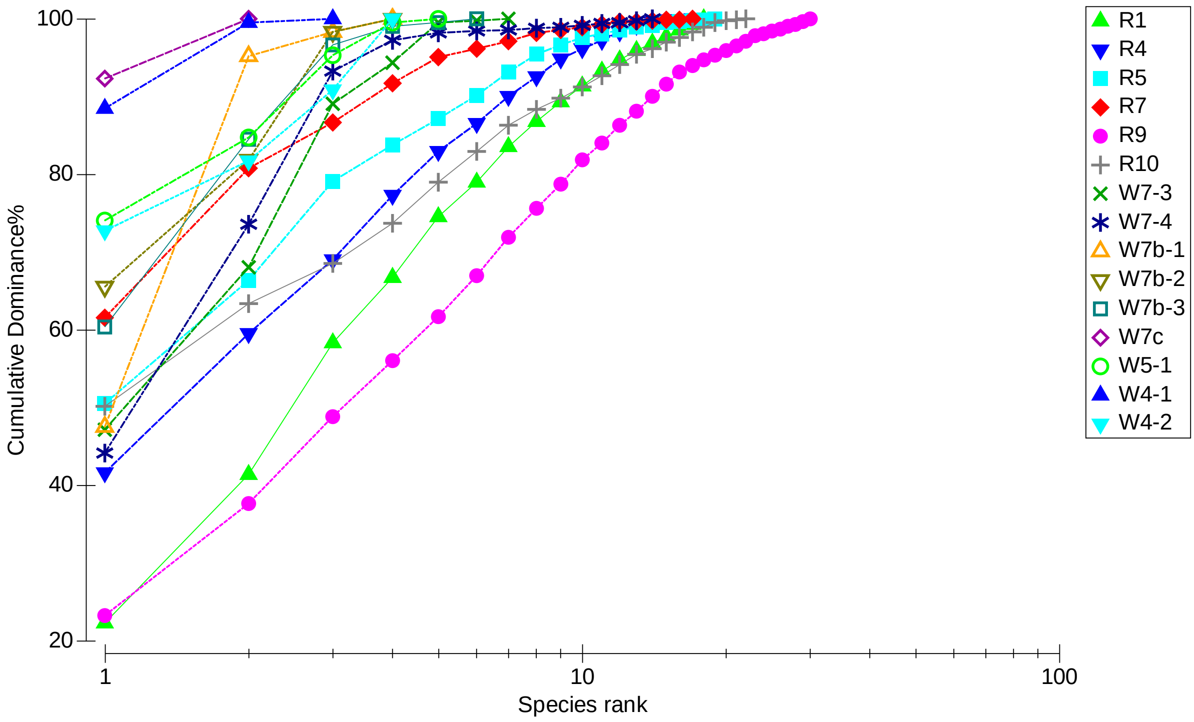


Figure 17. Dominance-diversity curves for each rehabilitation transect (R) and selected wetland releves (W). Only native species included. Basin and fringing wetland plots were excluded as they contain <3 species.

Older rehabilitation areas tend to have clear dominant species, whilst younger ones have much more even species distributions (Fig 17; Table 6). However these older sites have less clear dominance patterns than most wetland areas, particular fringing Melaleuca communities which are usually 80%+ dominated by a single species of Melaleuca. The vegetation of Sector 4 (Transect R7) has the most similar dominance patterns to natural wetland communities – this Sector has clear dominance (60% of total abundance) by *Lepidosperma longitudinale*, with the next five most common species contributing to 35% of the total abundance. This clear dominance by one to several species is more typical of wetland plant communities.

5.3 Soils

Chemical and physical characteristics of soil samples collected at each (visually) identifiable soil horizon within each Rehabilitation Sector are shown in Table 10. Rehabilitated soils were generally grey coloured (Plate 1) and fine textured (1.5 mm grain size) with concentrations of organic carbon under 2%, unlike wetland soils of 3–6% carbon. Mean rehabilitated area soil pH was also under 5, whilst wetlands soils were above pH 6. Soil pH was mildly to strongly acidic in rehabilitation, but generally in line with variation seen in natural wetland substrates. With one or two exceptions, rehabilitation soils were very low in nutrients with levels of nitrate and phosphate levels likely to be below the limits of detection limits at most sites (i.e., below 1 ppm). In contrast, levels of macro-nutrients in natural wetland soils were at least several times higher, on average, than that of rehabilitation (Table 10). Conductivity, an indicator of soil salinity, was generally lower in rehabilitated areas (Table 10).

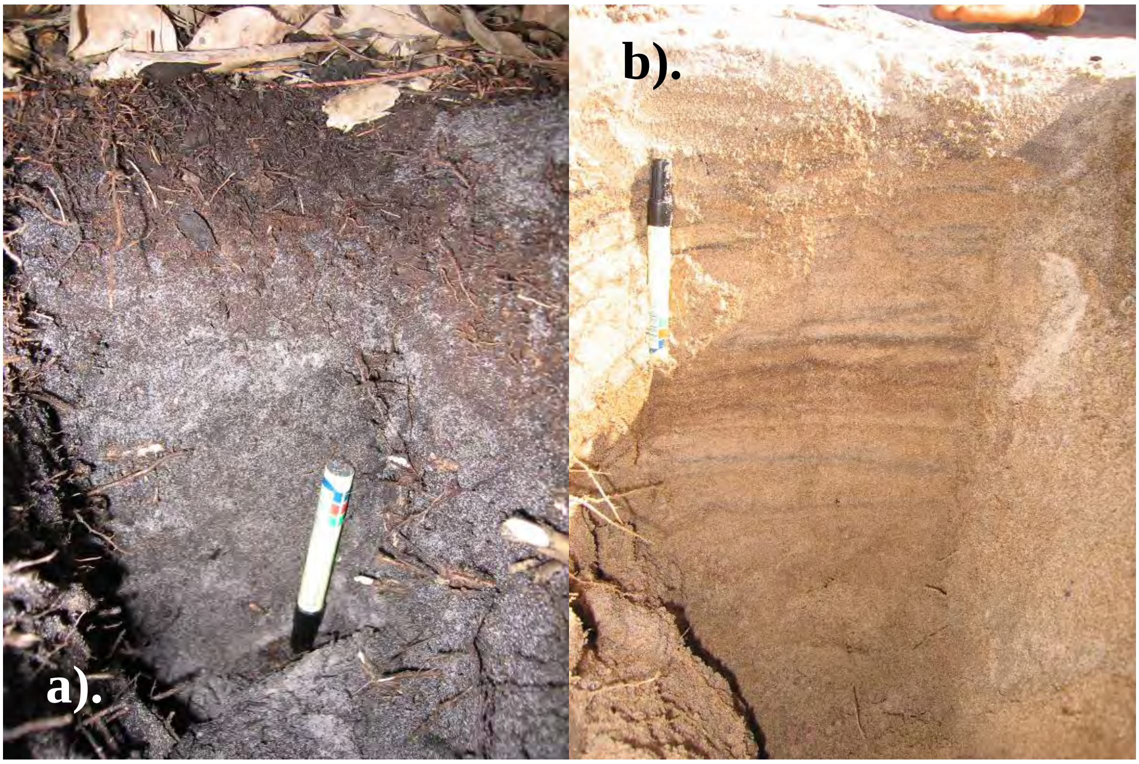


Plate 1. Typical natural wetland topsoil profile a)., and Rehabilitated Area topsoil profile b).

There were some distinct exceptions to this trend. Topsoil (first 32 cm) of Sector 2 was quite high in nitrogen in the form of ammonium. This Sector also has high organic carbon. This is not surprising given the high plant density and surface leaf litter cover in this area. Organic carbon was also relatively high in the newly rehabilitated areas, although it was somewhat higher at Sector 6 (fresh topsoil used) compared to Sector 5 (old, stored topsoil). However both these sites are low in available macronutrients (Table 10).

An ordination (Figure 18) illustrated overall differences in soil characteristics between sites and shows the rehabilitation is distinct and relatively uniform in soil when compared to the widespread variation found in natural wetlands. However no differences were detected between rehabilitated and natural wetland soils using ANOSIM tests, although this may reflect the huge variability in wetland soil characteristics. The topsoil of Sector 2 is most similar to the wetland soils, and then only that of fringing *Melaleuca* species at EPP wetland 7 (Table 10). The main differences, as determined by SIMPER, between rehabilitated and wetland soil is in terms of organic carbon, sulphur, potassium, texture and conductivity (all greater than 10% contribution to overall difference in soils, and all greater in wetlands compared to rehabilitated).

Table 10. Characteristics of distinguishable soil horizons of rehabilitation Areas and averages for natural wetland surface and sub-surface horizons.

Rehab Sector	Depth (cm)	Texture	Colour	Nitrate-N (mg/kg)	Ammonium (mg/kg)	Phosphate (mg/kg)	Potassium (mg/kg)	Sulphur (mg/kg)	Carbon (%)	Iron (mg/kg)	Conductivity (dS/cm)	pH
4	0-30	1.5	GR	1	6	2	39	10.5	1.29	289	0.079	5.6
4	30-50	1.5	GRBR	1	1	2	19	9.5	0.27	290	0.048	5.4
6	0-7	1.5	GR	1	3	2	47	7.3	2.3	453	0.038	5.5
6	7-29	1.5	GRBR	1	1	2	17	7.1	0.35	367	0.025	5.5
6	29-50	1.5	GRBR	1	1	2	15	5.9	0.28	78	0.020	5.4
1	0-50	1.5	GR	1	1	2	30	2.5	0.11	55	0.017	5.7
1	0-50	1.5	GRYW	1	1	2	15	1.9	0.11	221	0.020	6.3
1	0-10	1.5	DKGR	1	1	3	20	3.7	0.79	261	0.034	6.7
1	10-50	1.5	GR	1	1	2	16	2.8	0.16	171	0.018	6.2
5	0-10	1.5	DKGR	1	1	2	41	10.7	1.37	641	0.047	4.9
5	10-50	1.5	DKGR	1	1	2	27	9.7	1.17	243	0.053	4.9
3	0-50	1.5	DKGR	1	1	2	136	6	1.59	397	0.070	5.6
2	0-32	1.5	DKGR	1	13	2	27	6.7	2.35	179	0.066	5.3
2	32-50	1.5	GR	1	1	2	19	7.8	0.2	57	0.031	6.3
Wetland	Topsoil	2.3	–	2.3	7.9	20.3	319.1	66.9	5.9	692	1.00	6.0
Wetland	Subsoil	2.2	–	1.4	2.1	4.1	199.8	61.8	2.6	351	1.00	6.5

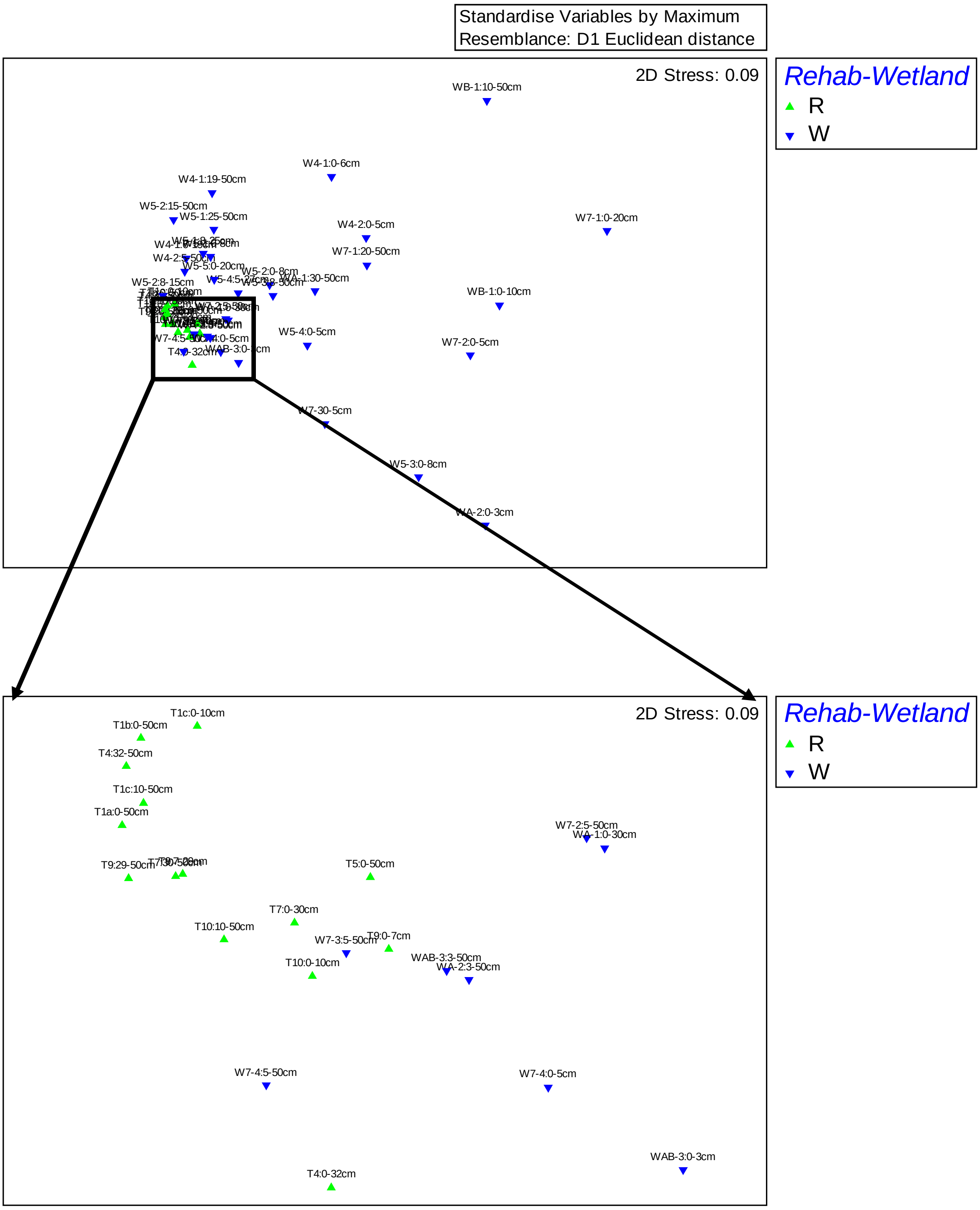
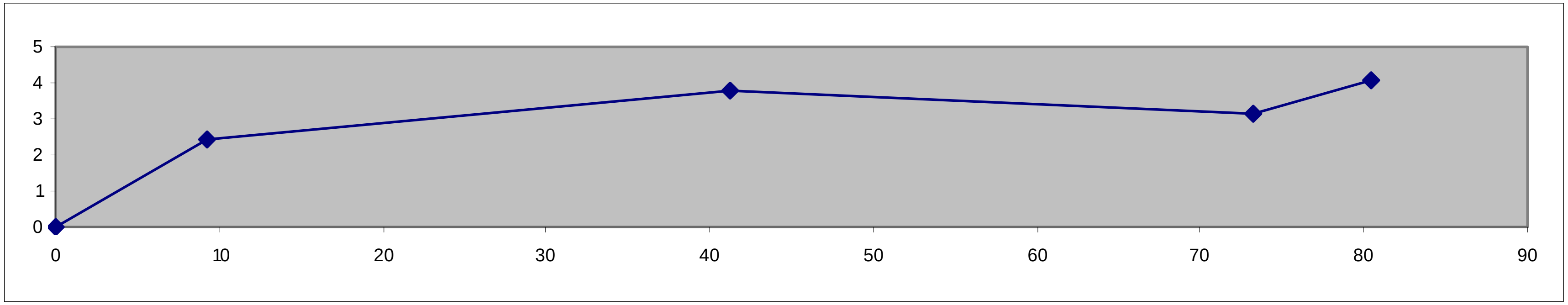


Figure 18. Ordination of rehabilitation and natural wetland quadrats and sites based on solid characteristics. Variation within rehabilitation is shown in more detail in bottom square.

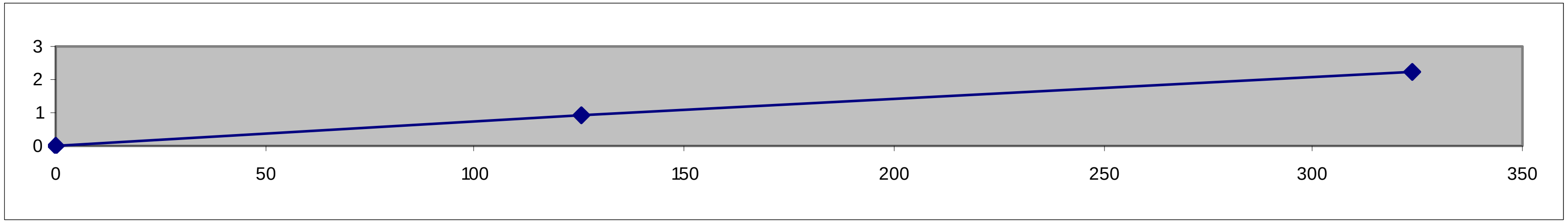
5.4 Topography

Although only four transects of rehabilitation were measured in terms of micro-topography, they demonstrate quite different slope profiles. The most recently revegetated Sectors (5 & 6) have very gradual and consistent slope, whereas the slope of Sector 1 rises relatively steeply within the first 10 m of the lake edge and is mostly 2 m above the lake level. It seems areas of poorest revegetation success are mainly in those greater than 2 m above lake levels (as of June 2007) suggesting that difficulty in accessing and utilising groundwater may be a critical factor. Areas of rehabilitated greater than 2 m above lake water were noted for the abundance of weeds, especially grasses, low species diversity and low growth rates of trees (see results for Sectors 1 & 2).

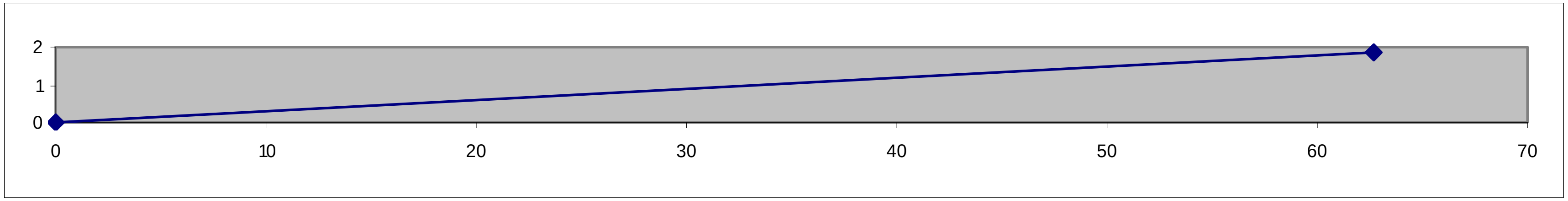
Transect #1 (Sector 1)



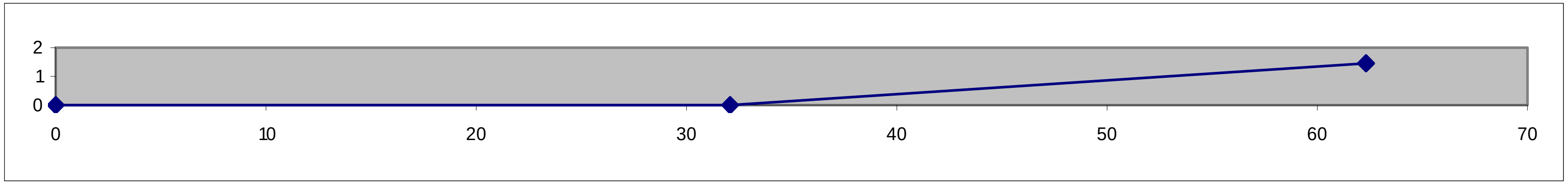
Transect #5 (Sector 3)



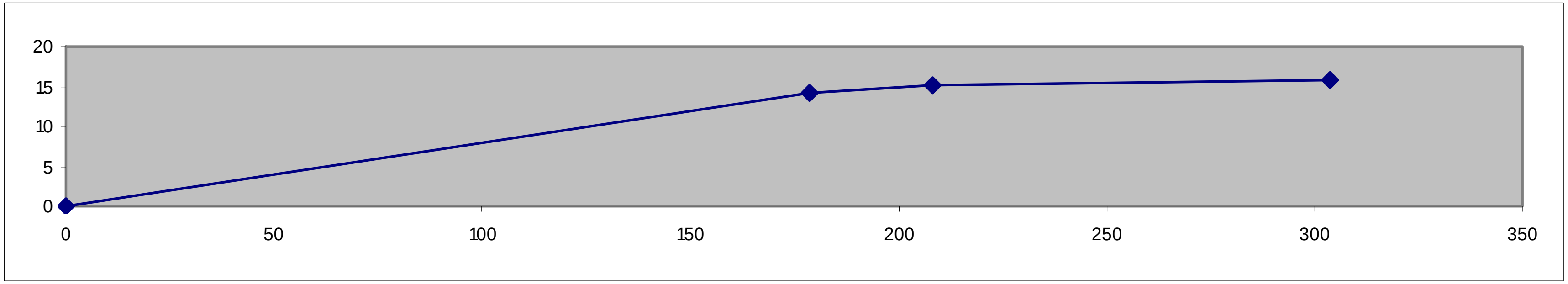
Transect #9 (Sector 6):



Transect #10 (Rehabilitated Sector 5):



Mean Natural Wetland 7



Mean Natural Wetland 5

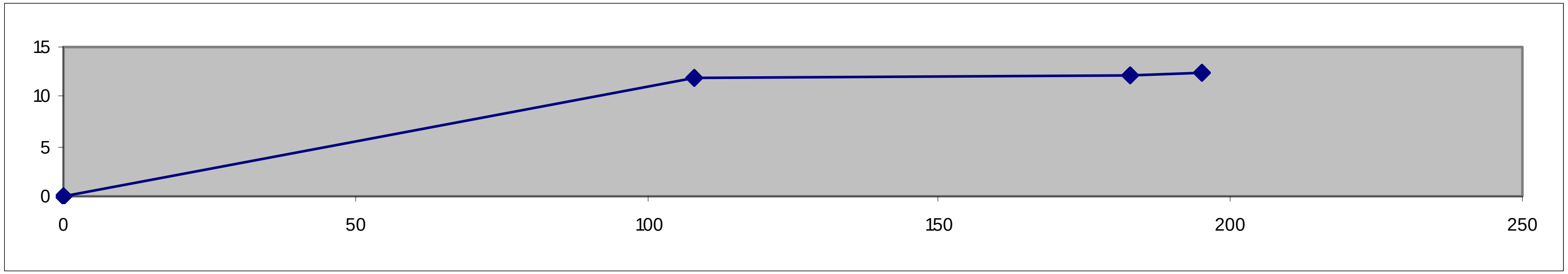


Figure 19. Topographic profiles of rehabilitated Areas around North Lake and mean profiles for wetlands 7 and 5. Vertical and horizontal axes measured in metres.

6 General rehabilitation guidelines

This review has identified both successful and not so successful rehabilitation practices employed at Kemerton over the last few years. By combining this information with that gleaned from the literature on mine-site rehabilitation/restoration, as well as that from expert opinion and current accepted practice at other mine sites of south-west W.A., a general set of recommended rehabilitation principles and strategies have been derived for future practice at Kemerton.

6.1 Rehabilitation Techniques

This review has confirmed the importance of using *fresh topsoil* as the prime method for plant species return across most rehabilitation areas. Topsoiling has the potential to return most of the plant biodiversity seen in native vegetation in the Kemerton area , but as it is unlikely to return all species, with key functional groups (eg resprouters, grass trees, small herbs) likely to be missing, it should be complemented with direct seeding and planting of targeted species (further details on such species are outlined below). To maximise the potential benefits of topsoil the following guidelines should be adhered to:

- Topsoil should be as fresh as possible, with direct return the best approach where feasible. This would require integration of mining and rehabilitation plans so that topsoil obtained when native vegetation of new mining areas is cleared is transported directly to rehab site;
- Topsoil should be spread approximately 10-30cm deep if sufficient resource is available. Spreading too thinly will tend to result in sparse vegetation; whereas seedlings may have difficultly in emerging where seeds are buried too deep;
- Topsoil should receive minimal screening and sieving as rootstock and underground storage organs (bulbs, tubers etc) may provide source of propagules and;consequently, regeneration for some species. Also organic matter and woody debris in soil is likely to be beneficial to soil stability and nutrient status;

- Litter and other debris on soil surface should also be separated and spread over topsoil. This would enhance organic matter status of topsoil, contribute to an on-going pool of nutrients in the ecosystem, and provides improved soil surface protection, especially during summer. (NB: Fine sieving of the leaf litter layer may provide a concentrated source of small seeds common for many herbaceous species. This technique could be trialled in select areas to see if it is beneficial in improving post-rehab diversity);
- Topsoil should be placed on soils/landforms which more closely reflect the characters of it origin (rather than broadly spread over all slopes). Interim guidelines recommend dividing topsoil into three zones (see next section for details).

6.2 Rehabilitation Zones

The lack of revegetation success in some sectors around North Lake seems attributable, at least in part, to poor matching of species to site characteristics. Fringing wetland vegetation is renown for it high level of variation and often distinct zonation is response to often subtle changes in topography. The depth to underlying groundwater resource is known to be very important in determining vegetation characteristics around wetlands and damplands, with the degree of groundwater fluctuations, seasonal and longer term, also influential. Therefore zonation should be based primarily on (vertical) distance above lake levels, rather than distance along slope from lake edge.

As an interim guideline, three rehabilitation zones are recommended based on height above lake levels (Figure 20). As other factors (e.g., soil and groundwater chemistry/pH) are known to influence fringing wetland vegetation of Kemerton (see complementary 'natural wetland' report; van Etten *et al*, in prep) this will be a simplification; however it should lead to an improvement over existing approaches that will also be reasonably practicable. The results of on-going monitoring should help determine how successful this division into three rehabilitation zones has been, and how it may be improved or expanded upon in the future.

Given topsoiling is recommended as the main revegetation technique, zoning will essentially require sourcing of topsoil from either 'upland' or 'fringing' native vegetation types (analogues) based on topographic position and dominant species (see Table 11). Topsoil will then need to be placed onto 'upland' or 'fringing' rehabilitation areas based on whether sites are ~ 2 m above or below high water levels of rehab lakes (Figure 20). This 2 m 'cut-off' is based primarily on measurement and observations of poor rehab performance on elevated sites, in conjunction with those of natural wetland vegetation patterns, and should be regarded as a general rule of thumb. Many species may migrate over time from one zone to another according to their requirements, dispersal means and environmental preferences, so the placement of topsoil doesn't need to be precise; however it makes sense to place species as closely to their preferred position in the landscape as this will give them the best chance of survival.

The area of 'upland' and 'fringing' rehabilitation zones depends greatly on the degree of slope, with gradual slopes resulting in more extensive areas of rehab compared to steeper slopes (Figure 20). Although topsoiling is planned as the primary means of species return in these zones, some key species found in analogue native vegetation do not seem to readily return from topsoil, or are unlikely to return in sufficient densities to form necessary structural and dominance characteristics. Such species need supplementary planting and/or direct seeding, and are outlined in Table 11.

The third rehabilitation zone is within the range of high (i.e., spring) and low (i.e., autumn) lake water levels. This range of lake levels is estimated to be around ½ m but would of course vary depending on seasonal rainfall patterns. Topsoiling here is not recommended given most of it would be inundated and washed away by shoreline wave action. Alternatively, rehabilitation techniques should focus on stabilisation of slopes using logs and other woody debris, sandbags (which could include planted sedges), and tubestock planting of sedges, paperbarks (*Melaleuca* trees) and other species tolerant of flooding. Rootstock of paperbarks have been observed resprouting and rooting when washed up at lake water edge and could be a convenient method to re-established such key species. Flooding regimes vary from lower slopes (more or less permanently flooded) to upper reaches (flooded for a few weeks only) of this zone; therefore careful locating of species according to their preferred flooding regime will be required.

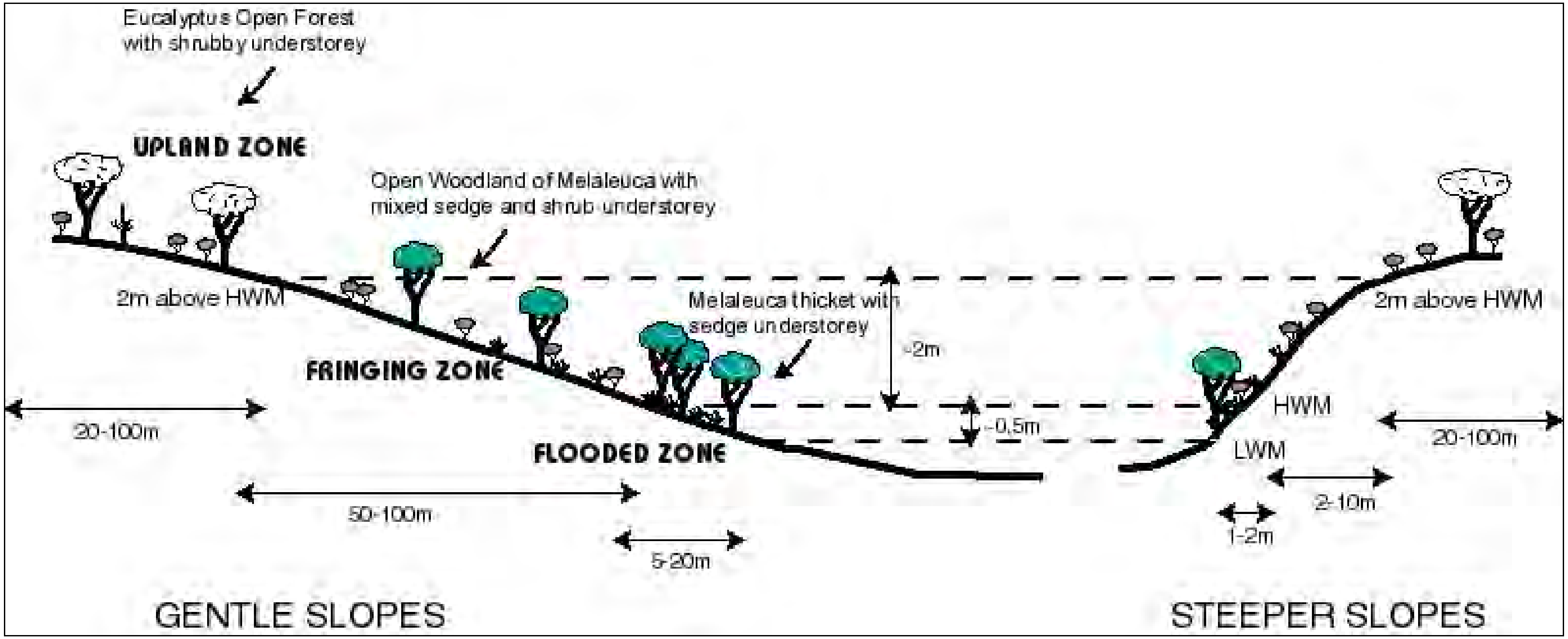


Figure 20. Generalised topographic profiles showing position of three rehabilitation zones relative to lake water levels (HWM refers to high water mark as reached in typical spring; LWM refers to low water mark as seen in typical autumn). Two profiles are shown: typical gentle slope (right) and steeper slopes (left; e.g., Sectors 1 & 2).Approximate horizontal distances and brief vegetation descriptions for each zone are also given. Note vertical and horizontal axes are at different scales.

Table 11. Typical and dominant species of three rehabilitation zones (see Figure 20) together with recommended main revegetation method and characteristics of analogue (reference) vegetation, including structural goals for rehab. Supplementary revegetation method to achieve necessary density and dominance are in parenthesis.

Rehabilitation Zone	Characteristics	Key Species & Revegetation Method (T=topsoil, P=planting of greenstock, S=direct seeding). **Typical dominant species are in bold**.
'Upland'	Open eucalypt woodland with shrubby understorey. (Approx > 2m above high water level.) **Structural Goals (% cover):** 10-30% Trees 10-20% Tall shrubs 30-60% Low shrubs and ground cover	***Eucalyptus rudis*** T (S + P) ***Corymbia calophylla*** T (S + P) ***Lepidosperma longitudinale*** T ***Pteridium esculentum*** P ***Astartea scoparia*** T ***Acacia pulchella*** T (S) *Hardenbergia comptoniana* T (S) *Agonis flexuosa* T (S) *Xanthorrhea priessii* P *Acacia saligna* T (S) *Dasypogon bromeliifolius* T (S) *Calytrix leshcenaultii* T *Jacksonia furcellata* T (S) *Hypocalymma angustifolium* T *Banksia littoralis* S (P) *Macrozamia reidlei* P (S) *Kunzea recurva* T *Eucalyptus marginata* T
'Fringing'	Open Melaleuca woodland with mixed sedge and shrubby understorey. (Approx between average high water mark to ~2m above HWM.) **Structural Goals (% cover):** 10-30% Trees 20-50% Low shrubs 20-50% Sedges and other monocots	***Melaleuca rhaphiophylla*** T (S) ***Melaleuca teretifolia*** T (S) ***Baumea articulata*** T (S) ***Lepidosperma longitudinale*** T ***Melaleuca preissiana*** T (S) *Astartea affinis* T *Kunzea ericifolia* T *Acacia saligna* T *Melaleuca lateriflora* T *Astartea scoparia* T *Leptocarpus* sp T (P) *Kunzea recurva* T *Melaleuca incana* subsp. *incana* T *Meeboldina scariosa* T *Acacia pulchella* T *Hakea trifurcata* T (S) *Melaleuca lateriflora* T (S) *Banksia littoralis* T (S) *Taxandria linearifolia* T *Juncus pallidus* T *Calothamnus lateralis* T *Pericalymma ellipticum* T *Hakea tuberculata* T (P) *Cassytha racemosa* S (P) *Euchilopsis linearis* T *Viminaria juncea* T *Cytogonidium leptocarpoides* T *Bossiaea eriocarpa* T *Banksia littoralis* S (P)

Rehabilitation Zone	Characteristics	Key Species & Revegetation Method (T=topsoil, P=planting of greenstock, S=direct seeding). **Typical dominant species are in bold**.
'Flooded'	Melaleuca thicket with sedge understorey. (Between seasonally upper and lower lake levels.) **Structural Goals (% cover):** 50-80% Trees 20-50% Sedges	***Melaleuca rhaphiophylla*** P ***Melaleuca teretifolia*** P ***Baumea articulata*** P ***Lepidosperma longitudinale*** P ***Melaleuca preissiana*** P

6.3 Soil Treatments

Although areas rehabilitated with fresh topsoil had higher organic carbon and general nutrient levels than other rehabilitation areas (at 1 year old), they were still well below the analogue wetland soils in these soil parameters. It is recommended that fertiliser be applied at time of topsoiling in upland and fringing zones, although slow release, 'complete' fertilisers are preferred given their longevity and lower likelihood to leach into aquatic ecosystems nearby.

In addition to fertilising, mulching and brushing is also recommended to stabilise topsoil (especially on steeper slopes and areas subject to wind and wave erosion) and to reduce soil evaporation. The most logical source of this material is from clearing of native vegetation for new mining areas and efforts should be made to match woody debris with topsoil given brushing material may contain woody fruits with viable plant seed (especially Myrtaceae and Proteaceae families). A chipper should be used to mulch native vegetation and this mulch should be trialled on rehab to gauge relative success. Such mulch cover on rehabilitation may be able to prevent drought deaths in young rehab over summer and early autumn, a phenomenon which has been observed recently in the 2006 rehabilitation.

6.4 Vegetation Goals

Key species and structural goals for each rehabilitation zone are summarised in Table 11. This information has been derived primarily from surveys of rehabilitation and comparisons with their natural wetland analogues. Most species have been demonstrated to return via (fresh) topsoil, although some dominant species may require supplementary seeding and/or planting to achieve their required density (Table 11). However a few species are not readily returned via topsoil. These include grass trees and their relatives (*Xanthorrhea, Kingia, Dasypogon, Lomandra*), some sedges/rushes which rely mainly on vegetative reproduction, and members of the Proteaceae family which can have difficult to germinate seeds (*Banksia littoralis* is the prime example here). These will need to be grown in nursery and planted into rehabilitated areas, and/or be seeded by hand. Although legumes have returned readily from topsoil, supplementary seeding by hand is recommended (using scarified seed) as a good initial cover of legumes is generally beneficial for nitrogen input and soil stability.

Species of Zone 3 (Flooded Zone) will be required to be planted from tubestock given topsoil and seed are unlikely to stay at site. The use of sedges planted into sandbags has proven to be a valuable establishment technique that also renders banks more stable. Logs and rootstock of Melaleuca trees should also be laid down. The duration of flooding increases with distance along slope which often results in distinct zoning of species (Figure 21). Such zonation may need to be replicated when planting in this zone based on available knowledge of flooding tolerance of wetland species (Water & Rivers Commission, 2001).

A small number of plant species could not be fully identified to species due to small size and/or lack of reproductive parts. Furthermore, greater survey effort of Kemerton wetland is likely to reveal more species, particularly rarer ones, as well as annuals and geophytes not present at time of early winter 2006 survey. Therefore the target species for rehabilitation (Table 11) should be regarded as interim list that will be expanded upon with future research and survey.

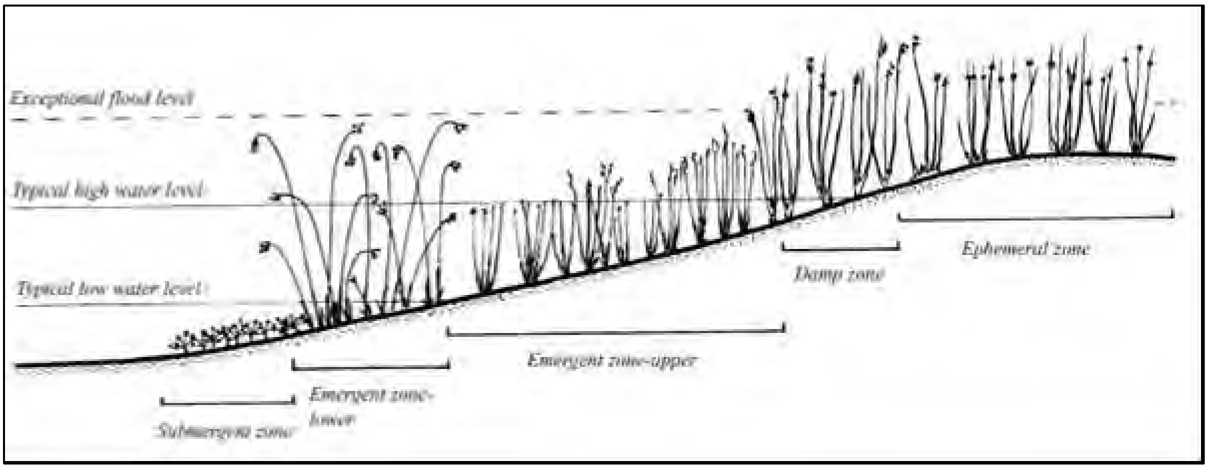


Figure 21. Example of differences in flooding regime and subsequent zonation in 'flooded' zone of wetlands. (Source: Water and Rivers Commission, 2001.)

Weed management will be a necessary component of rehabilitation at Kemerton. Sandy, upland areas seem to most prone to weed invasion and some control of weeds will be required where weeds are dominant to encourage growth of native species in rehab. However a strategic and targeted approach to weed control should be adopted in preference to large scale spraying as some level of weed cover may be beneficial in preventing wind erosion, especially on exposed slopes. Spot spraying or application of grass selective herbicide (e.g., Fusilade ®) is recommended in small patches where weeds are likely to be competing with native species and where new plantings/seeding has occurred. A complementary strategy as part of a more integrated approach to weed management would be to control weeds in lands surrounding rehabilitation, particularly along tracks and disturbed vegetation (such weed infestations provide a ready supply of weed seed into rehabilitation). Most weeds prefer growing space and full sunlight, therefore encouragement of good cover of native species is likely to be best long-term approach to minimise the adverse effects of weeds.

Herbivores (kangaroos, wallabies, rabbits etc) need to be controlled in rehab adjacent to remnant bushland to prevent large scale loss of seedlings. Rabbits can be controlled through baiting, whereas commercially available dingo/dog urine or scent should be trialled to discourage kangaroos and wallabies.

6.5 Landforming

Gradual slopes (<5%) are preferred to steeper ones as these more closely replicate natural wetland ecosystems of the region, result in larger areas of fringing wetland vegetation (Figure 19) and are less prone to water and wind erosion. Some of the steeper slopes on the eastern side of North Lake are being regularly undercut by wave action resulting in highly unstable and eroding faces which cannot be easily revegetated. Such faces will need to be battered down to gentle slopes and revegetated via topsoil (if available), seeding and/or planting.

7 Conclusions

Broad aims of successful rehabilitation are to provide a stable and self-sustaining ecosystem representative of the habitats lost to mining and of value to the region. This rehabilitated landform should blend into remaining natural landforms, yet provide no ongoing liability to these undisturbed communities.

The dredge ponds are the most prominent feature in the post-mining KSS landscape, however their depth and hydrology ensure that they are different to the surrounding natural wetlands. The aim of rehabilitation therefore should be to maximise the ponds ecological value and complement the surrounding natural wetlands rather than attempt to make them mimic natural wetlands. As vegetation around wetlands is largely determined by landform and depth to groundwater, it should be possible to recreate vegetation communities that are similar to those of natural wetlands.

This study and previous studies have shown that even minor differences in depth to groundwater result in differing plant community types (Muir Environmental, 1999). Although it would be difficult to reproduce these subtle vegetation patterns in their complexity, improvements in rehabilitation success are likely to follow if height above dredge pond water level is recognised as an important factor when deciding on appropriate revegetation approaches and techniques. It is recommended that, in the first instance, three ‘height above pond’ zones be used, each with characteristic species and structural goals and revegetation methods.

Acknowledgement must be given to the previously degraded state of KSS mined areas (McCullough *et al.*, 2007). Consequently, it is likely that scientifically-directed rehabilitation attempts of significant effort will provide for habitat superior to this previous degraded state. The ability to demonstrate this rehabilitation *improvement* upon previous ecosystem quality is both in line with the current KSS EMS (Galloway, 1997) and will also facilitate relinquishment (Arbotech Pty Ltd, 1997). Therefore, good baseline data and ongoing rehabilitation matched with appropriate and quality monitoring will be a tool to facilitate future aspirations of either project area relinquishment or extension.

8 Recommended future studies

This study highlighted a number of knowledge gaps relevant to scientifically demonstrable rehabilitation and understanding of the KSS wetland reference ecosystems. To address these gaps are series of studies and monitoring is proposed below. Generally, it is recommended that all rehabilitation undertaken is fully documented and regularly reviewed for performance. To ensure this we recommend that the Mattiske and this studies transects around North Lake are monitored annually. The success or otherwise can then feed into an adaptive management approach, ensuring that as much is learnt from each rehabilitation as possible.

1. *Quantifying levels of groundwater fluctuations and longer term trends.* The ~ ½ m seasonal fluctuations which define the proposed 'Flooded' rehabilitated zone is an estimate, so it is critical that the hydrological regime of the dredge ponds, as well as that of surrounding natural wetlands, be better understood. Also it is important to know if and to what degree groundwater levels may be declining over the long term due to rainfall reductions and even evaporation from permanent ponds;
2. *Further survey and clarification of analogue/reference wetland ecosystems*. Although the recent survey of natural wetlands of Kemerton (van Etten *et al.*, in prep) has identified many key species, four wetland systems were studied in detail. Therefore additional surveys should identify additional key 'target' species which should be returned to rehabilitated zones, especially those not readily returned via topsoil;
3. *Studies of reproductive ecology of key species not readily returned via topsoil*. Often known as recalcitrant species, a few such species and functional groups have been identified, and more are likely following further survey of wetlands (see 2.). Studies of seed germination treatments and resprouting characteristics may shed light on best methods for propagation and species return to mine-sites. This is important given wetland recalcitrants have received far less research compared to typical upland species of the south-west forests and woodlands;

4. *Explore potential for return of fringing paperbarks (*Melaleuca *tree species) using rootstock derived from cleared area*. Such resprouting from woody rootsock has been observed at the lake edge, and it may be a suitable method to return such key species in the 'flooded' rehabilitated zone. Generally the potential to use rootstock, either within topsoil or extracted from cleared areas, as source of revegetation should be evaluated.

5. *Does separating topsoil according to defined rehabilitation zones improve rehabilitation success?* In other words, on-going monitoring, including an expansion of permanent transects to capture variation within and between these zones, should be done to determine benefit of this approach and how it may be improved upon.

6. *Benefits of using sieved surface litter.* Some mining companies have reported benefits in sieving the surface litter layer to remove and concentrate seed of certain species (usually small seeded herbs, grasses etc) and sowing such seed over topsoil to improve post-mining species diversity;

7. *Benefits of using litter, plant debris and mulch e.g., (chipped woody plants) as cover for topsoil.* Does such coverage lead to improvements in to soil health, nutrition, stability and moisture retention which, in turn, improve rehab success?

8. *Seed store assessment of existing rehabilitation and potential topsoil sources.* Achieved through subjecting topsoil to ideal condition in a glasshouse, such studies would clarify the fundamental potential of soils to improve species diversity in rehabilitation, as well as what sorts of topsoil are best sources for rehabilitation. Additionally this information can help assess the degree to which existing rehab is on a trajectory toward self-sustenance.

9 References

Arbotech Pty Ltd (1997). *Annual Environmental Report*. Arbotech Pty Ltd, Perth, Australia. 39+pp.

Clarke, K. R. & Gorley, R. N. (2001). *PRIMER v5. User Manual*. PRIMER-E, Plymouth. 91pp.

English, V. & Blyth , J. (2000). *Shrublands and woodlands on Muchea Limestone - interim recovery plan 2000-2003*. Department of Conservation and Land Management, WA Threatened Species and Community Unit, Perth, Australia.

Environmental Protection Authority (2005). *Kemerton Silica Sand mining revised proposal - additional mining areas and transfer of land for conservation.* Report and recommendations of the Environmental Protection Authority Bulletin 1183. Environmental Protection Authority, Perth, Australia.

Galloway, R. (1997). *Gwalia Consolidfated Ltd. Kemerton Silica Sand Pty Ltd, proposal for the monitoring and rehabilitation program*. Arbotech Pty Ltd, Perth, Australia. 7pp.

Mattiske Consulting Pty Ltd (2004). *Assessment of rehabilitated wetland areas 2004 - Kemerton Silica Sands Limited - Kemerton operations*. KSS0401/025/03. Mattiske Consulting Pty Ltd, Perth, Australia. 15pp.

Mattiske Consulting Pty Ltd (2005). *Assessment of rehabilitated wetland areas 2005 - Kemerton Silica Sands Limited - Kemerton operations*. KSS0501/166/05. Mattiske Consulting Pty Ltd, Perth, Australia. 14pp.

Mattiske, E. M. & Havel, J. J. (1998). *Vegetation complexes of the South-west forest region of Western Australia*. Mattiske Consulting P/L, Perth, Australia.

McCullough, C. D.; Lund, M. A. & van Etten, E. (2007). *Synthesis of existing data and knowledge gaps for the rehabilitation of Kemerton Silica Sand mine dredge ponds*. Report number 2007-04. Centre for Ecosystem Management, Edith Cowan University, Perth, Australia. 53pp. Unpublished commercial-in-confidence report to Kemerton Silica Sands Pty Ltd.

Muir Environmental (1999). *Report of Biological Survey - Phase 1: Kemerton Industrial Estate*. Unpublished Report for Landcorp.

PRIMER-E Ltd (2006). PRIMER. 6.1.5, Plymouth Marine Laboratory, Plymouth.

Semeniuk, C. A. (1987). Wetlands of the Darling system - a geomorphic approach to habitat classification. *Journal of the Royal Society of Western Australia* 69: 95-112.

Water and Rivers Commission 2000, Using rushes and sedges in revegetation of wetland areas in the south west of WA, Water and Rivers Commission, River Restoration Report No. RR 8

10 Appendices

Appendix 1: SIMPER (Similarity Percentages - species contributions) results showing species which contribute to defining rehabilitation transects (groups) and species which account for differences between rehabilitation transects (groups).

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%
Group refers to transect number

Group 10
Average similarity: 29.90

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Hypocalymma angustifolium	0.88	6.30	0.92	21.09	21.09
Kunzea ericifolia	0.75	5.11	0.60	17.08	38.16
Acacia pulchella	0.74	4.94	0.85	16.52	54.69
Euchilopsis linearis	0.63	3.93	0.61	13.16	67.84
Pericalymma ellipticum	0.49	2.45	0.57	8.20	76.04
Calothamnus lateralis	0.66	2.03	0.39	6.80	82.84
Melaleuca sp.	0.35	1.22	0.37	4.07	86.92
Papillionaceae sp	0.35	1.16	0.37	3.89	90.81

Group 1
Average similarity: 30.96

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Hypocalymma angustifolium	1.51	20.17	2.41	65.14	65.14
Acacia pulchella	0.58	3.58	0.52	11.57	76.71
Melaleuca preissiana	0.57	1.53	0.25	4.95	81.66
Euchilopsis linearis	0.42	1.02	0.26	3.29	84.95
Pultenaea ochreata	0.37	0.90	0.26	2.92	87.87
Kunzea ericifolia	0.24	0.90	0.26	2.90	90.77

Group 4
Average similarity: 44.48

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Leptocarpus sp.	3.04	15.08	2.33	33.91	33.91
Lepidosperma longitudinale	2.09	10.39	2.60	23.36	57.27
Astartea scoparia	3.55	8.68	0.67	19.52	76.79
Melaleuca rhaphiophylla	1.38	3.74	0.68	8.40	85.19
Melaleuca lateriflora	1.47	2.74	0.49	6.16	91.35

Group 5
Average similarity: 35.01

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Kunzea recurva	2.08	19.22	1.60	54.89	54.89
Astartea scoparia	1.03	9.40	0.71	26.84	81.72
Jacksonia furcellata	0.45	2.38	0.49	6.79	88.51
Acacia pulchella	0.32	1.09	0.22	3.11	91.62

Group 7
Average similarity: 63.75

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Lepidosperma longitudinale	3.97	39.45	3.64	61.88	61.88

Myrtaceae sp.	2.06	16.62	2.33	26.06	87.94
Hypocalymma angustifolium	0.99	6.49	1.59	10.18	98.12

Group 9
Average similarity: 54.77

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Acacia pulchella	1.42	13.14	3.99	24.00	24.00
Hypocalymma angustifolium	1.06	8.98	3.20	16.40	40.40
Lepidosperma longitudinale	0.90	6.20	1.26	11.33	51.73
Melaleuca preissiana	0.45	4.87	5.50	8.90	60.63
Kunzea ericifolia	0.62	4.17	1.35	7.62	68.25
Pericalymma ellipticum	0.68	4.02	1.28	7.35	75.60
Platysace filiformis	0.56	2.75	0.83	5.01	80.61
Hypolaena sp.	0.42	2.65	0.91	4.84	85.45
Melaleuca sp.	0.32	2.14	0.91	3.91	89.36
Empodisma gracillimum	0.49	2.05	0.55	3.74	93.11

Groups 10 & 1
Average dissimilarity = 76.43

	Group 10	Group 1				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Hypocalymma angustifolium	0.88	1.51	7.56	1.03	9.89	9.89
Kunzea ericifolia	0.75	0.24	7.10	0.76	9.29	19.17
Euchilopsis linearis	0.63	0.42	5.49	1.09	7.18	26.35
Acacia pulchella	0.74	0.58	5.47	1.13	7.15	33.51
Calothamnus lateralis	0.66	0.00	4.88	0.78	6.38	39.89
Melaleuca preissiana	0.00	0.57	4.47	0.60	5.85	45.74
Baumea articulata	0.00	0.49	3.86	0.43	5.05	50.79
Pericalymma ellipticum	0.49	0.00	3.51	1.05	4.60	55.39
Pultenaea ochreata	0.14	0.37	3.19	0.72	4.17	59.56
Lepidosperma longitude.	0.35	0.20	3.00	0.86	3.93	63.49
Melaleuca lateriflora	0.14	0.28	2.77	0.61	3.63	67.12
Melaleuca sp.	0.35	0.00	2.70	0.78	3.53	70.65
Astartea scoparia	0.35	0.00	2.64	0.76	3.45	74.10
Papillionaceae sp	0.35	0.00	2.63	0.78	3.44	77.54
Viminaria juncea	0.20	0.10	1.97	0.52	2.58	80.12
Acacia saligna	0.00	0.24	1.83	0.48	2.39	82.51
Melaleuca rhaphiophylla	0.00	0.17	1.56	0.32	2.04	84.55
Gompholobium sp.	0.21	0.00	1.53	0.58	2.01	86.55
Acacia sp.	0.21	0.00	1.51	0.58	1.98	88.53
Eucalyptus marginata	0.00	0.19	1.49	0.58	1.96	90.49

Groups 10 & 4
Average dissimilarity = 93.68

	Group 10	Group 4				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Astartea scoparia	0.35	3.55	14.18	1.01	15.14	15.14
Leptocarpus sp.	0.00	3.04	13.93	2.19	14.87	30.01
Lepidosperma longitudinale	0.35	2.09	7.99	1.81	8.53	38.54
Melaleuca lateriflora	0.14	1.47	6.93	0.81	7.40	45.94
Melaleuca rhaphiophylla	0.00	1.38	6.04	1.08	6.45	52.39
Hypocalymma angustifolium	0.88	0.00	3.70	1.41	3.95	56.34
Kunzea ericifolia	0.75	0.00	3.66	0.86	3.91	60.25
Melaleuca incana	0.00	0.79	3.28	0.62	3.50	63.75
Acacia pulchella	0.74	0.00	3.19	1.23	3.40	67.15
Viminaria juncea	0.20	0.61	2.82	0.61	3.01	70.16
Calothamnus lateralis	0.66	0.00	2.78	0.78	2.97	73.12
Euchilopsis linearis	0.63	0.06	2.71	1.15	2.89	76.02
Melaleuca preissiana	0.00	0.65	2.56	0.65	2.73	78.75
Kunzea recurva	0.00	0.56	2.40	1.16	2.57	81.32
Pericalymma ellipticum	0.49	0.00	2.03	1.05	2.17	83.48
Acacia saligna	0.00	0.52	2.02	0.51	2.16	85.64
Hypolaena sp.	0.00	0.40	1.75	0.52	1.87	87.51
Melaleuca sp.	0.35	0.00	1.51	0.78	1.61	89.12
Papillionaceae sp	0.35	0.00	1.48	0.79	1.58	90.70

Groups 1 & 4

Average dissimilarity = 93.01

Species	Group 1 Av.Abund	Group 4 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Astartea scoparia	0.00	3.55	15.61	1.03	16.78	16.78
Leptocarpus sp.	0.00	3.04	14.63	2.20	15.73	32.51
Lepidosperma longitudinale	0.20	2.09	9.04	2.03	9.72	42.23
Melaleuca lateriflora	0.28	1.47	7.22	0.83	7.76	50.00
Hypocalymma angustifolium	1.51	0.00	7.00	2.40	7.53	57.53
Melaleuca rhaphiophylla	0.17	1.38	6.22	1.11	6.69	64.22
Melaleuca preissiana	0.57	0.65	4.03	0.90	4.34	68.55
Melaleuca incana	0.00	0.79	3.42	0.62	3.68	72.23
Baumea articulata	0.49	0.34	3.22	0.64	3.47	75.70
Acacia saligna	0.24	0.52	2.73	0.68	2.93	78.63
Viminaria juncea	0.10	0.61	2.65	0.56	2.85	81.48
Acacia pulchella	0.58	0.00	2.62	0.96	2.81	84.29
Kunzea recurva	0.00	0.56	2.52	1.16	2.71	87.00
Hypolaena sp.	0.19	0.40	2.25	0.70	2.42	89.42
Euchilopsis linearis	0.42	0.06	1.96	0.67	2.11	91.52

Groups 10 & 5

Average dissimilarity = 93.25

Species	Group 10 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Kunzea recurva	0.00	2.08	15.63	1.45	16.76	16.76
Astartea scoparia	0.35	1.03	8.09	1.01	8.68	25.44
Kunzea ericifolia	0.75	0.00	7.52	0.73	8.07	33.51
Hypocalymma angustifolium	0.88	0.00	6.42	1.39	6.89	40.39
Acacia pulchella	0.74	0.32	5.73	1.12	6.15	46.54
Euchilopsis linearis	0.63	0.00	4.87	1.06	5.22	51.76
Calothamnus lateralis	0.66	0.00	4.80	0.78	5.15	56.91
Viminaria juncea	0.20	0.51	4.70	0.57	5.04	61.95
Jacksonia furcellata	0.00	0.45	3.46	0.82	3.71	65.66
Pericalymma ellipticum	0.49	0.00	3.46	1.04	3.71	69.37
Acacia saligna	0.00	0.48	3.20	0.55	3.43	72.80
Corymbia calophylla	0.00	0.44	2.74	0.44	2.94	75.74
Melaleuca sp.	0.35	0.00	2.65	0.78	2.85	78.58
Papillionaceae sp	0.35	0.00	2.59	0.78	2.77	81.36
Lepidosperma longitudinale	0.35	0.00	2.43	0.77	2.61	83.96
Gompholobium sp.	0.21	0.00	1.51	0.58	1.62	85.58
Acacia sp.	0.21	0.00	1.49	0.58	1.60	87.18
Cytogonidium leptocarpoides	0.00	0.19	1.24	0.47	1.32	88.50
Aotus gracillima	0.14	0.00	1.19	0.40	1.28	89.78
Daviesia ?preissii	0.00	0.15	1.18	0.36	1.26	91.04

Groups 1 & 5

Average dissimilarity = 96.06

Species	Group 1 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Kunzea recurva	0.00	2.08	16.94	1.47	17.64	17.64
Hypocalymma angustifolium	1.51	0.00	13.37	2.10	13.92	31.55
Astartea scoparia	0.00	1.03	9.78	1.03	10.18	41.73
Acacia pulchella	0.58	0.32	5.52	0.95	5.75	47.48
Melaleuca preissiana	0.57	0.00	4.77	0.60	4.96	52.45
Viminaria juncea	0.10	0.51	4.64	0.53	4.83	57.28
Acacia saligna	0.24	0.48	4.58	0.74	4.77	62.05
Baumea articulata	0.49	0.00	4.12	0.44	4.29	66.33
Jacksonia furcellata	0.00	0.45	3.76	0.83	3.91	70.25
Corymbia calophylla	0.14	0.44	3.74	0.58	3.90	74.14
Euchilopsis linearis	0.42	0.00	3.30	0.61	3.44	77.58
Pultenaea ochreata	0.37	0.00	2.79	0.62	2.90	80.48
Kunzea ericifolia	0.24	0.00	2.37	0.61	2.47	82.95
Melaleuca lateriflora	0.28	0.00	2.30	0.48	2.40	85.35
Melaleuca rhaphiophylla	0.17	0.00	1.67	0.32	1.74	87.09
Eucalyptus marginata	0.19	0.00	1.59	0.58	1.66	88.75
Lepidosperma longitudinale	0.20	0.00	1.46	0.49	1.52	90.27

Groups 4 & 5

Average dissimilarity = 87.32

Species	Group 4 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptocarpus sp.	3.04	0.00	14.46	2.19	16.56	16.56
Astartea scoparia	3.55	1.03	13.77	1.07	15.76	32.32
Lepidosperma longitudinale	2.09	0.00	9.77	2.48	11.19	43.51
Melaleuca lateriflora	1.47	0.00	7.25	0.80	8.30	51.81
Kunzea recurva	0.56	2.08	7.18	1.15	8.22	60.04
Melaleuca rhaphiophylla	1.38	0.00	6.25	1.09	7.16	67.20
Viminaria juncea	0.61	0.51	3.95	0.70	4.53	71.72
Melaleuca incana	0.79	0.00	3.39	0.62	3.88	75.60
Acacia saligna	0.52	0.48	3.38	0.78	3.87	79.48
Melaleuca preissiana	0.65	0.00	2.64	0.65	3.03	82.50
Jacksonia furcellata	0.00	0.45	2.00	0.84	2.29	84.80
Hypolaena sp.	0.40	0.00	1.81	0.52	2.07	86.87
Corymbia calophylla	0.00	0.44	1.73	0.43	1.90	88.85
Acacia pulchella	0.00	0.32	1.55	0.55	1.77	90.63

Groups 10 & 7

Average dissimilarity = 85.11

Species	Group 10 Av.Abund	Group 7 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Lepidosperma longitudinale	0.35	3.97	24.08	2.66	28.29	28.29
Myrtaceae sp.	0.00	2.06	13.24	2.25	15.55	43.85
Kunzea ericifolia	0.75	0.29	6.68	0.89	7.85	51.69
Hypocalymma angustifolium	0.88	0.99	4.85	1.12	5.69	57.39
Acacia pulchella	0.74	0.00	4.66	1.23	5.48	62.86
Euchilopsis linearis	0.63	0.22	4.14	1.06	4.87	67.73
Calothamnus lateralis	0.66	0.00	4.02	0.79	4.72	72.45
Pericalymma ellipticum	0.49	0.09	2.98	1.05	3.50	75.95
Astartea scoparia	0.35	0.22	2.78	0.86	3.26	79.21
Melaleuca sp.	0.35	0.00	2.20	0.79	2.59	81.80
Papillionaceae sp	0.35	0.00	2.16	0.79	2.53	84.33
Leptocarpus sp.	0.00	0.27	1.81	0.58	2.13	86.46
Gompholobium sp.	0.21	0.04	1.36	0.64	1.60	88.06
Acacia sp.	0.21	0.00	1.25	0.58	1.47	89.52
Viminaria juncea	0.20	0.00	1.17	0.40	1.37	90.90

Groups 1 & 7

Average dissimilarity = 85.48

Species	Group 1 Av.Abund	Group 7 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Lepidosperma longitudinale	0.20	3.97	26.79	2.93	31.33	31.33
Myrtaceae sp.	0.00	2.06	14.17	2.31	16.57	47.91
Hypocalymma angustifolium	1.51	0.99	6.43	1.31	7.52	55.43
Acacia pulchella	0.58	0.00	3.90	0.96	4.57	60.00
Melaleuca preissiana	0.57	0.00	3.88	0.61	4.54	64.54
Euchilopsis linearis	0.42	0.22	3.62	0.75	4.24	68.78
Kunzea ericifolia	0.24	0.29	3.59	0.57	4.20	72.98
Baumea articulata	0.49	0.00	3.34	0.45	3.91	76.88
Pultenaea ochreata	0.37	0.00	2.32	0.63	2.71	79.60
Leptocarpus sp.	0.00	0.27	1.95	0.58	2.28	81.88
Melaleuca lateriflora	0.28	0.00	1.89	0.49	2.21	84.08
Acacia saligna	0.24	0.00	1.60	0.49	1.87	85.95
Melaleuca rhaphiophylla	0.17	0.04	1.51	0.38	1.76	87.71
Astartea scoparia	0.00	0.22	1.40	0.44	1.63	89.34
Eucalyptus marginata	0.19	0.00	1.30	0.59	1.52	90.86

Groups 4 & 7

Average dissimilarity = 79.22

Species	Group 4 Av.Abund	Group 7 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Astartea scoparia	3.55	0.22	13.42	1.02	16.94	16.94
Leptocarpus sp.	3.04	0.27	11.73	2.00	14.81	31.75
Myrtaceae sp.	0.00	2.06	8.28	2.24	10.45	42.20
Lepidosperma longitudinale	2.09	3.97	7.92	1.91	9.99	52.20

Melaleuca lateriflora	1.47	0.00	6.42	0.80	8.11	60.30
Melaleuca rhaphiophylla	1.38	0.04	5.56	1.11	7.02	67.32
Hypocalymma angustifolium	0.00	0.99	3.91	1.35	4.94	72.26
Melaleuca incana	0.79	0.00	3.05	0.63	3.85	76.11
Melaleuca preissiana	0.65	0.00	2.38	0.65	3.01	79.12
Kunzea recurva	0.56	0.00	2.23	1.17	2.81	81.93
Viminaria juncea	0.61	0.00	2.17	0.49	2.74	84.67
Acacia saligna	0.52	0.00	1.89	0.51	2.38	87.05
Hypolaena sp.	0.40	0.00	1.62	0.52	2.05	89.10
Baumea articulata	0.34	0.00	1.36	0.46	1.72	90.82

Groups 5 & 7
Average dissimilarity = 98.12

Species	Group 5 Av.Abund	Group 7 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Lepidosperma longitudinale	0.00	3.97	27.57	3.34	28.10	28.10
Myrtaceae sp.	0.00	2.06	13.95	2.28	14.22	42.32
Kunzea recurva	2.08	0.00	13.58	1.50	13.84	56.16
Astartea scoparia	1.03	0.22	7.26	1.07	7.40	63.56
Hypocalymma angustifolium	0.00	0.99	6.50	1.41	6.63	70.19
Viminaria juncea	0.51	0.00	3.36	0.47	3.43	73.61
Jacksonia furcellata	0.45	0.00	3.00	0.84	3.06	76.67
Acacia saligna	0.48	0.00	2.84	0.56	2.89	79.56
Corymbia calophylla	0.44	0.00	2.45	0.44	2.49	82.05
Acacia pulchella	0.32	0.00	2.42	0.54	2.46	84.52
Kunzea ericifolia	0.00	0.29	2.06	0.31	2.09	86.61
Leptocarpus sp.	0.00	0.27	1.92	0.58	1.95	88.56
Euchilopsis linearis	0.00	0.22	1.71	0.44	1.74	90.30

Groups 10 & 9
Average dissimilarity = 65.94

Species	Group 10 Av.Abund	Group 9 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Acacia pulchella	0.74	1.42	5.12	1.24	7.76	7.76
Kunzea ericifolia	0.75	0.62	4.65	0.93	7.06	14.82
Lepidosperma longitudinale	0.35	0.90	4.47	1.28	6.78	21.59
Calothamnus lateralis	0.66	0.21	4.07	0.90	6.17	27.76
Euchilopsis linearis	0.63	0.33	3.90	1.30	5.92	33.68
Hypocalymma angustifolium	0.88	1.06	3.73	1.11	5.66	39.34
Pericalymma ellipticum	0.49	0.68	3.32	1.27	5.03	44.37
Platysace filiformis	0.00	0.56	3.22	1.29	4.89	49.26
Empodisma gracillimum	0.00	0.49	3.01	0.98	4.56	53.82
Hypolaena sp.	0.00	0.42	2.89	1.18	4.39	58.21
Melaleuca preissiana	0.00	0.45	2.86	4.21	4.34	62.55
Melaleuca sp.	0.35	0.32	2.47	1.31	3.74	66.29
Astartea scoparia	0.35	0.13	2.30	0.98	3.48	69.77
Papillionaceae sp	0.35	0.13	2.23	0.95	3.38	73.15
unknown #2	0.00	0.27	1.65	0.76	2.50	75.65
Viminaria juncea	0.20	0.14	1.60	0.55	2.43	78.08
Gompholobium sp.	0.21	0.13	1.53	0.77	2.31	80.39
Acacia sp.	0.21	0.06	1.39	0.68	2.10	82.49
unknown sp#1	0.00	0.21	1.34	0.56	2.03	84.53
Dasypogon bromeliifolius	0.00	0.19	1.28	0.82	1.93	86.46
Bossiaea eriocarpa	0.06	0.13	0.95	0.69	1.44	87.90
Aotus gracillima	0.14	0.00	0.93	0.40	1.41	89.31
Pultenaea ochreata	0.14	0.00	0.90	0.40	1.36	90.67

Groups 1 & 9
Average dissimilarity = 72.03

Species	Group 1 Av.Abund	Group 9 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Acacia pulchella	0.58	1.42	6.13	1.30	8.51	8.51
Lepidosperma longitudinale	0.20	0.90	5.31	1.45	7.37	15.89
Melaleuca preissiana	0.57	0.45	4.98	1.33	6.92	22.81
Hypocalymma angustifolium	1.51	1.06	4.66	1.23	6.47	29.27
Pericalymma ellipticum	0.00	0.68	4.28	1.65	5.95	35.22

Euchilopsis linearis	0.42	0.33	3.55	0.95	4.93	40.15
Kunzea ericifolia	0.24	0.62	3.49	1.54	4.84	45.00
Platysace filiformis	0.00	0.56	3.43	1.30	4.76	49.76
Empodisma gracillimum	0.00	0.49	3.21	0.98	4.46	54.22
Baumea articulata	0.49	0.00	3.19	0.45	4.43	58.65
Hypolaena sp.	0.19	0.42	2.86	1.12	3.97	62.62
Pultenaea ochreata	0.37	0.00	2.23	0.62	3.09	65.71
Melaleuca sp.	0.00	0.32	2.08	1.44	2.89	68.60
Melaleuca lateriflora	0.28	0.00	1.81	0.49	2.51	71.11
unknown #2	0.00	0.27	1.76	0.76	2.44	73.54
Acacia saligna	0.24	0.00	1.53	0.49	2.12	75.67
unknown sp#1	0.00	0.21	1.43	0.56	1.99	77.66
Dasypogon bromeliifolius	0.00	0.19	1.37	0.83	1.90	79.56
Melaleuca rhaphiophylla	0.17	0.00	1.26	0.33	1.75	81.30
Eucalyptus marginata	0.19	0.00	1.24	0.59	1.72	83.02
Viminaria juncea	0.10	0.14	1.17	0.51	1.63	84.65
Calothamnus lateralis	0.00	0.21	1.11	0.60	1.54	86.19
Astartea scoparia	0.00	0.13	1.04	0.61	1.45	87.64
Hardenbergia comptoniana	0.14	0.00	0.94	0.44	1.31	88.94
Corymbia calophylla	0.14	0.00	0.92	0.45	1.27	90.22

Groups 4 & 9
Average dissimilarity = 89.71

Species	Group 4 Av.Abund	Group 9 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Astartea scoparia	3.55	0.13	13.18	1.03	14.69	14.69
Leptocarpus sp.	3.04	0.00	12.47	2.25	13.90	28.59
Melaleuca lateriflora	1.47	0.00	6.23	0.79	6.94	35.54
Acacia pulchella	0.00	1.42	5.63	4.31	6.28	41.81
Melaleuca rhaphiophylla	1.38	0.00	5.44	1.09	6.06	47.87
Lepidosperma longitudinale	2.09	0.90	5.06	1.40	5.64	53.51
Hypocalymma angustifolium	0.00	1.06	4.11	3.15	4.58	58.09
Melaleuca incana	0.79	0.00	2.97	0.62	3.31	61.40
Melaleuca preissiana	0.65	0.45	2.84	1.18	3.16	64.56
Pericalymma ellipticum	0.00	0.68	2.59	1.62	2.88	67.45
Hypolaena sp.	0.40	0.42	2.49	1.12	2.77	70.22
Kunzea ericifolia	0.00	0.62	2.41	1.78	2.68	72.90
Viminaria juncea	0.61	0.14	2.35	0.56	2.62	75.53
Kunzea recurva	0.56	0.00	2.17	1.16	2.41	77.94
Platysace filiformis	0.00	0.56	2.09	1.31	2.33	80.27
Empodisma gracillimum	0.00	0.49	1.91	1.02	2.13	82.40
Acacia saligna	0.52	0.00	1.84	0.51	2.05	84.45
Baumea articulata	0.34	0.00	1.32	0.46	1.48	85.93
Melaleuca sp.	0.00	0.32	1.24	1.50	1.38	87.31
Euchilopsis linearis	0.06	0.33	1.23	0.79	1.37	88.68
unknown #2	0.00	0.27	1.06	0.76	1.18	89.86
Melaleuca osullivanii	0.28	0.00	0.92	0.37	1.03	90.89

Groups 5 & 9
Average dissimilarity = 94.15

Species	Group 5 Av.Abund	Group 9 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Kunzea recurva	2.08	0.00	13.00	1.48	13.81	13.81
Acacia pulchella	0.32	1.42	7.55	2.02	8.02	21.82
Astartea scoparia	1.03	0.13	6.88	1.16	7.31	29.14
Hypocalymma angustifolium	0.00	1.06	6.78	3.35	7.21	36.34
Lepidosperma longitudinale	0.00	0.90	5.82	1.73	6.19	42.53
Pericalymma ellipticum	0.00	0.68	4.22	1.64	4.48	47.01
Kunzea ericifolia	0.00	0.62	3.98	1.79	4.23	51.25
Viminaria juncea	0.51	0.14	3.61	0.54	3.84	55.08
Platysace filiformis	0.00	0.56	3.38	1.30	3.59	58.67
Empodisma gracillimum	0.00	0.49	3.17	0.98	3.36	62.03
Hypolaena sp.	0.00	0.42	3.06	1.18	3.25	65.28
Melaleuca preissiana	0.00	0.45	3.01	4.19	3.20	68.48
Jacksonia furcellata	0.45	0.00	2.87	0.84	3.05	71.53
Acacia saligna	0.48	0.00	2.72	0.56	2.89	74.42
Corymbia calophylla	0.44	0.00	2.36	0.44	2.50	76.92

Melaleuca sp.	0.00	0.32	2.05	1.44	2.18	79.10
Euchilopsis linearis	0.00	0.33	1.91	0.77	2.02	81.13
unknown #2	0.00	0.27	1.73	0.76	1.84	82.97
unknown sp#1	0.00	0.21	1.41	0.56	1.50	84.47
Dasypogon bromeliifolius	0.00	0.19	1.35	0.83	1.43	85.90
Calothamnus lateralis	0.00	0.21	1.09	0.60	1.16	87.06
Cytogonidium leptocarpoides	0.19	0.00	1.06	0.47	1.12	88.18
Daviesia ?preissii	0.15	0.00	0.98	0.37	1.04	89.22
Papillionaceae sp	0.00	0.13	0.86	0.62	0.91	90.13

Groups 7 & 9

Average dissimilarity = 79.14

	Group 7	Group 9				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Lepidosperma longitudinale	3.97	0.90	17.35	2.52	21.92	21.92
Myrtaceae sp.	2.06	0.06	10.98	2.17	13.87	35.80
Acacia pulchella	0.00	1.42	7.98	4.28	10.09	45.88
Kunzea ericifolia	0.29	0.62	4.42	1.14	5.59	51.47
Pericalymma ellipticum	0.09	0.68	3.52	1.60	4.45	55.92
Hypocalymma angustifolium	0.99	1.06	3.22	0.96	4.07	60.00
Platysace filiformis	0.00	0.56	2.90	1.32	3.67	63.67
Empodisma gracillimum	0.00	0.49	2.69	1.00	3.40	67.07
Hypolaena sp.	0.00	0.42	2.56	1.22	3.23	70.30
Melaleuca preissiana	0.00	0.45	2.55	5.57	3.22	73.52
Euchilopsis linearis	0.22	0.33	2.40	0.84	3.04	76.56
Melaleuca sp.	0.00	0.32	1.75	1.49	2.21	78.76
Astartea scoparia	0.22	0.13	1.71	0.74	2.16	80.92
Leptocarpus sp.	0.27	0.00	1.54	0.59	1.95	82.87
unknown #2	0.00	0.27	1.48	0.77	1.87	84.74
unknown sp#1	0.00	0.21	1.20	0.56	1.51	86.25
Dasypogon bromeliifolius	0.00	0.19	1.13	0.84	1.43	87.68
Calothamnus lateralis	0.00	0.21	0.96	0.60	1.21	88.89
Jacksonia sp.	0.13	0.00	0.74	0.42	0.94	89.83
Papillionaceae sp	0.00	0.13	0.73	0.62	0.92	90.75

Appendix 2: SIMPER (Similarity Percentages - species contributions) results comparing rehabilitation (R) and natural wetlands (W).

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%
Group R
Average similarity: 36.32

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Euchilopsis linearis	0.83	3.52	1.32	9.70	9.70
Lepidosperma longitudinale	0.83	3.52	1.32	9.70	19.41
Astartea scoparia	0.83	3.48	1.32	9.59	28.99
Viminaria juncea	0.83	3.44	1.33	9.47	38.46
Hypocalymma angustifolium	0.67	2.05	0.77	5.65	44.12
Kunzea ericifolia	0.67	2.05	0.77	5.65	49.77
Restionaceae sp.	0.67	2.02	0.77	5.57	55.34
Acacia pulchella	0.67	1.99	0.78	5.49	60.83
Melaleuca rhaphiophylla	0.50	1.25	0.48	3.44	64.27
Cytogonidium leptocarpoides	0.50	1.23	0.48	3.37	67.64
Acacia saligna	0.50	1.20	0.48	3.30	70.95
Melaleuca lateriflora	0.50	1.13	0.48	3.12	74.07
Hypolaena sp.	0.50	0.99	0.48	2.73	76.80
Melaleuca preissiana	0.50	0.99	0.48	2.73	79.53
Gompholobium sp.	0.50	0.96	0.48	2.63	82.16
Pericalymma ellipticum	0.50	0.96	0.48	2.63	84.79
Leptocarpus sp.	0.33	0.42	0.26	1.15	85.94
Baumea articulata	0.33	0.40	0.26	1.11	87.05
Corymbia calophylla	0.33	0.40	0.26	1.11	88.16
Hardenbergia comptoniana	0.33	0.40	0.26	1.11	89.28
Cyperaceae	0.33	0.39	0.26	1.08	90.36

Group W
Average similarity: 20.26

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Melaleuca rhaphiophylla	0.59	7.56	0.62	37.31	37.31
Lepidosperma longitudinale	0.53	3.19	0.55	15.75	53.07
Melaleuca lateriflora	0.41	2.27	0.40	11.20	64.27
Baumea articulata	0.35	1.84	0.34	9.08	73.35
Leptocarpus sp.	0.35	1.76	0.33	8.69	82.04
Astartea scoparia	0.29	0.81	0.27	4.01	86.05
Melaleuca preissiana	0.24	0.45	0.21	2.22	88.27
Melaleuca incana subsp. incana	0.18	0.29	0.14	1.45	89.72
Eucalyptus rudis	0.18	0.25	0.15	1.25	90.97

Groups R & W
Average dissimilarity = 83.28

	Group R	Group W				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Euchilopsis linearis	.83	0.00	3.38	1.94	4.06	4.06
Viminaria juncea	.83	0.00	3.31	1.97	3.98	8.04
Astartea scoparia	.83	0.29	2.67	1.25	3.20	11.24
Restionaceae sp.	.67	0.00	2.63	1.30	3.15	14.39
Kunzea ericifolia	.67	0.06	2.58	1.25	3.10	17.49
Acacia pulchella	.67	0.12	2.48	1.22	2.98	20.47
Hypocalymma angustifolium	.67	0.18	2.47	1.16	2.97	23.45
Cytogonidium leptocarpoides	.50	0.00	2.24	0.97	2.69	26.13
Acacia saligna	.50	0.12	2.17	0.97	2.61	28.74
Lepidosperma longitudinale	0.83	0.53	2.10	0.92	2.53	31.26
Melaleuca lateriflora	0.50	0.41	2.07	0.95	2.48	33.75
Melaleuca preissiana	0.50	0.24	1.99	0.95	2.39	36.13
Melaleuca rhaphiophylla	0.50	0.59	1.99	0.96	2.39	38.52
Hypolaena sp.	0.50	0.06	1.96	0.94	2.35	40.87

Pericalymma ellipticum	0.50	0.06	1.91	0.94	2.30	43.17
Gompholobium sp.	0.50	0.00	1.90	0.94	2.29	45.46
Leptocarpus sp.	0.33	0.35	1.89	0.87	2.27	47.73
Baumea articulata	0.33	0.35	1.88	0.87	2.26	49.99
Kunzea recurva	0.33	0.18	1.63	0.78	1.96	51.95
Corymbia calophylla	0.33	0.12	1.59	0.74	1.91	53.85
Hardenbergia comptoniana	0.33	0.06	1.53	0.72	1.84	55.69
Cyperaceae	0.33	0.00	1.44	0.69	1.74	57.43
Melaleuca osullivanii	0.33	0.00	1.44	0.69	1.74	59.16
Jacksonia sp.	0.33	0.00	1.43	0.69	1.72	60.88
Pultenaea ochreata	0.33	0.00	1.39	0.69	1.67	62.55
Lomandra?	0.33	0.00	1.27	0.66	1.52	64.07
Myrtaceae sp.	0.33	0.00	1.27	0.66	1.52	65.59
Papillionaceae sp	0.33	0.06	1.20	0.72	1.44	67.03
Calothamnus lateralis	0.33	0.06	1.19	0.72	1.43	68.46
Melaleuca incana	0.17	0.18	1.17	0.61	1.40	69.86
Acacia sp.	0.33	0.00	1.11	0.68	1.33	71.20
Bossiaea eriocarpa	0.33	0.00	1.11	0.68	1.33	72.53
Melaleuca sp.	0.33	0.00	1.11	0.68	1.33	73.86
Eucalyptus marginata	0.17	0.12	1.03	0.55	1.24	75.10
Cassytha glabella	0.17	0.06	0.90	0.50	1.08	76.18
Melaleuca teretifolia	0.17	0.12	0.89	0.54	1.07	77.26
Jacksonia furcellata	0.17	0.06	0.84	0.50	1.01	78.27
Dasypogon bromeliifolius	0.17	0.12	0.80	0.55	0.96	79.23
unknown #5	0.17	0.00	0.79	0.44	0.95	80.18
Daviesia ?preissii	0.17	0.00	0.72	0.44	0.87	81.05
Grassy weeds	0.17	0.00	0.72	0.44	0.87	81.92
Juncus sp.	0.17	0.00	0.72	0.44	0.87	82.79
Loxocarya sp.	0.17	0.00	0.72	0.44	0.87	83.65
Patersonia occidentalis	0.17	0.00	0.72	0.44	0.87	84.52
Eucalyptus rudis	0.00	0.18	0.65	0.45	0.78	85.30
Aotus gracillima	0.17	0.00	0.64	0.44	0.77	86.07
Poaceae sp	0.17	0.00	0.64	0.44	0.77	86.84
Xanthorrhea priessii	0.00	0.18	0.62	0.45	0.74	87.58
Pimelea sp	0.00	0.12	0.48	0.36	0.57	88.15
?Conostylis sp.	0.17	0.00	0.47	0.44	0.57	88.72
Acacia uliginosa	0.17	0.00	0.47	0.44	0.57	89.28
Empodisma gracillimum	0.17	0.00	0.47	0.44	0.57	89.85
Platysace filiformis	0.17	0.00	0.47	0.44	0.57	90.42

Appendix 3: Average cover of each species at each monitoring transect.

REHAB SECTOR:	**1**	**2**	**3**	**4**	**6**	**5**
MONITORING TRANSECT:	**1**	**4**	**5**	**7**	**9**	**10**
*Grassy weeds	3.0	0.0	21.0	0.0	0.0	2.9
*Other weeds	3.5	0.0	4.7	1.4	0.3	11.0
?*Conostylis* sp.	0.0	0.0	0.0	0.0	0.0	0.0
Acacia pulchella	0.7	0.0	0.4	0.0	2.1	0.9
Acacia saligna	0.3	1.4	0.9	0.0	0.0	0.0
Acacia sp.	0.0	0.0	0.0	0.0	0.0	0.2
Acacia uliginosa	0.0	0.0	0.0	0.0	0.0	0.0
Aotus gracillima	0.0	0.0	0.0	0.0	0.0	0.1
Astartea scoparia	0.0	24.6	1.9	0.3	0.1	0.3
Baumea articulate	1.3	0.7	0.0	0.0	0.0	0.0
Bossiaea eriocarpa	0.0	0.0	0.0	0.0	0.1	0.0
Calothamnus lateralis	0.0	0.0	0.0	0.0	0.2	1.1
Cassytha glabella	0.0	0.0	0.1	0.0	0.0	0.0
Corymbia calophylla	0.1	0.0	1.3	0.0	0.0	0.0
Cyperaceae	0.0	0.3	0.1	0.0	0.0	0.0
Cytogonidium leptocarpoides	0.0	0.0	0.2	0.1	0.0	0.0
Dasypogon bromeliifolius	0.0	0.0	0.0	0.0	0.1	0.0
Daviesia ?preissii	0.0	0.0	0.2	0.0	0.0	0.0
Empodisma gracillimum	0.0	0.0	0.0	0.0	0.5	0.0
Eucalyptus marginate	0.1	0.0	0.0	0.0	0.0	0.0
Euchilopsis linearis	0.7	0.0	0.0	0.3	0.3	0.7
Gompholobium sp.	0.0	0.0	0.0	0.0	0.1	0.2
Grassy weeds	0.0	0.0	1.3	0.0	0.0	0.0
Hardenbergia comptoniana	0.1	0.0	0.0	0.0	0.0	0.0
Hypocalymma angustifolium	2.6	0.0	0.0	1.6	1.3	1.1
Hypolaena sp.	0.1	0.8	0.0	0.0	0.3	0.0
Jacksonia furcellata	0.0	0.0	0.5	0.0	0.0	0.0
Jacksonia sp.	0.0	0.0	0.0	0.1	0.0	0.0
Juncus sp.	0.0	0.1	0.0	0.0	0.0	0.0
Kunzea ericifolia	0.2	0.0	0.0	0.9	0.5	1.1
Kunzea recurve	0.0	0.5	6.6	0.0	0.0	0.0
Lepidosperma longitudinale	0.2	4.9	0.0	16.6	1.0	0.3
Leptocarpus sp.	0.0	10.5	0.0	0.3	0.0	0.0
Lomandra?	0.0	0.0	0.0	0.0	0.0	0.0
Loxocarya sp.	0.0	0.0	0.1	0.0	0.0	0.0
Melaleuca incana subsp. Incana	0.0	2.1	0.0	0.0	0.0	0.0
Melaleuca lateriflora	0.4	5.6	0.0	0.0	0.0	0.1
Melaleuca osullivanii	0.0	0.6	0.1	0.0	0.0	0.0
Melaleuca preissiana	1.2	1.5	0.0	0.0	0.2	0.0
Melaleuca rhaphiophylla	0.3	3.4	0.0	0.0	0.0	0.0
Melaleuca sp.	0.0	0.0	0.0	0.0	0.1	0.3
Melaleuca teretifolia	0.0	0.0	0.0	0.0	0.1	0.0
Myrtaceae sp.	0.0	0.0	0.0	5.2	0.0	0.0
Other weeds	0.0	0.0	0.1	0.0	0.0	0.0
Papillionaceae sp	0.0	0.0	0.0	0.0	0.1	0.3
Patersonia occidentalis	0.0	0.0	0.1	0.0	0.0	0.0
Pericalymma ellipticum	0.0	0.0	0.0	0.1	0.7	0.5
Platysace filiformis	0.0	0.0	0.0	0.0	0.5	0.0
Poaceae sp	0.0	0.0	0.0	0.0	0.0	0.1

REHAB SECTOR:	**1**	**2**	**3**	**4**	**6**	**5**
MONITORING TRANSECT:	**1**	**4**	**5**	**7**	**9**	**10**
Pultenaea ochreata	0.5	0.0	0.0	0.0	0.0	0.1
Restionaceae sp.	0.0	0.0	0.1	0.0	0.0	0.0
unknown #2	0.0	0.0	0.0	0.0	0.2	0.0
unknown #3	0.0	0.0	0.0	0.0	0.1	0.0
unknown #4	0.0	0.0	0.0	0.0	0.0	0.0
unknown #5	0.0	0.0	0.0	0.1	0.0	0.0
unknown sp#1	0.0	0.0	0.0	0.0	0.2	0.0
Viminaria juncea	0.1	2.0	1.4	0.0	0.1	0.3

APPENDIX 8:
EVALUATION OF POST-MINING REHABILITATION AT THE KEMERTON SILICA SAND PROJECT AREA
FEBRUARY 2009
CENTRE FOR ECOSYSTEM MANAGEMENT
EDITH COWAN UNIVERSITY

Centre for ecosystem management

EDITH COWAN
UNIVERSITY
PERTH WESTERN AUSTRALIA

February 2009

EVALUATION OF POST MINING REHABILITATION EFFORTS AT THE KEMERTON SILICA SAND PTY. LTD. PROJECT AREA, NOVEMBER 2008

By, Dr. Eddie van Etten
Dr. Clint McCullough
Assoc. Prof. Mark Lund

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Frontispiece

Plate 1:. Rehabilitated edge of 'North Lake' dredge pond near transect 7 looking east (November 2008).

1 Executive Summary

- Eddie van Etten and colleagues at ECU's Centre for Ecosystem Management (CEM) were engaged to evaluate rehabilitation at the KSS minesite at Kemerton in mid 2007 and to provide recommendation to help improve restoration success of post-mining environments. In early November 2008, KSS contracted the CEM to report on changes to rehabilitation since 2007 and to evaluate their most recent rehabilitation.

- Overall, the monitoring has revealed a slight to modest improvement in rehabilitation since the previous monitoring in mid 2007. Plant cover showed the most marked increase from 2007, with plant abundance and species richness generally stable overall

- Generally plant cover increased more substantially in low-lying areas closer to lake, with new species appearing more readily in such areas. Areas higher in the topographic profile have experience a decline in fringing/flooded zone species such as Melaleucas, rushes and sedges. Therefore it is apparent that some degree of species sorting according to moisture and flooding preferences is occurring. This is encouraging, as is the seemingly natural recolonisation in lower areas by sedges, melaleucas and other wetland species.

- Differences between rehabilitation sectors revealed in previously monitoring were mostly maintained and can be clearly related to differences in rehabilitation technique and topographic position in relation to lake levels. This and previous monitoring confirm that good to excellent ecological restoration can be achieved at post-mining landscape at Kemerton through use of fresh topsoil. Matching of topsoil to topographic position should improve overall rehabilitation success. Recent rehabilitation of low-lying areas using topsoil has achieved excellent results at the Kemerton mine site. The challenge now is to improve upland restoration so it achieves similar success in terms of return of plant cover, species richness and resemblance to nearby native upland communities.

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3 Study Area, Monitoring Sites & Methods

3.1 Location & Study Area

The Kemerton Silica Sand Pty Ltd (KSS) project area occupies some 1 600 ha of land at the northern end of Kemerton Industrial Park, 20 km north of Bunbury (Figure). The KSS Project Area is located in the Swan Coastal Plain, primarily on gently undulating Bassendean Sands, with vegetation comprising *Eucalypt-Banksia* woodland on uplands and wetlands on lower parts of the landscape.

Feldspathic silica sands are extracted from below the water table using dredge ponds. The resource generally lies beneath <1 m of topsoil and 4 to 7 m of overburden (which generally contains a band of coffee rock at the inter-phase between high and low groundwater levels). The overburden is removed by earth moving equipment. The ore resource is then extracted from a 30 m deep superficial aquifer using a surface floating dredge to a maximum permitted depth of 15 m. Once ore extraction is complete, the dredge pond is approximately 10 m deep. As the dredge pond is essentially an expression of the groundwater, the results are permanently inundated lakes. Fines, overburden and topsoil are available for sculpting and landscaping of the dredge ponds and surrounds.

The study has focussed on the main rehabilitation area around the northern most dredge pond of the Kemerton active mining area, hereafter referred to as “North Lake” (Figure 1). This area was mined and the pond created in the late 1990’s. Rehabilitation of the surrounding slopes commenced in 2001 and progressively implemented until 2007 with different techniques used in different areas (known as rehab ‘sectors’). Active mining is currently occurring in dredge ponds immediately south of North Lake, with the southern edge of the dredge ponds rehabilitated in 2007. This rehabilitation was monitored for the first time in this study.

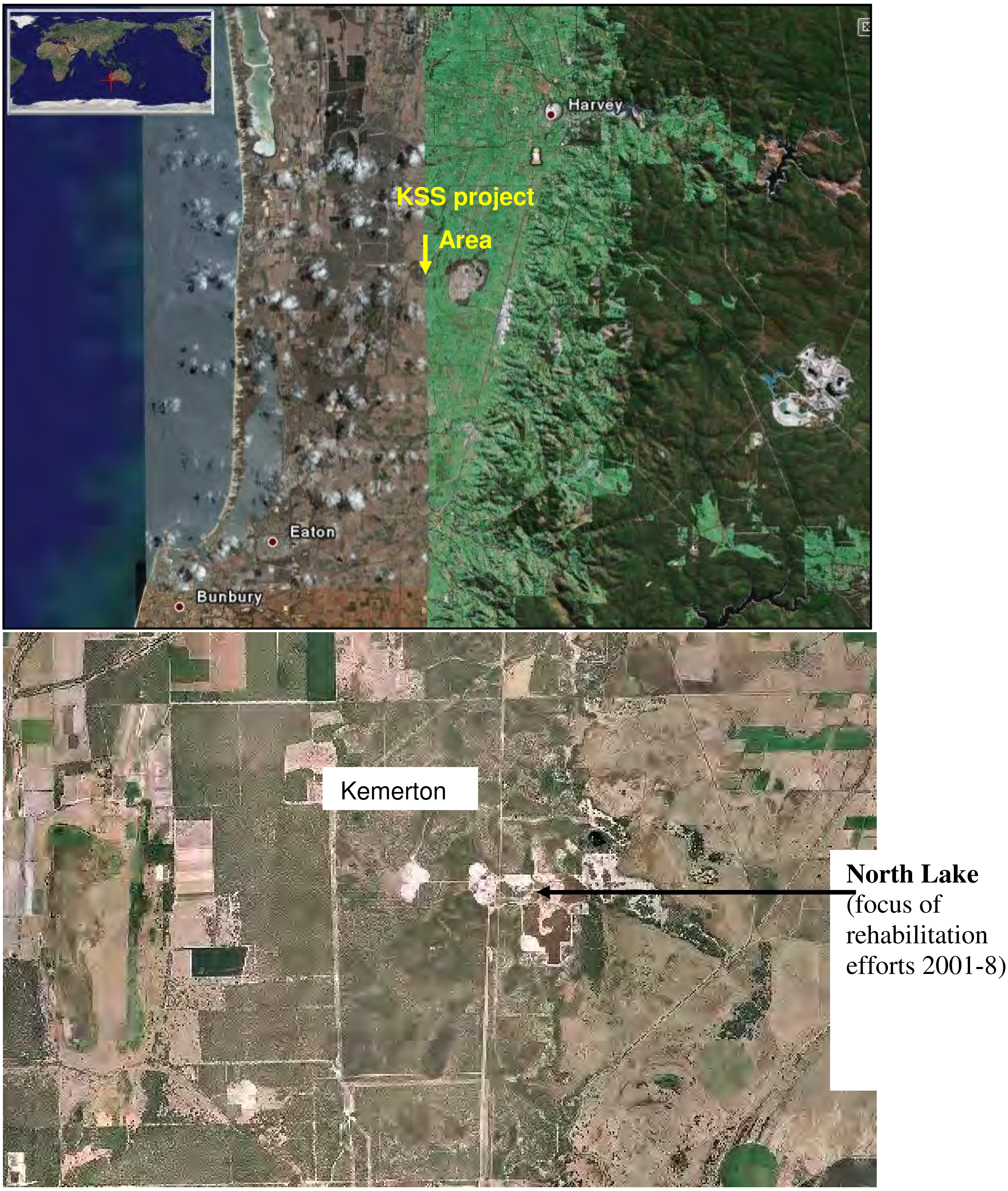

Figure 1. Location of Kemerton wetlands and mine site in south-western Australia.

3.2 Rehabilitation History & Sectors

The slopes of North Lake have been progressively rehabilitated between 2001 and 2007. We have identified six distinct rehabilitation areas or 'sectors' delineated by different histories of soil treatments and revegetation techniques, as well as fundamental environmental differences. These are described in Table 1 and are mapped in Figure 2.

Table 1. Summary of rehabilitation history and monitoring around North Lake.

Sector	Monitoring Transect	Area (ha)	Treatment(s)	Monitoring History
1 (north-east)	Mattiske #1	~2	**Feb 2001**: contoured and spread with topsoil (and understorey debris) **Autumn/winter 2002**: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags **Autumn 2006:** ripped, hand-seeded, brushed, herbicide and fertilised/limed	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM **November 2008**: CEM
2 (east)	Mattiske #4	~2	**Feb 2001**: contoured and spread with topsoil (and understorey debris) **Autumn/winter 2002**: minor ripping on contour, herbicide treatment and planting of seedlings (in gaps only); fertilised and covered with tree bags	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM **November 2008**: CEM
3 (south-east)	Mattiske #5	~1	**Feb 2001**: contoured and spread with topsoil (and understorey debris) **Autumn/winter 2002**: major ripping on contour, herbicide treatment, planting of seedlings' fertilised and covered with tree bags **Autumn 2006:** hand-seeded and fertilised/limed	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM **November 2008**: CEM
4 (west)	Mattiske #7	~4	**April 2003**: contoured and spread with 20cm topsoil (and understorey debris)	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM **November 2008**: CEM
5 (north)	New Transect (#10)	~2	**Autumn 2006**: contoured and spread with 10 year old, stored topsoil (with some understorey debris)	**June 2007**: CEM **November 2008**: CEM
6 (south)	New Transect (#9)	~2	**Autumn 2006:** contoured and spread with direct fresh topsoil return (understorey debris). Most topsoil from dampland Area. Upland soil placed on higher ground	**June 2007**: CEM **November 2008**: CEM

Sector	Monitoring Transect	Area (ha)	Treatment(s)	Monitoring History

Figure 2. Aerial photograph from 2006 showing Sectors around North Lake. Topsoil has been recently applied to Sector 5 in the photo. Position of monitoring transects are shown by red lines.

3.3 Climate

Average rainfall in the Kemerton Area is around 900 mm per year (based on interpolation of Bureau of Meteorology records from Bunbury, some 20 km to the south, and Wokalup, some 10 km to the north-east). Rainfall is distinctly Mediterranean in distribution, with the vast majority of precipitation falling in winter and spring (

Figure). Summers are typically very dry and warm to hot, whereas winters are cool and wet (Figure). Frosts are rare, with an average of 1 day per year with minimum ground temperatures below -1^{o}C recorded at Wokalup, although this seems to be increasing with dry winters.

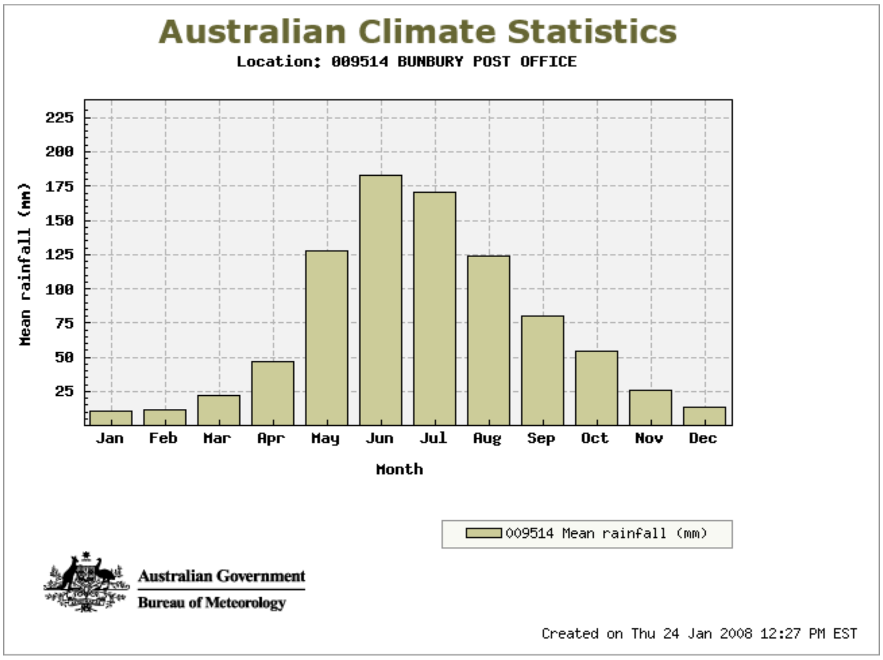

Figure 3. Average monthly rainfall for Bunbury P.O. (1880-1985) (Source: Bureau of Meteorology 2008).

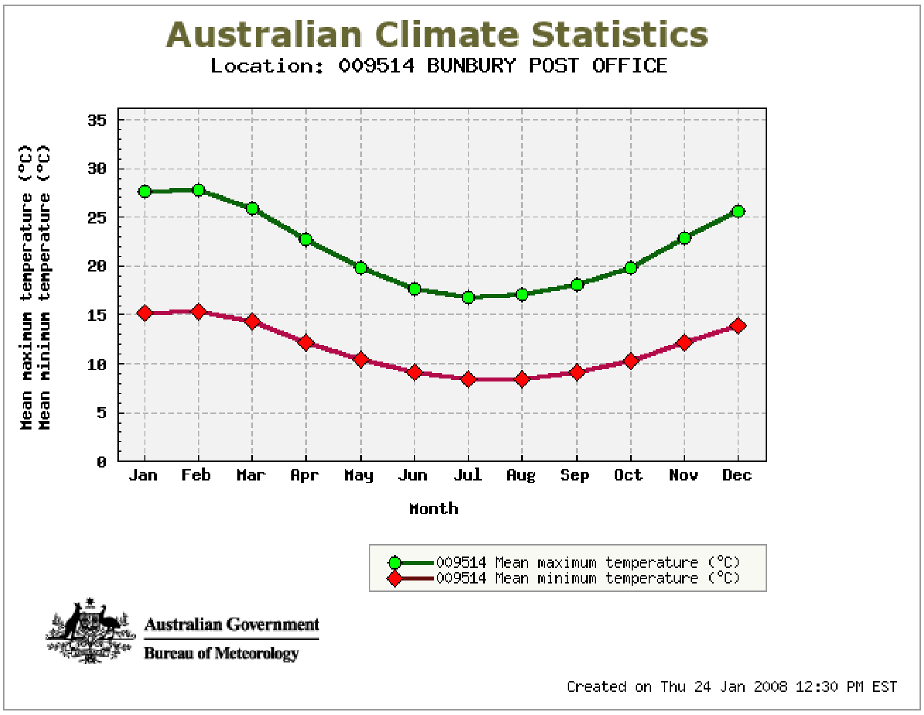

Figure 4. Average monthly maximum and minimum temperatures for Bunbury P.O. (1880-1985). (Source: Bureau of Meteorology 2008).

The rehabilitation period 2001–2008 was one of the driest periods on record (Figure). Each year was below the long term average, with many below the recent (1996–2006) average. The year 2006 was very close to the lowest annual rainfall on record. Since then, two years (2007-8) just under the long-term average have occurred.

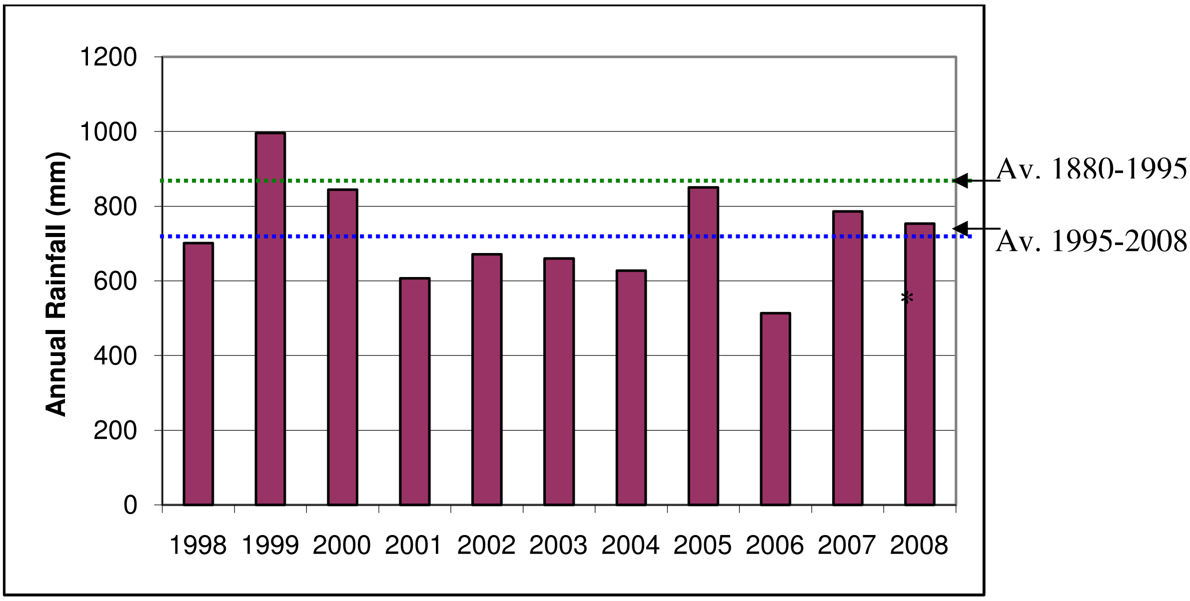

Figure 5. Annual rainfall for Bunbury for the period 1998-2008 compared against average annual rainfall for 1880-1995 (long-term; green broken line) and 1995-2006 (recent; blue broken line

3.4 Rehabilitation Monitoring Methods

Assessment of exiting rehabilitation was made through re-measurement of existing permanent monitoring transects established by Mattiske Consulting P/L in 2004-5 and the Centre for Ecosystem Management in 2007. One monitoring transect was measured in each of the six distinct rehabilitation sectors (as defined above). In addition a new transect was established in recent rehabilitation on the southern edge of the dredge ponds. Field measurements took place on 6th and 7th November 2008.

Each monitoring transect was positioned transverse to the slope and extended from the lake shoreline to the end of the rehabilitation at the top of the slope. They varied in length from 80 to 200 m. At each 5 m interval along transects a 2 m x 2 m sampling quadrat was established and the cover and abundance of each plant species was recorded. Notes on plant size, particularly the number of seedlings, and condition were made.

Plant species were identified using a combination of prior experience, published keys, Florabase (DEC website), herbarium records and other resources. Nomenclature follows that of Florabase as of January 2009. The focus was on native species, although total weed cover was recorded in quadrats. Some plant species names have changed or are more certain since the last monitoring for a number of reasons. Firstly, seedlings in newer rehab are now larger and are thereby easier to correctly identify. Also many species were in flower during this (spring) monitoring period, even in recent rehab, whereas previous monitoring was completed in early winter. Lastly, some species names were changed to reflect recent changes in taxonomy. Examples of key changes since last monitoring include: *Desmocladus* (*Loxocarya*) *flexuosa* is now *Empodisma gracillimum*, *Baumea articulata* is now *Juncus pallidus*, *Kunzea ericifolia* is now *K. glaucescens* and *Gompholobium* sp is now *G. aristatum*.

Data analysis involved calculating the mean and standard error of quadrat cover, density (number of plants per quadrat) and richness (number of species per quadrat) for each transect. The mean values of these parameters were then compared between transects and between monitoring periods. Analysis was conducted on perennial species only to enable fair comparison between monitoring periods given previous monitoring has occurred over different seasons. Differences in species composition between transects and quadrats were explored using ordinations. Ordination techniques attempt to arrange surveyed sites so that the degree of similarity in plant species composition is represented in the physical spacing of the sites when the data are plotted i.e., similar sites sit close to one another. Differences between sites were then tested using ANOSIM which can be considered to be similar to analysis of variance (ANOVA) for this type of analysis. Similarities were determined using the Bray-Curtis measure (based on square root transformed cover values of species). Ordination and ANOSIM were then performed using the Primer (v6) software (PRIMER-E Ltd, 2006).

4 Summary of Rehabilitation Trends by Sectors

4.1 Sector 1: North-East Corner (Transect #1)

History:

- February 2001: contoured and spread with topsoil (and understorey debris);
- Autumn/winter 2002: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags;
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- Autumn 2006: Ripping between existing plants with 3 tyne ripper to 30 cm depth, hand-seeded (with ~9 common understorey species), limed (2t/ha) and fertilised (incl. trace elements). Also hand spread with brush to avoid re-compacting the area;
- June 2007: 3rd monitoring by CEM
- November 2008: 4th monitoring by CEM

Sector 1 has experienced little change since 2007 (Figure 6). Most quadrats along the monitoring transect have experienced growth of more well established and larger plants, and this has been more pronounced closer to the lake edge where sedges and sedge-like species such as *Juncus pallidus* and *Lepidosperma longitudinale* have proliferated at lower elevations where soils were waterlogged or partially flooded at time of monitoring. Seedlings of several species not previously recorded in quadrats were also found in these lower areas closer to the lake. This rehabilitation sector was one of the first attempted in 2001 and was initially poor in terms of native plant cover and species diversity. Soil remediation measures implemented in autumn 2006 (ripping, seeding, fertilising) made a significant difference to native species cover and diversity, and this improvement has been sustained over the last 16 months. However, although lower areas are improving, loss of some species and individual plants, particularly legumes such as *Viminaria juncea, Hardenbergia comptoniana* and *Acacia* spp, in upper parts of this area is a concern. Some of these species are relatively short-lived and declines in cover may represent loss of individuals established in initial rehab of the site in 2001. Some loss of young *Melaleuca* spp. in the middle of the quadrat is also of concern –

these seedlings established following direct seeding in Autumn 2006 and appear to be drought impacted. In contrast, new shrub species such as *Aotus gracillima, Astartea scoparia* and *Pericalymma ellipticum* have established in middle to lower reaches of the sector; these most likely represent delayed germination from the 2006 seeding presumably responding to good winter rainfall in 2008. It is recommended that more planting and/or seeding of typical upland species of the local area be conducted, with accompanying weed control, in areas >2m above the lake height.

Plate 2 a,b. Rehabilitation in Sector 1 (along transect #1) showing patchy native shrub cover and abundant weeds.

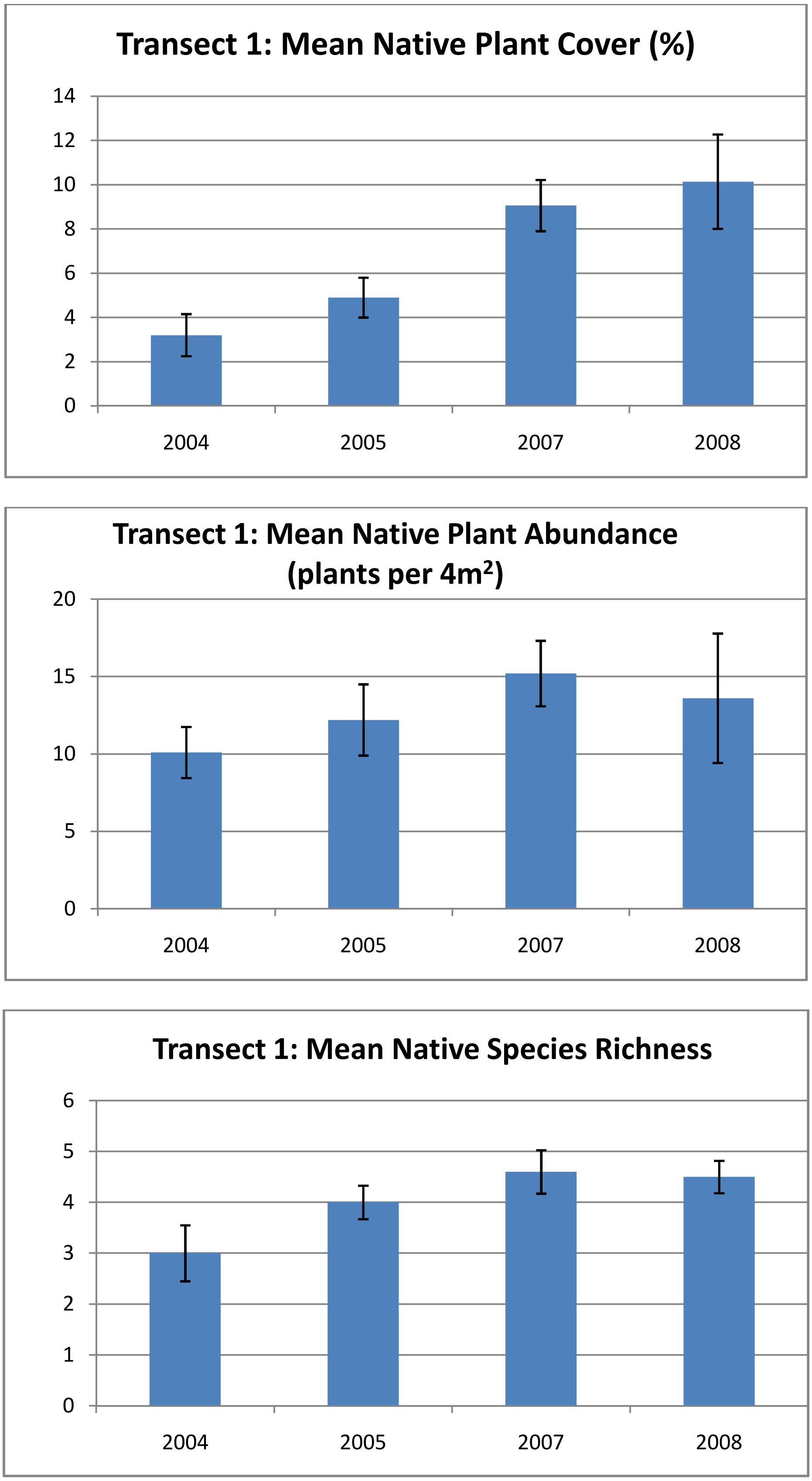

Figure 6. Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 1 within rehab Sector 1. Error bars are ±standard errors.

4.2 Sector 2: East Side Lowlands (Transect #4)

4.2.1.1 History

- February 2001: contoured and spread with topsoil (and understorey debris);
- Autumn/winter 2002: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags;
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- June 2007: 3rd monitoring by CEM
- Oct 2008: 4th monitoring (this report)

Sector 2 has been the most successful area in terms of restoration of plant cover at Kemerton, as well being most similar to native wetland communities of the study area in terms of species composition and structure. It is dominated by several tall *Melaleuca* tree species (i.e., 'paperbarks') and tall Myrtaceous shrubs such as *Astartea scoparia.* It also has good cover of native sedges and sedge-like plants as would be expected in such fringing wetland communities. The success of this Sector in terms of rehabilitation is due to low lying nature of the land and appropriate species selection in terms of topsoiling and seeding. There is also evidence of natural recolonisation in areas closest to the lake.

Even though very successful, this area continues to improve, with a significant increase in number of native plant species recorded (Figure). Also most quadrats experienced an increase in plant abundance and cover (Figure). Most of this improvement can be attributed to colonisation by new understorey species and growth of existing plants. There has been some loss (death) of individuals in dense stands of shrubs (most likely due to competition), but this has been more than counter-balanced by recruitment of seedlings and colonisation by new species. Species such as *Astartea scoparia, Acacia pulchella, Hypocalymma angustifolium,* and *Kunzea glaucescens* appeared to have colonised upper reaches of this sector. Some of the improvement in species diversity can also be attributed to different seasons of monitoring; for instance several geophytes species, such as sundews (*Drosera*) and orchids (*Caladeni*a), recorded for first time in this monitoring period, are only detectable in spring and survive underground as tubers in other seasons (the previous monitoring was in June 2007).

In summary, the most recent monitoring confirms that excellent restoration can be achieved in lowlands surrounding the lake if appropriate species selection and/or topsoil matching is practiced.

Plate 3 a,b: showing dense and tall rehabilitation in Sector 2 (along transect #4).

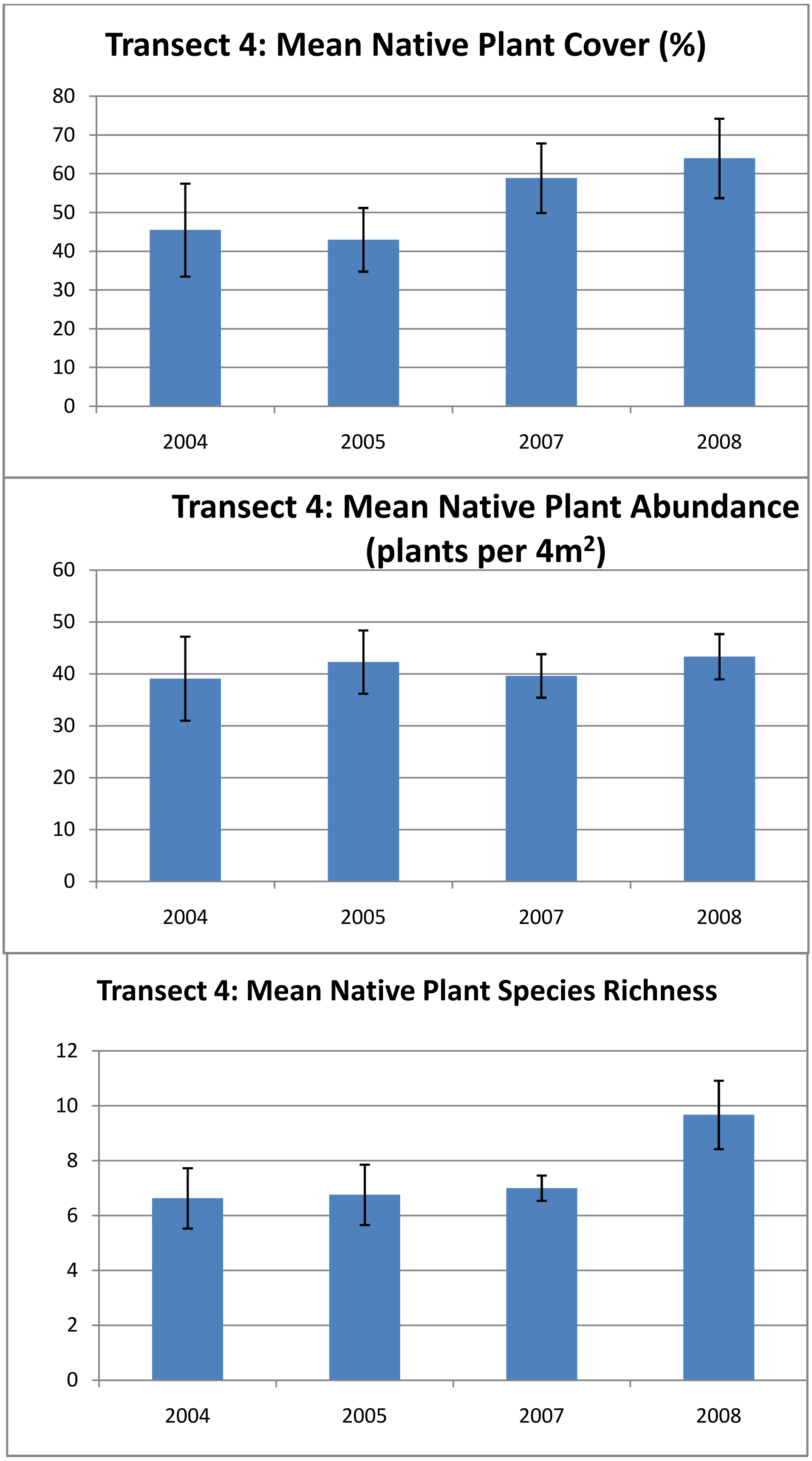

Figure 7: Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 4 within rehab Sector 2. Error bars are ±standard error.

4.3 Sector 3: South-East Side Uplands (Transect #5)

4.3.1.1 History

- Feb 2001: contoured and spread with topsoil (and understorey debris);
- Autumn/winter 2002: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags;
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- Autumn 2006: hand-seeded (with ~9 common species), fertilised (including trace elements), limed (2t/ha) and (apparently) treated with herbicide;
- June 2007: 3rd monitoring by CEM
- Oct 2008: 4th monitoring (this report)

Sector 3 has experience a significant increase in plant cover since previous monitoring in 2007 (**Figure 1**) mostly attributable to growth of existing large plants, particularly legumes such as *Acacia pulchella* and *Acacia saligna*, and in Myrtaceous shrubs such as *Kunzea recurva* and *Hypocalymma angustifolium*. These species were seeded in autumn 2006, so this treatment was relatively successful. Plant abundance and species richness have stayed relatively constant over the last 16 months on average (Fig 8); however this masks a dynamic where dying shrubs have been more-or less balanced by new recruitment and colonisation. New germinants of perennial native species is encouraging which demonstrates viable seed of such remains in the topsoil. Such recent recruitment has included species such as *Acacia pulchella, Hypocalymma angustifolium, Pericalymma ellipticum* and *Kunzea glaucescens* –all except the first of these were seeded in 2006. A higher than average winter rainfall no doubt contributed to recruitment. Some legumes have been lost or are dying (eg *Juncea viminaria*) which is perhaps indicative of individuals reaching the end of their life span. Some *Melaleuca* seedlings which established after the 2006 direct seeding have not survived.

Despite the improvements in rehabilitation, this area remains species poor and structurally simple for 7 year old rehabilitation, especially compared to Sector 2 adjacent. The higher topography is likely to be cause with most of Sector 3 greater than 2 m above high lake levels. It is recommended that ongoing work in seeding/planting of <u>upland</u> species and weed control occurs in this Sector. If any excess upland topsoil is available, it should be spread on this Sector.

Plate 3 a,b: showing typical plant cover of Sector 3 (transect 5) showing dominance of weeds and stunted tree and shrub growth.

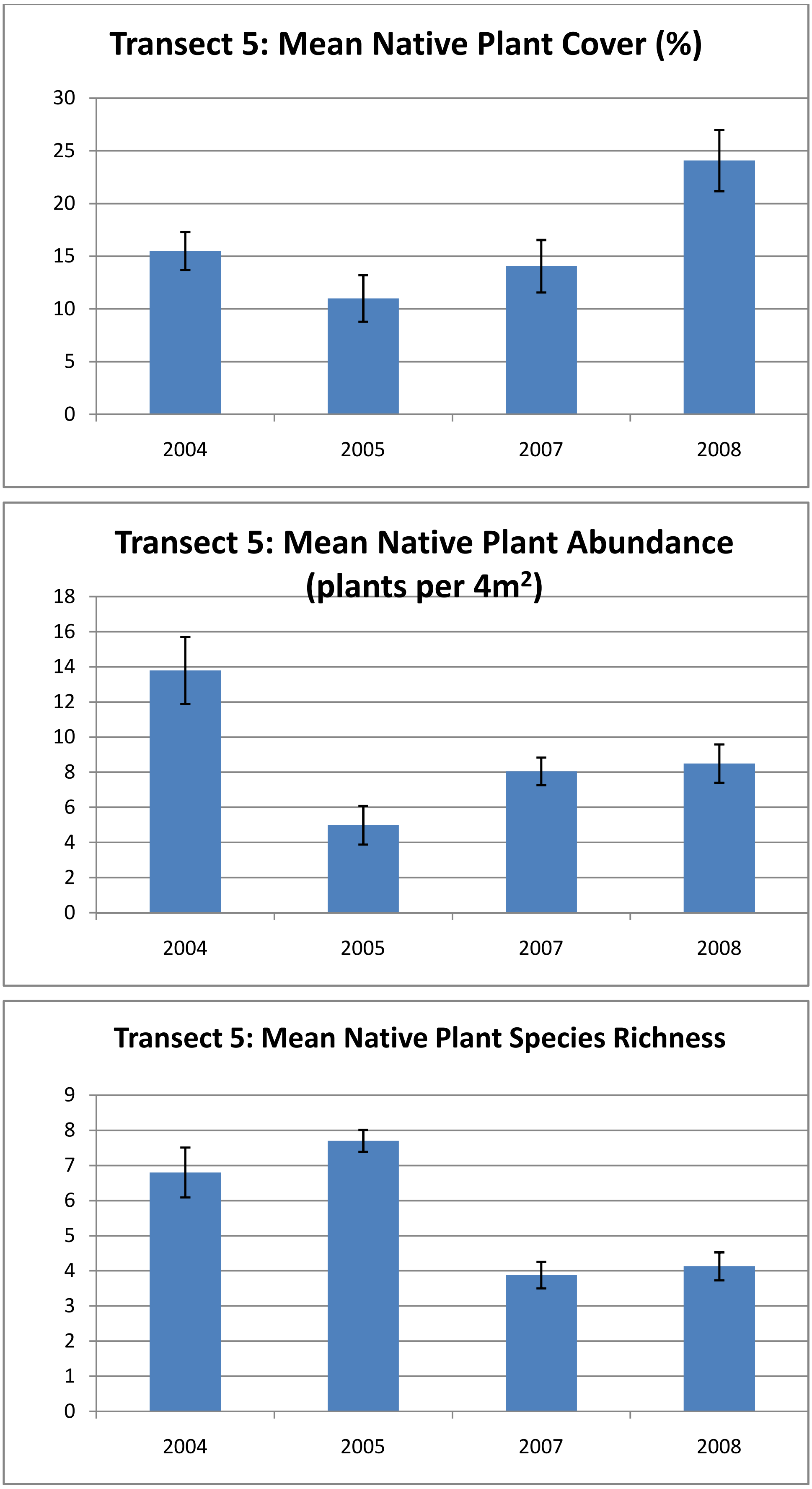

Figure 1. Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 5 with rehab Sector 3. Error bars are ±standard error.

4.4 Sector 4: West Side (Transect #7)

4.4.1.1 History

- April 2003: contoured and spread with topsoil (and understorey debris);
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- June 2007: 3rd monitoring by CEM
- November 2008 (this report).

Sector 4 received topsoil treatment later than those described above but is generally superior in terms of plant cover and species diversity (Figs 6-9). Cover is continuing to increase on average (Fig 9) with quadrats closer to the lake experiencing increased cover and abundance. Encouragingly, many seedlings were recorded in monitoring quadrats; these included both existing plant species and species not recorded in quadrats previously. Such colonisation by new species has resulted in average species richness significantly increasing since 2007 and is now approaching the peak in species richness found in 2005. Despite significant increases in species numbers, species richness is relatively low at just over 7 per quadrat, although this value is actually similar to that of the successful Sector 2. Of more concern is the simplicity of structure and unevenness of species dominance; although cover is reasonable for 5 year old rehabilitation, Sector 4 is clearly dominated by *Lepidosperma longitudinale* and some low shrubs like *Hypocalymma angustifolium* and *Kunzea recurva.* The absence of taller shrubs and trees like tea trees and paperbarks (*Melaleuc*a spp.) is a concern especially in low lying areas close to the lake. The presence of very young *Melaleuca rhaphiophylla* near the lake edge is therefore encouraging especially as they seem to the result of washed-up and/or wind-blown seed. If such seedlings do not establish into trees, consideration needs to be given to planting, brushing and/or seeding with *Melaleuca* close to the lake edge.

Plate 4 a,b. showing typical plant cover of Sector 4 (along transect 7) showing dominance of *Lepidosperma longitudinale*.

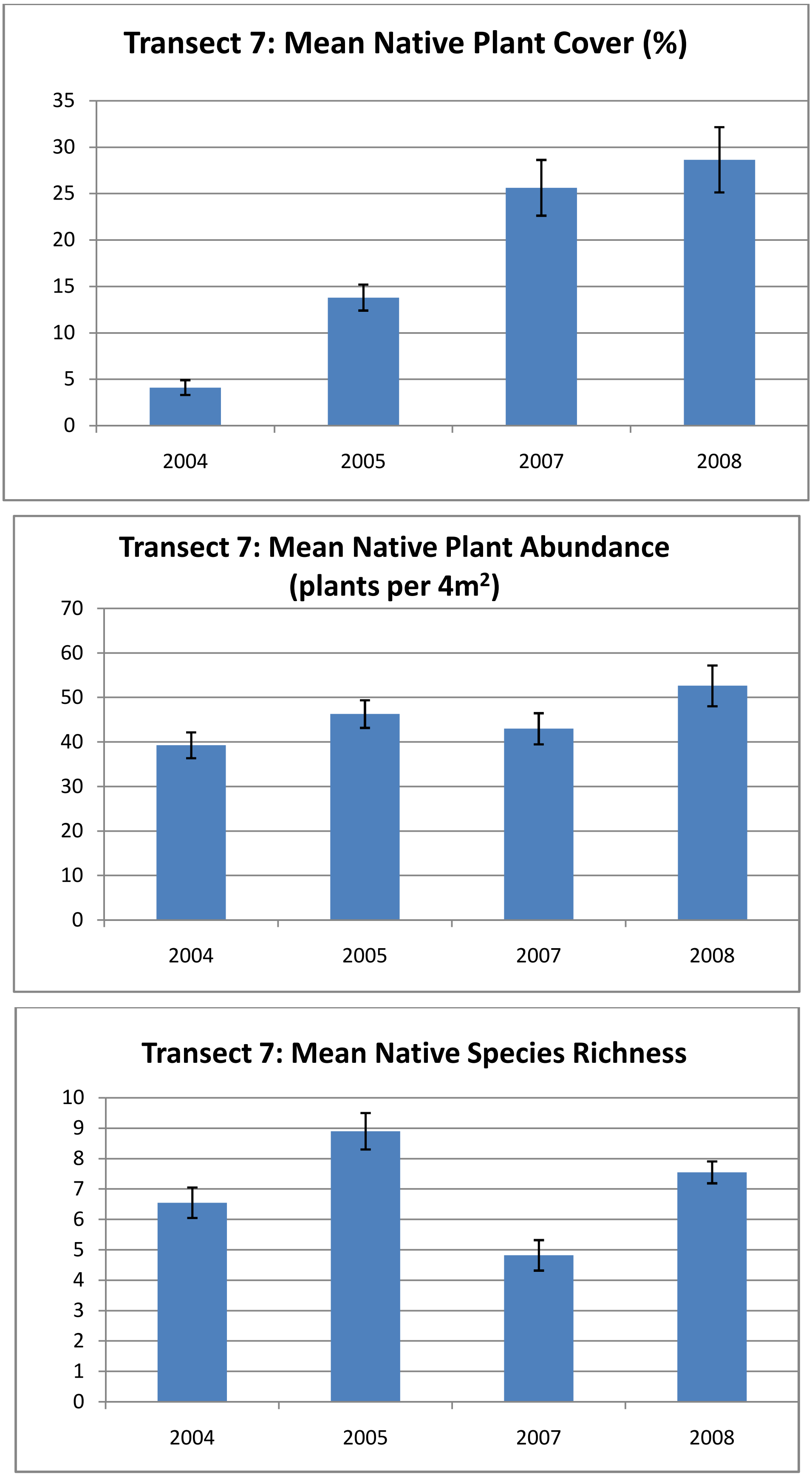

Figure 2. Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 7 within rehab Sector 4. Error bars are ±standard errors.

4.5 Sectors 5 & 6: North & South Sides of Lake (Both New Rehabilitation Areas)

(Transects 9 &10)

4.5.1.1 History

- Autumn 2006: contoured and spread with topsoil (with some understorey debris); Sector 5 used 10 year old, stored topsoil, whereas Sector 6 used fresh topsoil.
- June 2007: Initial monitoring by CEM.
- November 2008: 2nd Monitoring by CEM (this report).

These two rehabilitation sectors are clumped together as they were both rehabilitated using topsoil two and half years previously. In terms of all measures, this treatment has been highly successful with good initial cover and diversity achieved. This monitoring has demonstrated improvements in rehabilitation success since previous monitoring in 2007 (Fig 10; Appendix 3). In particular, significant increases in cover have occurred with Sector 5 increasing from 8 to 45% cover on average, and Sector 6 from 9 % to 27% (Fig 10). A relatively severe summer drought resulted in loss of individuals at this site, especially more typical wetland species in quadrats higher in the topographic profile. This loss has been more than balanced by recruitment of new individuals, most likely from soil stored seed, in the wetter than average winter.

Species richness, on average, increased only slightly from 2007 to 2008 (Fig 10); however this masks a dynamic which saw increased abundance of fringing wetland species such as sedges and *Melaleuca* lower in the profile and decline of such species in higher areas. Species richness is still relatively high (8-13 species per 4 m^2 quadrat) which compares favourably with some of the most species-rich wetland margins and damplands in the surrounding area. Figure 11 shows the gradient in species composition across transects with upland quadrats on the left side and lower quadrats closer to lake edge towards the right. This ordination also show the shift in species composition between June 2007 and November 2008 with quadrats towards the lake developing more typical wetland characteristics with increase in sedges/rushes (e.g., *Lepidosperma longitudinale*, *Juncus pallidus* and *Baumea articulata*) and Melaleuca species and cover (Appendix 3). Upper quadrats have shifted in the opposite direction with more typical upland species such as *Calytrix* sp., *Acacia pulchella*, *Gompholobium aristatum* and *Hakea* sp increasing in cover. Quadrats in the middle of the profile have changed relatively little in terms of species composition (1). The species mostly contributing to overall differences between the 2007 and 2008 are *Acacia pulchella, Lepidosperma longitudinale, Kunzea glaucescens, Hypocalymma angustifolium* and *Calothamnus lateralis*, all of which have increased in cover (Appendix 3).

Sector 6 received fresh topsoil in 2005, whereas Sector 5 received topsoil which was stored for many years. The significantly higher species richness and plant abundance in areas receiving fresh topsoil has been maintained, however the increase in plant cover has been more substantial in areas receiving older topsoil. This is due to prolific growth of a small number of shrub species in Sector 5, which may be a result lower overall inter-specific competition in this area. Species differences between sector 5 and 6 are shown in Appendix 3. Main differences are: *Lepidosperma longitudinale, Acacia pulchella, Euchilopsis linearis, Hypolaena exsulca, Melaleuca preissiana* and *Empodisma gracillimum* being more common in Sector 6; whilst *Aotus gracillima, Calothamnus lateralis, Juncus pallidus, Viminaria juncea* and *Baumea articulata* are more common in Sector 5.

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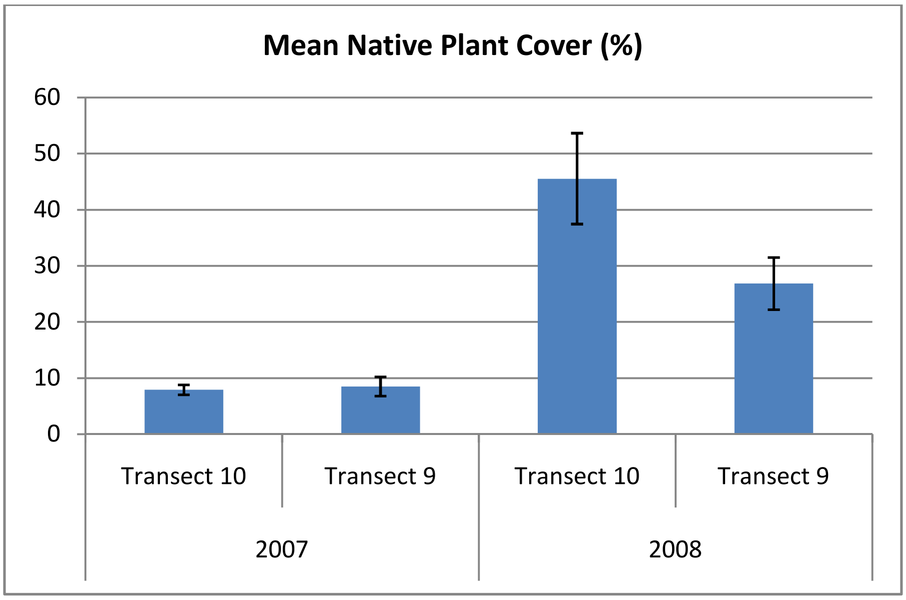
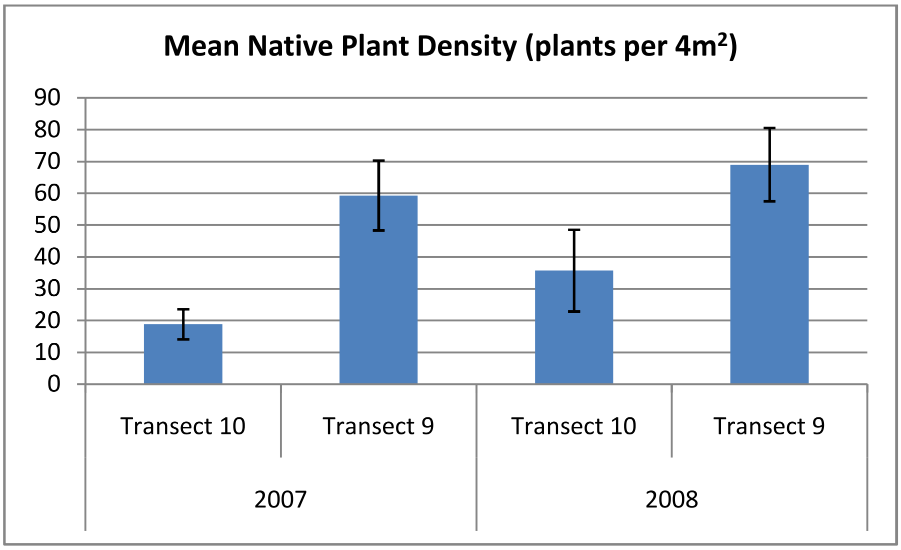
Plate 5 a,b. Rehabilitation in Sector 5 (along transect 10).

Plate 6 a,b: showing typical cover of rehabilitation in Sector 6 (transect #9).





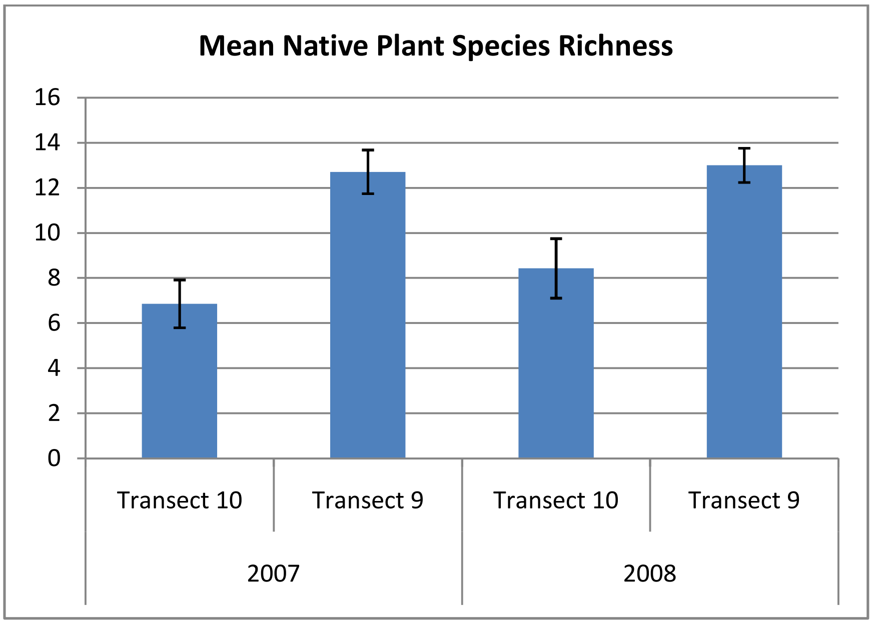


Figure 10: Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 9 (Sector 6) and Transect 10 (Sector 5). Error bars are ±standard error.

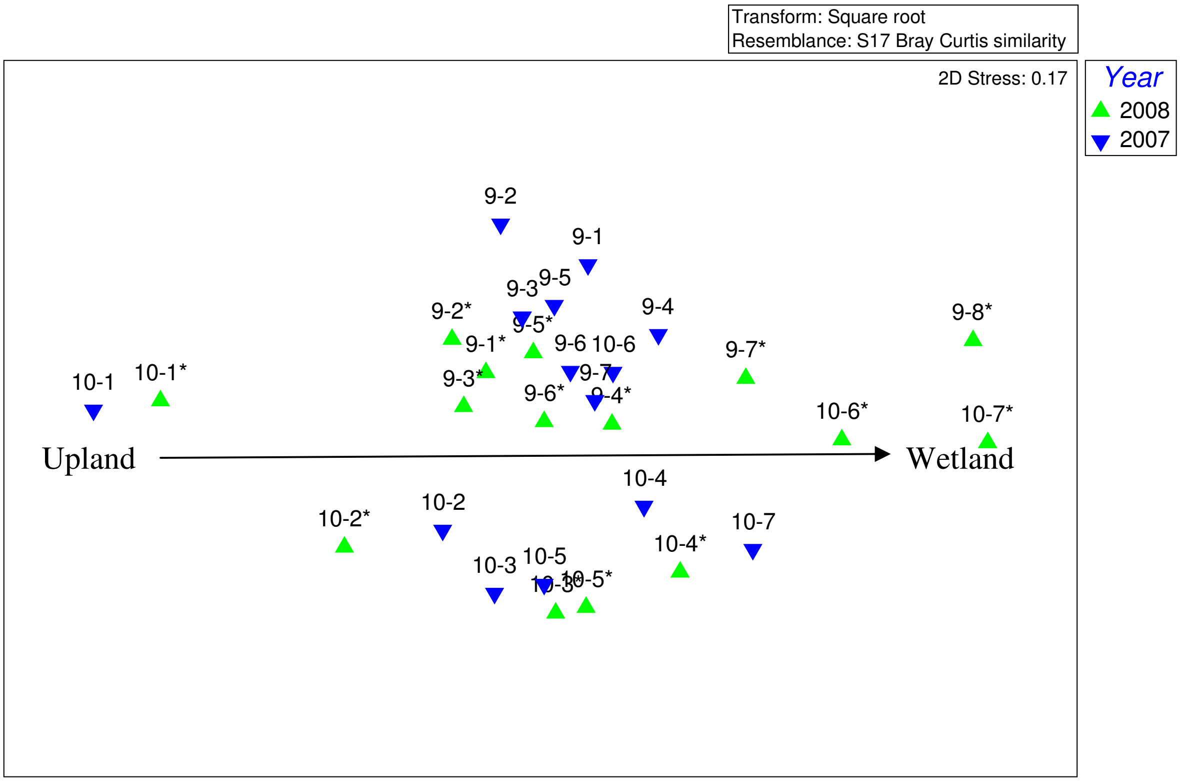


Figure 11. Ordination showing differences in species composition between quadrats of transects 9 and 10 and relative shifts in composition from June 2007 (blue triangles) to November 2008 (green triangles).

5 Recent Rehabilitation of Wetland Area

In mid 2007, a new area south of North Lake was rehabilitated using topsoil and spreading of brushing and logs. A new monitoring transect was established in this area (Transect #11) and monitored for the first time in November 2008.

This area was low lying and at November 2008 contained large areas submerged by water (see Plate 7–Plate). Areas under shallow water or waterlogged had very high plant cover in the order of 60-100%. This represents prolific growth over just over one year post rehabilitation and confirms the readiness for plant establishment in low lying areas which are flooded or waterlogged for most of the years as long as appropriate (i.e., wetland or fringing wetland) topsoil is used. This area did not contain any upland areas, i.e. areas >2m above water table.

Although the area appeared visually to be dominated by a single species (*Juncus pallidus*), the species richness was relatively high with an average of 8 species per 4 m^2 quadrat (highest of 10 per quadrat). Most of the species were rushes, sedges and related species (Appendix 1). *Juncus pallidus* was indeed the most common and widespread species occurring in every quadrat and averaging 22%. Other common species were *Juncus planifolius, Isolepis sp, Meeboldina scariosa* and *Lepidosperma longitudinale*. Encouragingly many seedlings of *Melaleuca* and other Myrtaceous shrubs typical of fringing wetlands were found, particularly in quadrats close to the deep water edge. This suggests that more diverse structure and typical fringing wetland structure of paperbarks and other shrubs may develop over time. Seedlings were mostly of *Melaleuca preissiana* with many of these were growing close to or amongst brushing which suggest this may have been a valuable source of seed.

Plate 7. This panorama shows rehabilitated wetland in early 2008, whereas the photo below show wetland at time of monitoring in November 2008 showing high cover and dominance by *Juncus pallidus*.. Photos by Clint McCullough.

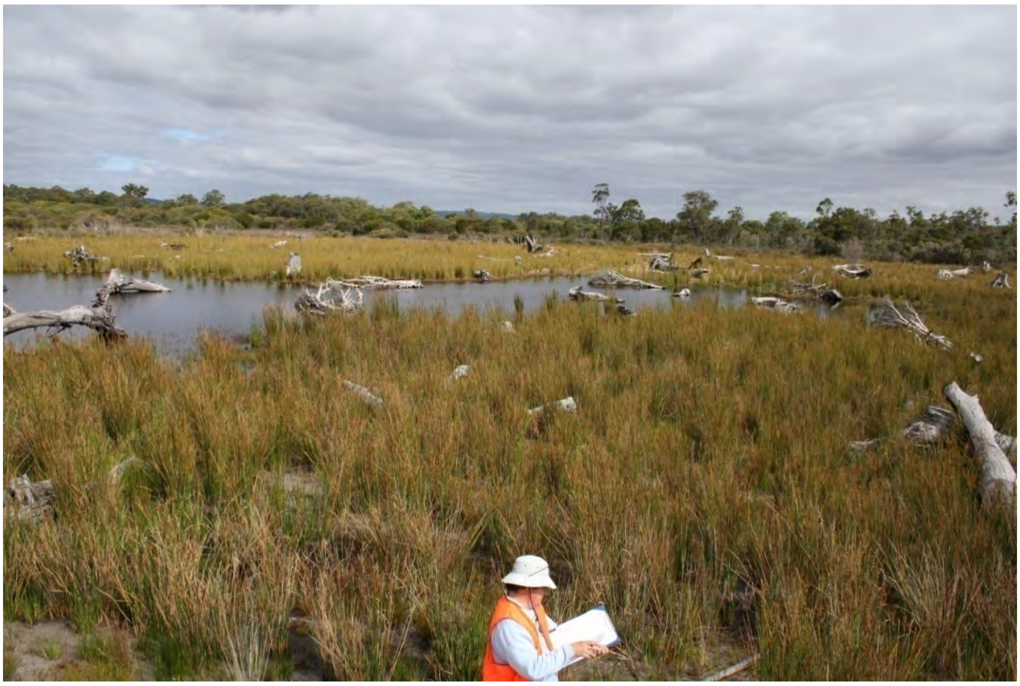


Plate 8 a,b. Extensive cover of rushes and sedges in new rehabilitation south of dredge pond (transect 11).

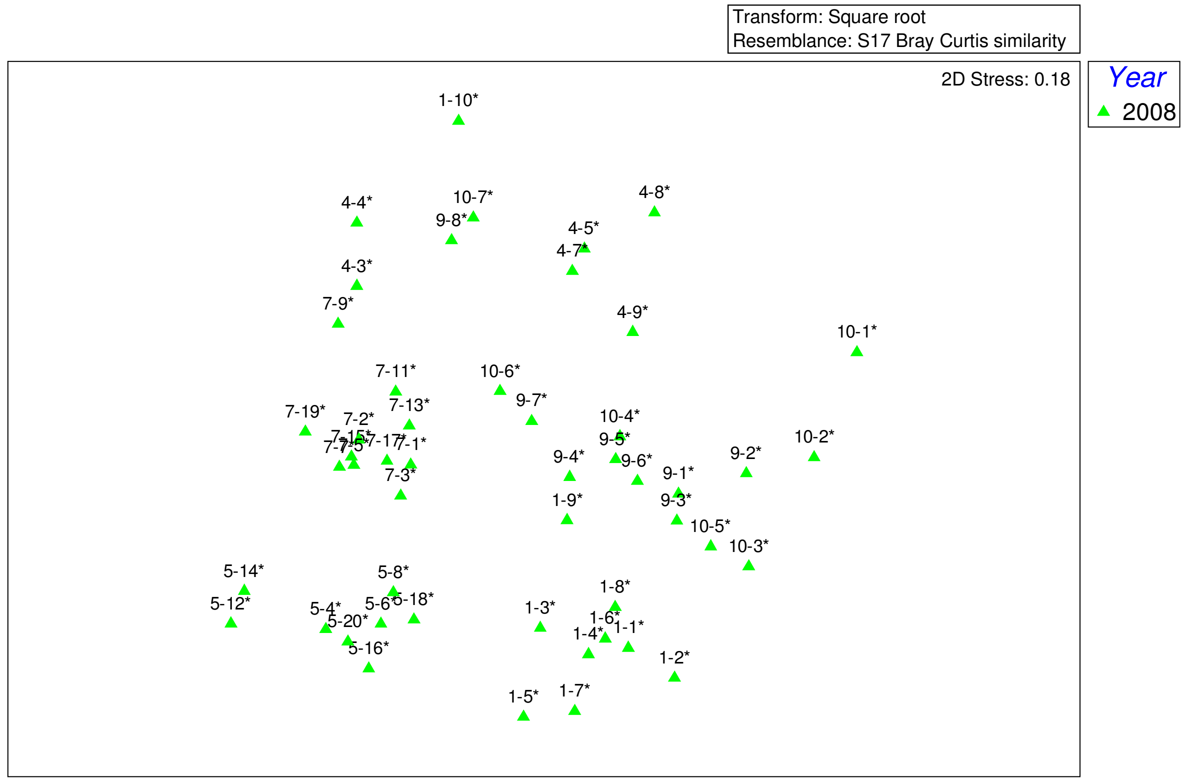
6 Summary & Conclusions

Monitoring in November 2008 has revealed an overall slight to modest improvement in rehabilitation since the previous monitoring in mid 2007. This improvement can be generally attributed to moist conditions provided by above average late autumn and early winter rains in 2008. This improvement was despite observations of drought death over a particularly dry summer in the previous year. Plant cover showed most marked increase from the previous year, with plant abundance and species richness generally stable overall.

This slight to modest improvement generally masks quite significant dynamics in plant species composition both within quadrats and across the rehabilitated landscape. Generally plant cover increased more substantially in low-lying areas closer to lake, with new species appearing more readily in such areas. Some of these species appear to have arisen by seeds dispersed by seed or water as they appear on areas without topsoil or rehabilitated. Areas higher in topographic profile have seen the loss of typically fringing/flooded zone species and although becoming floristically more simple (ie fewer species) are at least maintaining plant cover with some individuals growing substantially over the intervening period. Therefore it is apparent that some degree of species sorting according to moisture and flooding preferences is occurring. This is encouraging, as is the seemingly natural recolonisation in lower areas by sedges, Melaleucas and other wetland species. Upland areas of recent rehabilitation by topsoiling however need to be carefully monitored as they may trend toward that experienced in the older upland rehabilitation where growth is limited and species diversity low. Remediation is recommended in upland areas with poor rehabilitation success; spreading upland topsoil would be preferred approach if such resource is available, otherwise seeding, brushing and planting (using upland and transitional species) should occur.

Each rehabilitation sector remains distinct in terms of species composition (Fig 12 and ANOSIM results at Appendix 4). As outlined in previous reports, this reflects the different timing and techniques for rehabilitation, as well as contrasting topographic/edaphic/hydrological conditions. Older rehabilitation areas above ~2m of the high (spring) lake level (vertical distance) are generally the poorest in terms of species cover/diversity and therefore restoration success. It is believed the initial treatment of topsoil application was inappropriate (not matched to site characteristics) and subsequent remedial efforts have met with limited success. Future rehabilitation of such sites greater than 2 m above high water mark should ideally be sourced from upland sites (eg Jarrah-Marri woodland).

Restoration success in lower sections is generally good to excellent, especially in areas flooded or waterlogged close to the lake edge where extensive coverage of sedges and rushes have developed. Some young paperbarks are also well established in many shoreline sections. Success of the most recent rehabilitation in 2006 and 2007, although still in its infancy, is promising with diversity remaining relatively high despite hot and dry summer in 2007-8. These results confirm the potential benefits of using relatively fresh topsoil applied to similar environments from which it is sourced. Sector 4 is currently the most successful in terms of plant cover and its close resemblance to local fringing wetland communities. It is also clear that species composition in low-lying areas of other rehab sectors is shifting towards that of Sector 4 and hence are on a satisfactory trajectory in terms of resembling analogue (reference) sites found in native vegetation (Plate 3). Some of these species may be colonising shoreline or near-shore areas by seed dispersed by wind from nearby wetlands and hence may reflect the relative ease of restoring these lower parts of the rehabilitation. This is supported by the results of monitoring the most recent rehab south of the dredge ponds where extensive cover and relatively high diversity have developed in flooded and waterlogged areas in less than two years.



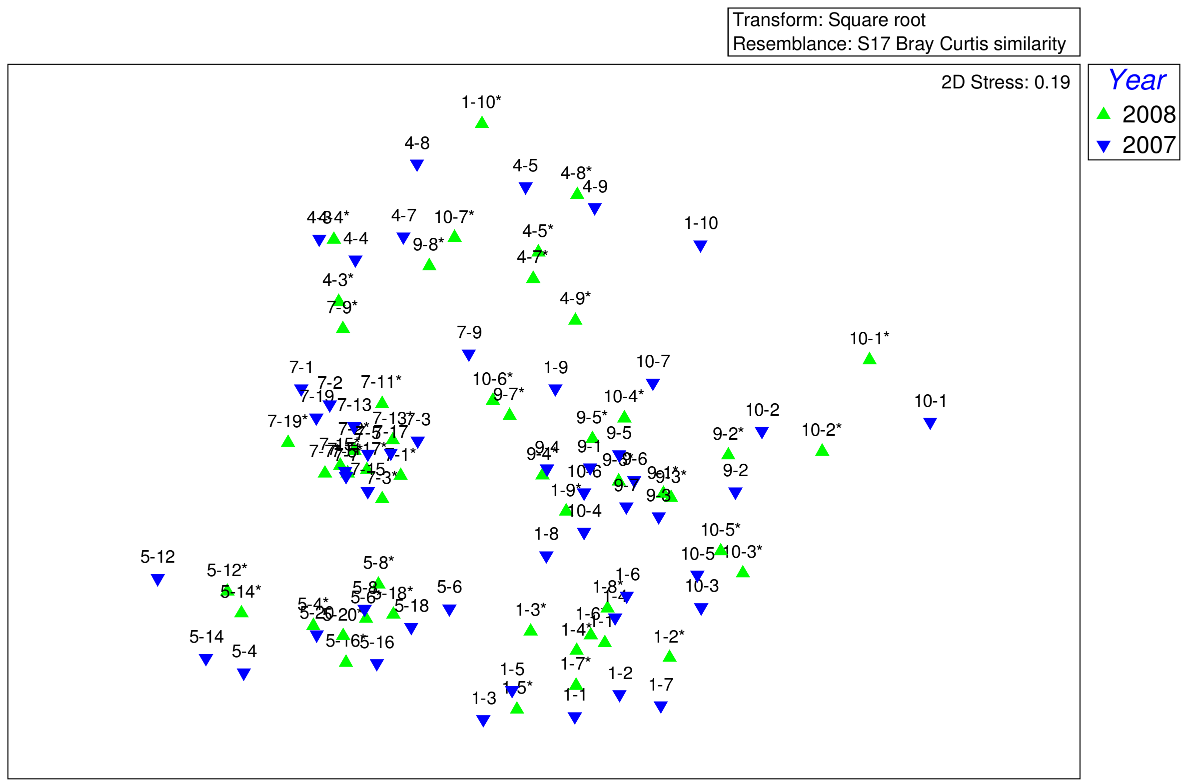


Figure 12 a,b. Ordination of 2008 monitoring quadrats (top) showing general distinction between transects in terms of species composition, with shifts in species composition from 2007 to 2008 monitoring shown below. First number of labels refers to transect #, with 2nd number referring to quadrat sequence along transects.

7 Appendices

Appendix 1: Raw Data for Each Quadrat Measured Oct/Nov 2008.

Transect	Quadrat	Species	% Cover	Abundance (plants per $4m^2$)	Notes
5	20	*Kunzea recurva*	8	4	
		Hypocalymma angustifolium	2	3	
		Jacksonia furcellata	2	2	
		Corymbia calophylla	2	1	2.4 m high
		*Grassy weeds	80	100's	
		*Other weeds	1	10	
5	18	*Hypocalymma angustifolium*	6	5	
		Kunzea recurva	8	3	
		Empodisma gracillimum	2	1	
		*Grassy weeds	15	100's	
		*Other weeds	1	10	
5	16	*Hypocalymma angustifolium*	7	4	
		Kunzea recurva	6	1	
		Acacia saligna	15	1	
		Jacksonia furcellata	3	2	
		Microtis media	<1	2	
		*Grassy weeds	60	100's	
		*Other weeds	1	20	
5	14	*Jacksonia furcellata*	3	4	2 seedlings
		Microtis media	<1	6	
		Acacia pulchella	<1	1	new
		Kunzea recurva	15	2	
		*Grassy weeds	30	100's	
		*Other weeds	1	15	
5	12	*Acacia saligna*	4	1	
		Melaleuca osullivanii	1.5	1	
		Kunzea recurva	30	2	
		Cytogonidium leptocarpoides	1	1	
		Hypocalymma angustifolium	<1	1	
		Microtis media	<1	3	
		*Grassy weeds	60	100's	
5	8	*Kunzea recurva*	16	3	
		Hypocalymma angustifolium	9	2	
		Lepidosperma longitudinale	<1	1	
		*Grassy weeds	20	100's	
		*Other weeds	1	20	
5	6	*Kunzea recurva*	22	6	
		Hypocalymma angustifolium	5	6	
		Daviesia physodes	4	1	
		Euchilopsis linearis	1	1	
		Jacksonia furcellata	<1	1	

		*Grassy weeds	2	100	
		*Other weeds	<1	5	
5	4	*Viminaria juncea*	5	1	2.5 m high
		Jacksonia furcellata	2	1	
		Acacia saligna	3	1	
		Kunzea recurva	9	2	
		Empodisma gracillimum	2	2	
		Hypocalymma angustifolium	1	1	
		*Grassy weeds	30	100's	
		*Other weeds	<1	5	
4	3	*Lepidosperma longitudinale*	10	15	
		Meeboldina scariosa	5	5	
		Juncus pallidus	1	5	
		Melaleuca rhaphiophylla	12	1	
		Kunzea recurva	3	3	
		Melaleuca incana ssp. *incana*	20	1	
		Hypolaena exsulca	2	7	
		Kunzea glaucescens	<1	1	
4	4	*Melaleuca rhaphiophylla*	20	1	
		Meeboldina scariosa	10	6	
		Lepidosperma longitudinale	4	15	
		Melaleuca lateriflora	40	1	
		Hypolaena exsulca	1	5	
		Astartea scoparia	2	2	
		Kunzea recurva	3	1	
		Philotheca sp.*icata*	<1	2	
		Drosera glanduligera	1	100	
		Juncus pallidus	1	2	
		Centella asiatica	<1	1	
4	5	*Lepidosperma longitudinale*	2	12	
		Meeboldina scariosa	20	10	
		Melaleuca lateriflora	40	1	
		Juncus pallidus	1	3	
		Acacia saligna	<1	1	
		Kunzea glaucescens	2	2	
		Astartea scoparia	2	12	
		Ptilotus? s.	<1	5	
		Microtis media	<1	5	
		Acacia pulchella	<1	1	seedling
		Hypocalymma angustifolium	<1	1	
		Drosera glanduligera	<1	20	
		Centella asiatica	<1	2	
4	7	*Astartea scoparia*	4	1	
		Meeboldina scariosa	10	9	
		Melaleuca lateriflora	6	1	
		Lepidosperma longitudinale	2	20	
		Kunzea glaucescens	1	2	
		Philotheca sp.*icata*	<1	1	
		Siloxerus filifolius	<1	20	

		Hypocalymma angustifolium	<1	1	
		Acacia pulchella	<1	1	seedling
		Drosera glanduligera	<1	5	
		Ptilotus sp.	<1	5	
4	8	*Meeboldina scariosa*	10	10	
		Astartea scoparia	27	14	
		Lepidosperma longitudinale	2	10	
		Melaleuca lateriflora	1	1	
		Kunzea glaucescens	20	3	
		Caladenia ?paludosa	<1	2	
		Ptilotus sp.	<1	10	
4	9	*Astartea scoparia*	20	10	
		Lepidosperma longitudinale	2	5	
		Viminaria juncea	10	1	
		Meeboldina scariosa	2	10	
		Melaleuca osullivanii	2	2	
		Melaleuca preissiana	3	4	
		Kunzea glaucescens	25	10	
		Hypocalymma angustifolium	2	5	
9	1	*Acacia pulchella*	5	5	
		Hypocalymma angustifolium	1	2	
		Euchilopsis linearis	1	1	
		Lepidosperma longitudinale	<1	1	
		Kunzea glaucescens	2	5	
		Melaleuca preissiana	2	2	
		Pericalymma ellipticum	<1	2	
		Siloxerus filifolius	1	50	
		Empodisma gracillimum	<1	5	
		Aotus gracillima	<1	1	
9	2	*Acacia pulchella*	10	11	
		Hypolaena exsulca	1	1	
		Hypocalymma angustifolium	<1	5	
		Empodisma gracillimum	1	3	
		Kunzea glaucescens	1.5	6	
		Pericalymma ellipticum	1	1	
		Melaleuca ?thymoides	<1	2	1 seedling
		Melaleuca preissiana	<1	1	
		Lomandra sp..	<1	1	
		Bossiaea eriocarpa	<1	2	
		Euchilopsis linearis	<1	1	
		Gompholobium aristatum	<1	6	2 seedlings
		Lepidosperma longitudinale	<1	4	
		Hakea sp.	<1	1	seedling
		Epacridaceae	<1	1	
		Calytrix fraseri	1	1	
9	3	*Acacia pulchella*	10	3	
		Hypocalymma angustifolium	5	10	
		Kunzea glaucescens	8	7	
		Lepidosperma longitudinale	<1	3	

		Pericalymma ellipticum	2	1	
		Euchilopsis linearis	1	2	
		Platysace filiformis	1	2	
		Empodisma gracillimum	<1	3	
		Hibbertia huegelii	<1	1	
		Hypolaena exsulca	<1	1	
		Hakea sp.	<1	1	seedling
		Gompholobium aristatum	<1	4	2 seedlings
9	4	*Lepidosperma longitudinale*	5	30	
		Acacia pulchella	15	4	
		Pericalymma ellipticum	1	3	
		Platysace filiformis	1	1	
		Calothamnus lateralis	1	3	
		Hypocalymma angustifolium	5	5	
		Kunzea recurva	1	2	
		Hypolaena exsulca	<1	2	
		Aotus gracillima	<1	1	
		Gompholobium aristatum	1	1	
		Pericalymma ellipticum	<1	2	
		Melaleuca preissiana	<1	1	
		Euchilopsis linearis	1	2	
		Kunzea glaucescens	1	5	
		Empodisma gracillimum	<1	2	
		Siloxerus filifolius	<1	30	
9	5	*Acacia pulchella*	15	5	
		Lepidosperma longitudinale	5	23	
		Hypolaena exsulca	1	7	
		Pericalymma ellipticum	2	5	
		Kunzea glaucescens	2	6	
		Empodisma gracillimum	3	25	
		Hypocalymma angustifolium	2	20	
		Hypolaena exsulca	1	6	
		Dasypogon bromeliifolius	<1	1	
		Melaleuca ?*thymoides*	<1	1	
		Euchilopsis linearis	2	2	
9	6	*Acacia pulchella*	8	4	
		Hypocalymma angustifolium	2	17	
		Lepidosperma longitudinale	2	25	
		Pericalymma ellipticum	1	7	
		Aotus gracillima	<1	1	
		Kunzea glaucescens	1	5	
		Acacia semitrullata	1	1	
		Euchilopsis linearis	1	1	
		Gompholobium aristatum	1	2	
		Empodisma gracillimum	<1	2	
		Lomandra sp..	<1	1	
		Viminaria juncea	<1	1	
		Drosera macrantha	1	1	
9	7	*Euchilopsis linearis*	1	1	
		Lepidosperma longitudinale	17	40	

		Empodisma gracillimum	1	2	
		Acacia pulchella	<1	1	dying
		Kunzea glaucescens	1	1	
		Calothamnus lateralis	3	9	
		Hypocalymma angustifolium	23	40	
		Pericalymma ellipticum	<1	3	
		Melaleuca preissiana	<1	1	
		Astartea scoparia	1	4	
		Meeboldina scariosa	1	2	
9	8	*Calothamnus lateralis*	3	5	
		Astartea scoparia	3	2	
		Lepidosperma longitudinale	60	100's	
		Acacia pulchella	<1	1	dying
		Juncus pallidus	10	15	
		Baumea articulata	2	10	
		Meeboldina scariosa	1	10	
		Melaleuca preissiana	<1	2	young plants
1	1	*Hypocalymma angustifolium*	2	1	
		Kunzea glaucescens	1	1	
		Viminaria juncea	3	1	
		Hakea sp.	<1	1	seedling
		Pericalymma ellipticum	<1	1	seedling
		Microtis media	<1	1	
		*Grassy weeds	5	20	
		*Other weeds	1	20	
1	2	*Acacia pulchella*	<1	1	
		Eucalyptus marginata	<1	1	
		Hypocalymma angustifolium	1	1	
		Corymbia calophylla	1	1	
		Kunzea glaucescens	1	1	
		Podotheca angustifolia	1	2	
		*Grassy weeds	10	50	
		*Other weeds	5	10	
1	3	*Hypocalymma angustifolium*	8	9	
		Viminaria juncea	2	1	
		Astartea scoparia	1	1	
		Pericalymma ellipticum	1	1	
		*Grassy weeds	5	20	
		*Other weeds	5	20	
1	4	*Hypocalymma angustifolium*	8	5	
		Kunzea glaucescens	2	2	
		?*Melaleuca* sp.	<1	1	
		*Grassy weeds	20	100	
		*Other weeds	2	10	
1	5	*Hypocalymma angustifolium*	6	5	
		*Grassy weeds	5	50	
		*Other weeds	5	20	

1	7	*Hypocalymma angustifolium*	1	1	
		Kunzea	2	3	
		Empodisma gracillimum	<1	1	
		Pericalymma ellipticum	1	1	
		Viminaria juncea	1	1	
		*Grassy weeds	1	10	
		*Other weeds	1	10	
1	9	*Pultenaea ochreata*	1	1	
		Juncus pallidus	3	3	
		Lepidosperma longitudinale	1	6	
		Hypocalymma angustifolium	6	8	
		Aotus gracillima	12	1	
		Pericalymma ellipticum	1	1	
		Empodisma gracillimum	<1	1	
		Hypolaena exsulca	<1	1	
1	10	*Juncus pallidus*	15	34	
		Astartea scoparia	1	2	
		Lepidosperma longitudinale	1	8	
		Baumea articulata	1	4	
10	1	*Kunzea glaucescens*	20	2	
		*Other weeds	2	10	
		*Grassy weeds	50	100's	
		Acacia pulchella	<1	1	
10	2	*Kunzea glaucescens*	8	3	
		Acacia pulchella	12	4	
		Aotus gracillima	3	1	
		Pericalymma ellipticum	<1	1	seedling
		Siloxerus filifolius	<1	1	
		Gompholobium aristatum	1	3	
		Stirlingia latifolia	<1	1	
		Daviesia physodes	5	6	5 seedling
		Hakea sp.	1	1	
		Calytrix fraseri	2	2	
		*Other weeds	1	5	
10	3	*Acacia pulchella*	25	5	
		Hypocalymma angustifolium	2	1	
		Aotus gracillima	10	7	
		Gompholobium aristatum	<1	1	
		Pericalymma ellipticum	2	1	
		Calytrix fraseri	1	1	
		Calytrix flavescens	<1	1	
		Gonocarpus paniculatus	<1	1	
		Calothamnus lateralis	1	1	
10	4	*Hypocalymma angustifolium*	32	5	
		Acacia pulchella	4	2	
		Pericalymma ellipticum	6	1	
		Lepidosperma longitudinale	5	11	
		Viminaria juncea	12	1	

		Aotus gracillima	20	1	
		Calothamnus lateralis	8	1	
		Kunzea glaucescens	1	1	
		Unknown #5	1	1	
10	5	*Calothamnus lateralis*	30	7	
		Kunzea glaucescens	3	2	
		Acacia pulchella	2	3	
		Hypocalymma angustifolium	3	4	
		Microtis media	<1	1	
		Aotus gracillima	8	1	
		Siloxerus filifolius	<1	3	
		Pericalymma ellipticum	<1	1	
		Stipa sp.	<1	3	
10	6	*Lepidosperma longitudinale*	15	3	
		Astartea scoparia	<1	2	
		Hypocalymma angustifolium	6	15	
		Melaleuca preissiana	2	3	
		Pericalymma ellipticum	<1	1	
		Restionaceae sp..	<1	1	
		Empodisma gracillimum	<1	1	
		Aotus gracillima	1		
		Calothamnus lateralis	10	11	
		Juncus pallidus	2	1	
		Baumea articulata	3	20	many seedlings
10	7	*Calothamnus lateralis*	4	5	
		Melaleuca lateriflora	4	1	
		Pericalymma ellipticum	1	1	
		Astartea scoparia	1	2	
		Lepidosperma longitudinale	10	8	
		Juncus pallidus	20	12	
		Baumea articulata	10	10	
7	1	*Kunzea recurva*	5	26	24 seedlings
		Lepidosperma longitudinale	2	12	
		Meeboldina scariosa	1	2	
		Hypocalymma angustifolium	2	2	
		Astartea scoparia	1	3	
		Melaleuca rhaphiophylla	1	2	seedlings
7	2	*Lepidosperma longitudinale*	15	40	
		Hypocalymma angustifolium	1	3	
		Kunzea recurva	4	2	
		Melaleuca rhaphiophylla	1	1	seedling
		Unknown #5	<1	2	
		Platysace sp.	<1	2	
		Siloxerus filifolius	<1	10	
7	3	*Kunzea recurva*	10	7	
		Lepidosperma longitudinale	13	40	
		Hypocalymma angustifolium	6	12	

		Meeboldina scariosa	<1	1	
		unknown #5	<1	10	seelings
		Stipa sp.	1	13	
		Siloxerus filifolius	<1	10	
		Aotus gracillima	<1	2	
7	5	*Lepidosperma longitudinale*	15	30	
		Hypocalymma angustifolium	1	5	
		Kunzea recurva	8	2	
		Platysace sp.	<1	1	
		unknown #5	<1	10	seedlings
		*Other weeds	<1	1	
7	7	*Lepidosperma longitudinale*	15	40	
		Hypocalymma angustifolium	1	1	
		Unknown #5	<1	1	
		Siloxerus filifolius	1	50	
		Platysace sp.	<1	4	
		Stipa sp.	1	20	
		Kunzea recurva	15	6	5 seedlings
7	9	*Lepidosperma longitudinale*	5	30	
		Melaleuca rhaphiophylla	1	1	
		Podotheca angustifolia	<1	5	
		Acacia pulchella	<1	1	seedling
		Unknown #5	<1	4	seedlings
		Daviesia physodes	<1	1	
		Siloxerus filifolius	<1	1	
		Platysace sp.	<1	3	
		Kunzea recurva	<1	5	4 seedlings
7	11	*Lepidosperma longitudinale*	30	40	
		Kunzea recurva	<1	2	1 seedling
		Hypocalymma angustifolium	1	2	
		Empodisma gracillimum	1	2	
		Stipa sp.	1	20	
		Unknown #5	<1	1	seedling
		Podotheca angustifolia	<1	5	
		Platysace sp.	<1	3	
7	13	*Lepidosperma longitudinale*	30	16	
		Hypocalymma angustifolium	2	7	
		Kunzea recurva	3	3	
		Astartea scoparia	2	2	
		Gompholobium aristatum	<1	1	
		Aotus gracillima	<1	1	seedling
		Platysace sp.	<1	1	
7	15	*Lepidosperma longitudinale*	20	40	
		Kunzea recurva	20	5	
		Hypocalymma angustifolium	1	5	
		Astartea scoparia	<1	2	
		Daviesia physodes	<1	2	
		Aotus gracillima	2	1	

		unknown #5	<1	1	
7	17	*Lepidosperma longitudinale*	15	25	
		Kunzea recurva	10	5	3 seedlings
		Hypocalymma angustifolium	2	1	
		Astartea scoparia	2	1	
		Unknown #5	<1	1	seedling
		Platysace sp.	<1	2	
		Viminaria juncea	4	1	
7	19	*Lepidosperma longitudinale*	25	30	
		Kunzea recurva	15	15	10 seedlings
		Daviesia physodes	<1	1	
		Unknown #5	<1	4	seedlings
		Pericalymma ellipticum	<1	2	seedlings
		Siloxerus filifolius	<1	10	
11	1	*Juncus pallidus*	25	8	
[new rehab area]		*Juncus planifolius*	10	30	
		Juncus ?articulatus	2	1	
		Polypogon tenellus	2	20	
		Haemodorum laxum	2	8	
11	2	*Juncus pallidus*	25	14	
		Hypocalymma angustifolium	1	10	
		Pericalymma ellipticum	<1	1	
		Baumea articulata	1	1	
		Isolepis sp..	2	30	
		Hypolaena exsulca	1	1	
		Weeds	2	10	
11	3	*Juncus pallidus*	25	7	
		Hypocalymma angustifolium	3	8	
		Lepidosperma longitudinale	1	1	
		Polypogon tenellus	<1	10	
		Isolepis sp..	5	50	
		Meeboldina scariosa	5	3	
		Baumea articulata	<1	1	
		Stipa sp.	1	20	
11	4	*Juncus pallidus*	15	12	
		Hypocalymma angustifolium	1	5	
		Isolepis sp..	5	50	
		Meeboldina scariosa	2	1	
		Stipa sp.	<1	10	
		Polypogon tenellus	<1	10	
		Lepidosperma longitudinale	1	1	
		Astartea scoparia	1	1	
		Juncus caespciticius	1	10	
		Weeds	1	10	
11	5	*Juncus pallidus*	25	12	
		Hypocalymma angustifolium	1	6	
		Kunzea glaucescens	1	1	

		Melaleuca preissiana	2	10	
		Pericalymma ellipticum	1	2	
		Polypogon tenellus	<1	10	
		Isolepis sp..	5	30	
		Meeboldina scariosa	1	1	
		Aphelia cyperiodes	1	1	
11	6	*Juncus pallidus*	12	7	
		Lepidosperma longitudinale	2	1	
		Melaleuca preissiana	5	14	
		Hypocalymma angustifolium	1	5	
		Isolepis sp..	5	50	
		Meeboldina scariosa	1	1	
		Astartea scoparia	<1	2	
		Polypogon tenellus	<1	10	
		Weeds	2	10	
	7	*Juncus pallidus*	25	19	
		Melaleuca preissiana	4	30	seedlings
		Hypocalymma angustifolium	<1	2	
		Haemodorum laxum	<1	5	
		Isolepis sp..	5	30	
		Juncus ?articulatus	<1	1	
		Isolepis cyperoides	<1	1	
		Schoenoplectus pungens	<1	5	
		Lepidosperma longitudinale	<1	1	
		Polypogon tenellus	<1	10	
		Meeboldina scariosa	1	1	

Appendix 2. Species X Quadrat Matrix showing Cover (%) Values

Sum of 2008 % cover	QuadCode																							
Species	10-1	10-2	10-3	10-4	10-5	10-6	10-7	1-1	1-10	11-1	11-2	11-3	11-4	11-5	11-6	11-7	1-2	1-3	1-4	1-5	1-6	1-7	1-8	1-9
?Conostylis sp.																								
?Jacksonia																								
?Melaleuca sp																			0.2			0.2		
Acacia pulchella	0.2	12	25	4	2												0.2					1	3	
Acacia saligna																								
Acacia semitrullata																								
Aotus gracillima		3	10	20	8	1																		12
Aphelia cyperiodes														1										
Astartea scoparia						0.2	1		1				1		0.2			1						
Baumea articulata						3	10		1		1	0.2												
Bossiaea eriocarpa																								
Caladenia ?paludosa																								
Calothamnus lateralis			1	8	30	10	4																	
Calytrix flavescens			0.2																					
Calytrix fraseri		2	1																					
Cassytha glabella																								
Centella asiatica																								
Corymbia calophylla																	1							
Cyperaceae																								
Cytogonidium leptocarpoides																								
Dasypogon bromeliifolius																								
Daviesia physodes		5																						
Drosera glanduligera																								
Drosera macrantha																								
Empodisma gracillimum																					0.2		0.2	0.2
Empodisma gracillimum						0.2																		
Epacridaceae																								
Eucalyptus marginata																	0.2							
Euchilopsis linearis																								
Gompholobium aristatum		1	0.2																					
Gonocarpus paniculatus			0.2																					
Haemodorum laxum										2						0.2								
Hakea sp		1						0.2																
Hardenbergia comptoniana																								
Hibbertia huegelii																								
Hypocalymma angustifolium			2	32	3	6		2			1	3	1	1	1	0.2	1	8	8	6	3	2	6	6
Hypolaena exsulca											1													0.2
Isolepis cyperoides																0.2								
Isolepis sp.											2	5	5	5	5	5								
Jacksonia furcellata																								
Juncus ?articulatus										2						0.2								
Juncus caespciticius													1											
Juncus pallidus						2	20		15	25	25	25	15	25	12	25								3
Juncus planifolius										10														
Juncus sp.																								
Kunzea glaucescens	20	8		1	3			1						1			1		2		2			
Kunzea glaucescens																								
Kunzea recurva																								
Lepidosperma longitudinale				5		15	10		1			1	1		2	0.2								1
Leptocarpus sp																								
Leptocarpus sp.																								
Lomandra sp.																								
Lomandra?																								
Meeboldina scariosa												5	2	1	1	1								
Melaleuca ?thymoides																								
Melaleuca incana subsp. incana																								
Melaleuca lateriflora							4																	
Melaleuca osullivanii																								
Melaleuca preissiana						2								2	5	4							0.2	
Melaleuca rhaphiophylla																								
Melaleuca sp.																								
Melaleuca teretifolia																								
Microtis media					0.2			0.2														0.2		
Patersonia occidentalis																								
Pericalymma ellipticum		0.2	2	6	0.2	0.2	1	0.2			0.2			1				1					1	1
Philotheca spicata																								
Platysace filiformis																								
Platysace sp																								
Poaceae sp																								
Podotheca angustifolia																	1							
Podotheca angustifolium																								
Polypogon tenellus										2		0.2	0.2	0.2	0.2	0.2								
Ptilotus sp																								
Ptilotus? Sp																								
Pultenaea ochreata																								1
Restionaceae																								
Restionaceae sp.						0.2																		
Schoenoplectus pungens																0.2								
Siloxerus filifolius		0.2			0.2																			
Siloxerus filifolius																								
Stipa sp					0.2							1	0.2											
Stirlingia latifolia		0.2																						
unknown #2																								
unknown #4																								
Unknown #5				1																				
Viminaria juncea				12				3										2					1	

Species	4-3	4-4	4-5	4-7	4-8	4-9	5-12	5-14	5-16	5-18	5-20	5-4	5-6	5-8	7-1	7-11	7-13	7-15	7-17	7-19	7-2	7-3	7-5	7-7	7-9	9-1	9-2	9-3	9-4	9-5	9-6	9-7	9-8
?Conostylis sp.																																	
?Jacksonia		0.2																															
Acacia pulchella			0.2	0.2				0.2																	0.2	5	10	10	15	15	8	0.2	0.2
Acacia saligna			0.2				4		15			3																					
Acacia semitrullata																															1		
Aotus gracillima																	0.2	0.2				0.2							0.2		0.2		
Astartea scoparia		2	2	4	27	20									1		2	0.2	2													1	3
Baumea articulata																																	2
Bossiaea eriocarpa																											0.2						
Caladenia ?paludosa					0.2																												
Calothamnus lateralis																													1			3	3
Calytrix fraseri																											1						
Centella asiatica		0.2	0.2																														
Corymbia calophylla											2																						
Cyperaceae																																	
Cytogonidium leptocarpoides							1																										
Dasypogon bromeliifolius																														0.2			
Daviesia physodes													4					0.2		0.2					0.2								
Drosera glanduligera		1	0.2	0.2																													
Drosera macrantha																															1		
Empodisma gracillimum										2		2														0.2	1	0.2	0.2	3	0.2	1	
Empodisma gracillimum																1																	
Epacridaceae																											0.2						
Euchilopsis linearis													1													1	0.2	1	1	2	1	1	
Gompholobium aristatum																	0.2										0.2	0.2	1		1		
Hakea sp																											0.2	0.2					
Hardenbergia comptoniana																																	
Hibbertia huegelii																												0.2					
Hypocalymma angustifolium			0.2	0.2		2	0.2		7	6	2	1	5	9	2	1	2	1	2		1	6	1	1		1	0.2	5	5	2	2	23	
Hypolaena exsulca	2	1																									1	0.2	0.2	2			
Jacksonia furcellata								3	3		2	2	0.2																				
Juncus pallidus	1	1	1																														10
Kunzea glaucescens																										2	1.5	8	1	2	1	1	
Kunzea glaucescens	0.2		2	1	20	25																											
Kunzea recurva	3	3					30	15	6	8	8	9	22	16	5	0.2	3	20	10	15	4	10	8	15	0.2				1				
Lepidosperma longitudinale	10	4	2	2	2	2								0.2	2	30	30	20	15	25	15	13	15	15	5	0.2	0.2	0.2	5	5	2	17	60
Leptocarpus sp																																	
Leptocarpus sp.	5	10	20	10	10	2																											
Lomandra sp.																											0.2				0.2		
Lomandra?																																	
Meeboldina scariosa															1							0.1										1	1
Melaleuca ?thymoides																											0.2			0.2			
Melaleuca incana subsp. inc	20																																
Melaleuca lateriflora		40	40	6	1																												
Melaleuca osullivanii						2	1.5																										
Melaleuca preissiana						3																				2	0.2		0.2			0.2	0.2
Melaleuca rhaphiophylla	12	20													1						1				1								
Melaleuca sp.																																	
Melaleuca teretifolia																																	
Microtis media			0.2				0.2	0.2	0.2																								
Pericalymma ellipticum																				0.2						0.2	1	2	1.2	2	1	0.2	
Philotheca spicata		0.2		0.2																													
Platysace filiformis																												1	1				
Platysace sp																0.2	0.2		0.2		0.2		0.2	0.2	0.2								
Podotheca angustifolium																0.2									0.2								
Ptilotus sp				0.2	0.2																												
Ptilotus? Sp			0.2																														
Restionaceae sp.																																	
Siloxerus filifolius																				0.2	0.2	0.2		1	0.2	1			0.2				
Siloxerus filifolius				0.2																													
Stipa sp																1						1		1									
unknown #2																																	
unknown #4																																	
Unknown #5																0.2		0.2	0.2	0.2	0.2	0	0.2	0.2	0.2								
Viminaria juncea						10						5							4												0.2		
Grand Total (% Cover)	53.2	82.6	68.4	24.2	60.4	66	36.9	18.4	31.2	16	14	22	32.2	25.2	12	33.8	37.6	41.8	33.4	40.8	21.6	30.5	24.4	33.4	7.4	12.6	17.5	28.2	33.2	33.4	18.8	48.6	79.4

Appendix 3: Species characterising Sector 5 (transect #10) and Sector 6 (transect #9) including those characterising differences between 2007 and 2008 monitoring, and differences between transects 9 and 10.

Examines Year groups
(across all transect groups)
Group 2008
Average similarity: 37.67

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Acacia pulchella	2.16	8.69	1.00	23.06	23.06
Kunzea glaucescens	1.33	4.84	0.86	12.85	35.91
Lepidosperma longitudinale	1.89	4.60	0.82	12.21	48.12
Hypocalymma angustifolium	1.65	4.55	0.95	12.07	60.19
Pericalymma ellipticum	0.87	3.24	1.23	8.59	68.78
Calothamnus lateralis	1.26	2.61	0.53	6.92	75.69
Euchilopsis linearis	0.46	2.53	0.79	6.72	82.41
Aotus gracillima	0.94	2.21	0.46	5.85	88.26
Empodisma gracillimum	0.40	1.58	0.78	4.19	92.45

Group 2007
Average similarity: 44.05

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Acacia pulchella	1.08	9.25	1.46	21.00	21.00
Hypocalymma angustifolium	0.97	7.82	1.42	17.75	38.74
Kunzea glaucescens	0.68	4.80	0.71	10.89	49.63
Pericalymma ellipticum	0.67	4.56	1.00	10.34	59.97
Aotus gracillima	0.52	3.78	0.55	8.57	68.55
Lepidosperma longitudinale	0.62	3.67	0.76	8.33	76.88
Melaleuca preissiana	0.30	2.47	0.96	5.60	82.48
Platysace filiformis	0.28	1.39	0.51	3.15	85.63
Hypolaena exsulca	0.21	1.35	0.55	3.06	88.69
Calothamnus lateralis	0.44	1.13	0.29	2.58	91.26

Groups 2008 & 2007
Average dissimilarity = 63.73

	Group 2008	Group 2007				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Acacia pulchella	2.16	1.08	7.00	1.34	10.98	10.98
Lepidosperma longitudinale	1.89	0.62	6.64	0.94	10.43	21.41
Kunzea glaucescens	1.33	0.68	5.79	0.73	9.08	30.49
Hypocalymma angustifolium	1.65	0.97	5.34	1.11	8.38	38.87
Calothamnus lateralis	1.26	0.44	5.17	0.82	8.12	46.99
Aotus gracillima	0.94	0.52	3.67	0.79	5.75	52.74
Pericalymma ellipticum	0.87	0.67	2.68	1.21	4.21	56.95
Juncus pallidus	0.60	0.00	2.48	0.44	3.88	60.83
Euchilopsis linearis	0.46	0.24	1.93	0.93	3.02	63.86
Baumea articulata	0.42	0.00	1.76	0.45	2.76	66.61
Astartea scoparia	0.28	0.24	1.75	0.81	2.75	69.37
Gompholobium aristatum	0.29	0.17	1.51	0.86	2.37	71.73
Viminaria juncea	0.26	0.17	1.42	0.47	2.23	73.97
Empodisma gracillimum	0.40	0.25	1.39	0.78	2.18	76.15
Melaleuca preissiana	0.31	0.30	1.36	0.65	2.13	78.28
Calytrix fraseri	0.23	0.06	1.27	0.60	2.00	80.28
Platysace filiformis	0.13	0.28	1.16	0.69	1.81	82.09
Hypolaena exsulca	0.22	0.21	1.07	0.68	1.67	83.77
Daviesia physodes	0.15	0.03	0.80	0.31	1.26	85.03
Melaleuca lateriflora	0.13	0.07	0.79	0.35	1.24	86.27
Melaleuca sp.	0.00	0.17	0.77	0.52	1.20	87.47
Siloxerus filifolius	0.16	0.00	0.75	0.50	1.18	88.65
unknown #2	0.00	0.14	0.60	0.49	0.94	89.59
Hakea sp	0.13	0.00	0.57	0.44	0.90	90.49

Examines transect groups(across all Year groups)
Group 10
Average similarity: 30.30

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Aotus gracillima	1.39	6.16	0.84	20.32	20.32
Acacia pulchella	1.25	4.67	0.78	15.42	35.74
Hypocalymma angustifolium	1.24	4.63	0.75	15.28	51.02
Kunzea glaucescens	1.09	4.47	0.54	14.75	65.77
Pericalymma ellipticum	0.76	3.59	0.83	11.85	77.62
Calothamnus lateralis	1.37	3.58	0.60	11.80	89.42

Group 9
Average similarity: 49.46

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Acacia pulchella	2.00	12.61	1.80	25.50	25.50
Hypocalymma angustifolium	1.40	7.28	1.72	14.72	40.22
Lepidosperma longitudinale	1.69	6.48	1.27	13.11	53.33
Kunzea glaucescens	0.95	5.12	1.44	10.35	63.67
Pericalymma ellipticum	0.78	4.06	1.33	8.21	71.89
Euchilopsis linearis	0.61	2.81	0.89	5.68	77.57
Melaleuca preissiana	0.42	2.74	1.19	5.53	83.10
Empodisma gracillimum	0.60	2.46	0.86	4.97	88.07
Hypolaena exsulca	0.42	1.60	0.65	3.23	91.30

Groups 10 & 9
Average dissimilarity = 67.69

	Group 10	Group 9				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Lepidosperma longitudinale	0.84	1.69	6.23	1.08	9.20	9.20
Acacia pulchella	1.25	2.00	6.07	1.35	8.96	18.17
Aotus gracillima	1.39	0.12	5.57	1.35	8.23	26.39
Calothamnus lateralis	1.37	0.39	5.21	0.99	7.70	34.09
Kunzea glaucescens	1.09	0.95	5.12	0.98	7.56	41.66
Hypocalymma angustifolium	1.24	1.40	4.86	1.15	7.17	48.83
Pericalymma ellipticum	0.76	0.78	2.77	1.20	4.10	52.93

Euchilopsis linearis	0.07	0.61	2.65	1.26	3.92	56.84
Empodisma gracillimum	0.03	0.60	2.62	1.03	3.87	60.71
Melaleuca preissiana	0.17	0.42	2.34	1.40	3.46	64.17
Hypolaena exsulca	0.00	0.42	2.14	0.94	3.16	67.34
Platysace filiformis	0.00	0.39	1.98	0.83	2.92	70.26
Astartea scoparia	0.28	0.24	1.86	0.85	2.75	73.01
Juncus pallidus	0.42	0.21	1.84	0.44	2.71	75.73
Viminaria juncea	0.35	0.10	1.50	0.51	2.22	77.95
Gompholobium aristatum	0.21	0.25	1.47	0.85	2.17	80.11
Baumea articulata	0.35	0.09	1.33	0.45	1.96	82.07
Calytrix fraseri	0.17	0.13	1.11	0.65	1.65	83.72
Melaleuca lateriflora	0.21	0.00	0.85	0.40	1.26	84.98
unknown #2	0.00	0.13	0.79	0.46	1.17	86.15
Melaleuca sp.	0.10	0.06	0.79	0.46	1.17	87.32
Daviesia physodes	0.19	0.00	0.77	0.37	1.14	88.46
Hibbertia huegelii	0.00	0.13	0.75	0.41	1.11	89.57
Dasypogon bromeliifolius	0.00	0.12	0.71	0.56	1.04	90.61

Appendix 4: ANOSIM (Analysis of Similarity) results showing significant differences between transects in terms of species composition.

Global Test
Sample statistic (Global R): 0.704
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
10, 1	0.401	0.2	19448	999	1
10, 4	0.565	0.5	1716	999	4
10, 5	0.836	0.1	6435	999	0
10, 7	0.808	0.1	31824	999	0
10, 9	0.233	3.1	6435	999	30
1, 4	0.733	0.2	8008	999	1
1, 5	0.649	0.1	43758	999	0
1, 7	0.813	0.1	352716	999	0
1, 9	0.447	0.1	43758	999	0
4, 5	0.998	0.1	3003	999	0
4, 7	0.913	0.1	12376	999	0
4, 9	0.692	0.1	3003	999	0
5, 7	0.822	0.1	75582	999	0
5, 9	0.894	0.2	6435	999	1
7, 9	0.847	0.1	75582	999	0

APPENDIX 9:
SYNOPSIS OF WETLAND CHARACTERISATION STUDY: POTENTIAL IMPLICATIONS FOR PER
KEMERTON SILICA SAND
SEPTEMBER 2008
CENTRE FOR ECOSYSTEM MANAGEMENT
EDITH COWAN UNIVERSITY

Centre for ecosystem management

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Prepared for,

Kemerton Silica Sand Pty Ltd

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Frontispiece

Figure 1. New paperbark trees (*Melaleuca* sp.) establishing themselves across the middle of EPP 4.

This document should be referenced as follows.

Van Etten, E., McCullough, C. D. and Lund, M. A. (2008). Synopsis of wetland characterisation study: Potential implications for P.E.R. Centre for Ecosystem Management Report No. 2008-17a, Edith Cowan University, Perth, Australia. 10pp. Unpublished commercial-in-confidence report.

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2 Background

The Kemerton Silica Sand Pty Ltd (KSS) project area occupies some 1,600 ha of land at the northern end of Kemerton Industrial Park, 20 km north of Bunbury. The KSS Project Area is located in the Swan Coastal Plain, primarily on gently undulating Bassendean Sands, with vegetation comprising *Eucalypt-Banksia* woodland on uplands and wetlands on lower parts of the landscape.

Feldspathic silica sands are extracted from below the water table using dredge ponds. The resource generally lies beneath <1 m of topsoil and 4 to 7 m of overburden (which generally contains a band of coffee rock at the inter-phase between high and low groundwater levels). The overburden is removed by earth moving equipment. The resource is then extracted from a 30 m deep superficial aquifer using a surface floating dredge to a maximum permitted depth of 15 m. Once extraction is complete, the dredge pond is approximately 10 m deep. As the dredge pond is essentially an expression of the groundwater, the results are permanently inundated lakes. Fines, overburden and topsoil are available for sculpting and landscaping of the dredge ponds and surrounds.

The shallow depth to groundwater in the inter-dunal depressions results in numerous wetland areas of palusplain, damplands, sumplands and lakes (as per the definitions of Semeniuk, (1987) within the project area. These wetlands become inundated from rainfall or the rising groundwater table, typically from July to November. Some of the wetlands are perched above the water table and so are dependant on rainfall for inundation. Six EPP wetlands (one crosses the boundary) located across 200 ha of the project area have now been vested with the Department of Environment and Conservation (DEC) as the Kemerton (formerly Gwalia) Nature Reserve. One and part of another EPP lake remain in the project area, but are away from the current operations. One EPP lake has been lost in previous KSS mining activities. The KSS project area contains examples of remnant and regrowth native vegetation following selective logging and stocking in the past (GHD, 2005). Some of these vegetation communities have been identified as threatened. A threatened ecological community ("Shrublands and Woodlands on Muchea Limestone" (English & Blyth 2000)) listed as endangered by the DEC and endangered under the Commonwealth Environment and Biodiversity Conservation Act 1999 has been reported as occurring on the eastern side of the existing dredge ponds (Environmental Protection Authority, 2005). Ownership of this land (13 ha in total) was transferred from KSS to the conservation estate in 2006 to help protect this Threatened Ecological Community (TEC).

In June 2007, we were commissioned by KSS to study selected natural wetlands in the KSS project area. The objectives of this study were to describe both characteristic features and variability of riparian vegetation around the natural wetlands of Kemerton, and to use this information to provide advice for management of these wetland areas and rehabilitation of mined areas and pit lakes. This report presents a summary of the Wetland Characterisation Study of the Kemerton Area, a report which is currently being prepared by the authors, and is presently in draft form. The objective of this report is to summarise the main findings of the study that are likely to be of relevance to the P.E.R. currently being written for the extension of mining by KSS.

3 Methods

Three main wetlands were studied, together with several associated wetlands adjoining and linked to these EPP and CC wetlands. The details of wetland studied at outlined in Table 1. Their location within the KSS project area is shown in Figure 2.

Table 1. Natural Kemerton wetlands surveyed for riparian vegetation and soils and the wetland names.

Wetland name	Description of wetland
CC5	Conservation Category wetland #5
CC5P	Conservation Category wetland 5 paperbark area immediately south-east of dredge pond
CCX	Rehabilitated wetland next to CC5
EP4	EPP wetland # 4
EP7	EPP wetland #7
PD	‘Paperbark deep' - deep wetland nor-north west of EPP wetland 7
PS	‘Paperbark new' - small shallow wetland north-west of EPP wetland 7

We sampled wetland vegetation along transects through wetlands commencing at the lowest point in the wetland through to the outside of fringing vegetation. Major distinct floral communities (typically around four types) were identified along each transect. For each floral community, fringing vegetation species composition and cover was measured and soil samples were taken at regular points along transects. In addition, wetland topography was measured along transect with a theodolite and staff. Analyses involved relating vegetation to soil and topography using a variety of multivariate statistics and graphing tools.

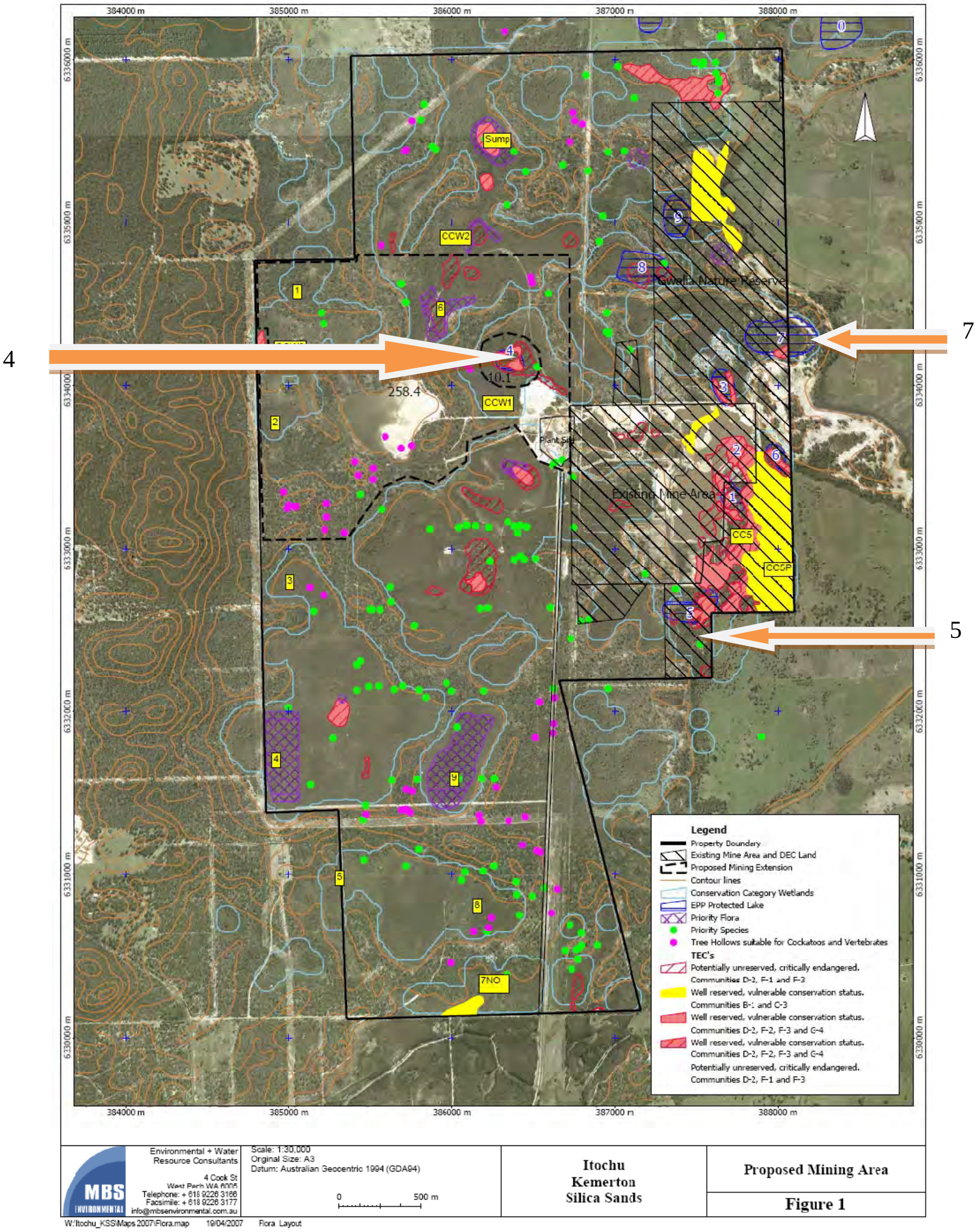

Figure 2. Aerial photograph of Kemerton Area showing KSS project area Kemerton wetlands as at 2007 and location of 3 wetland studied.

4 Results

Figures 3-7 show the major vegetation communities associated with slope and soil chemistry for each of the study sites.

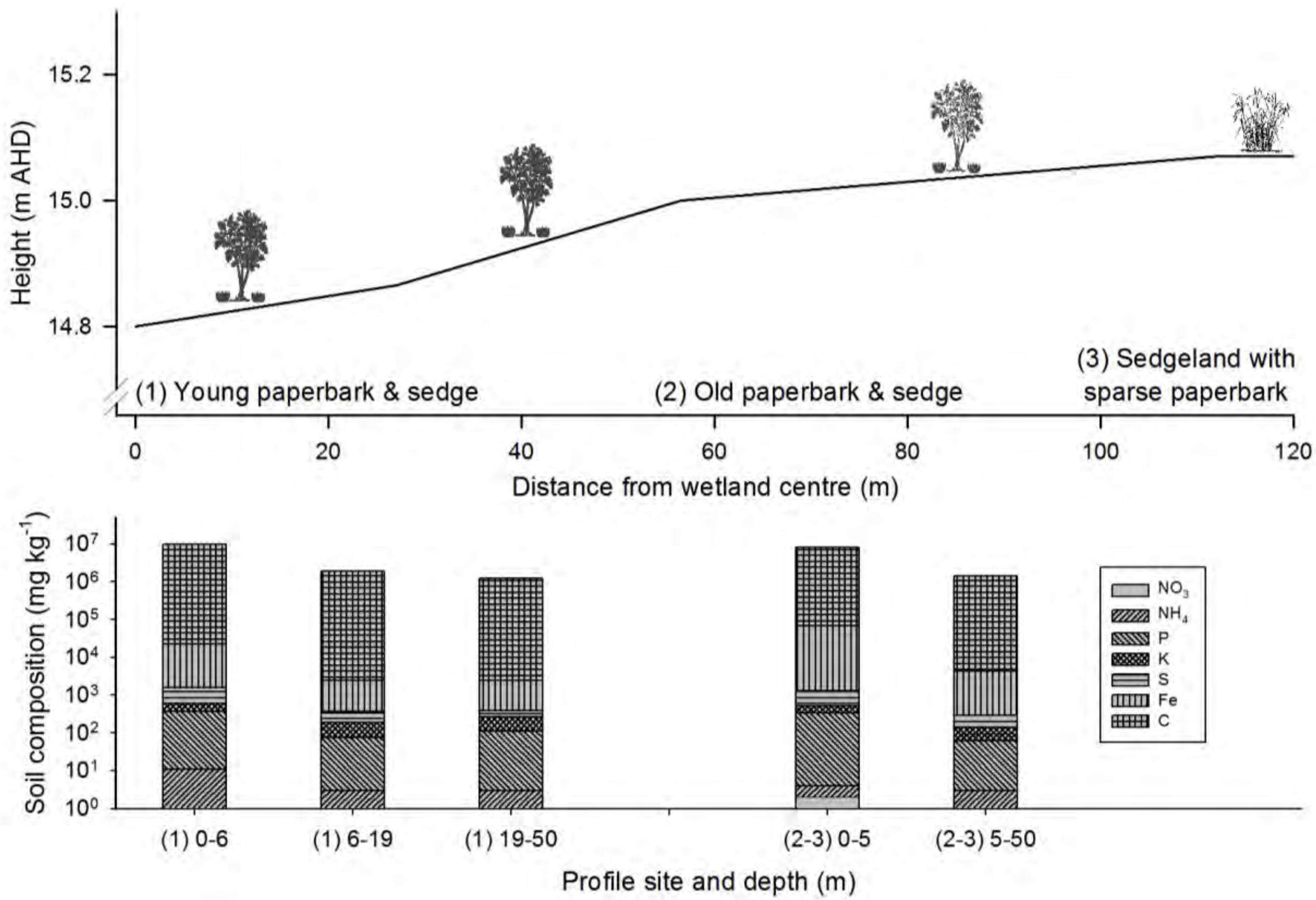

Figure 3. Wetland EPP 4 riparian topographic profile, vegetation structure classification and soil composition.

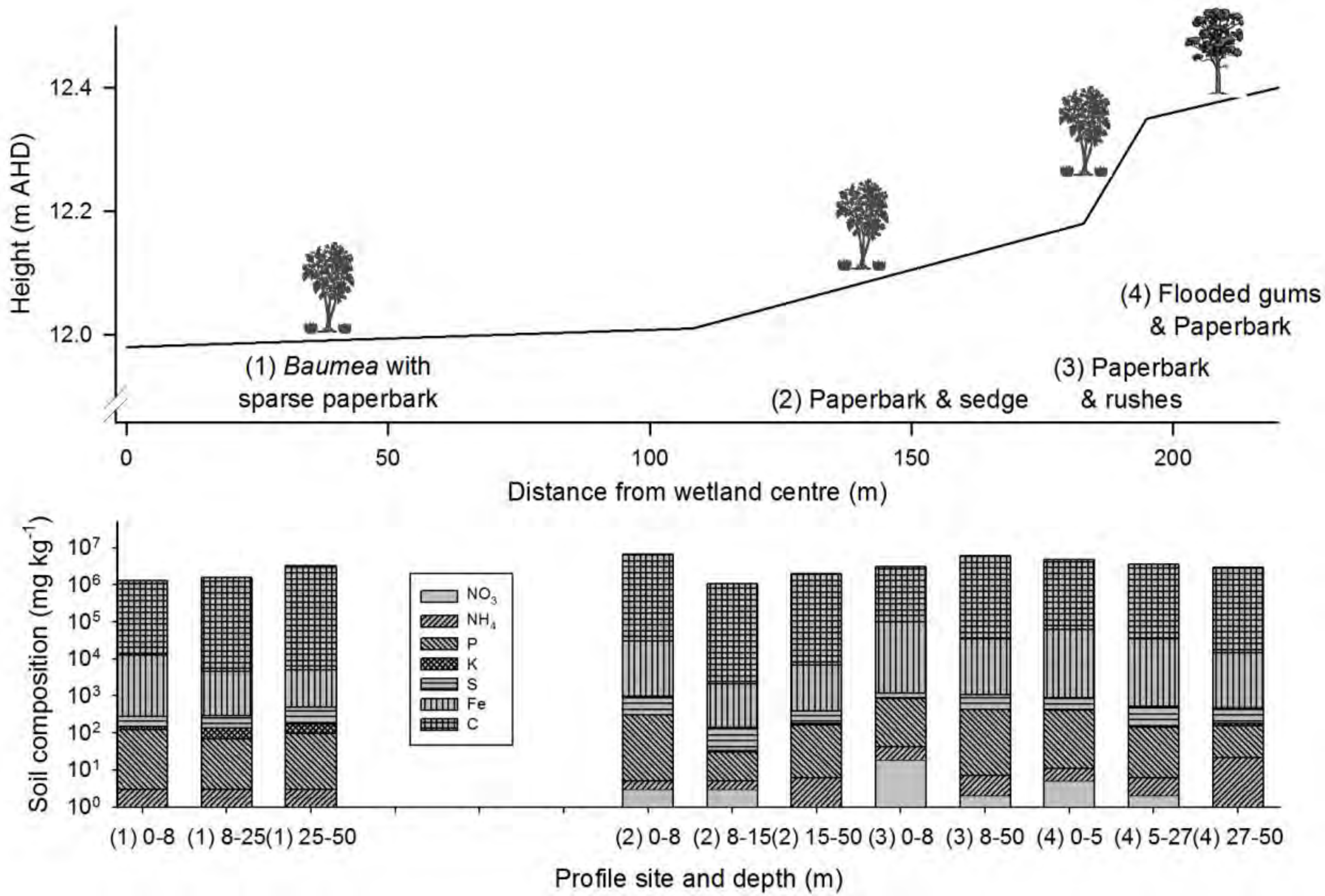

Figure 4. Wetland EPP 5 riparian topographic profile, vegetation structure classification and soil composition.

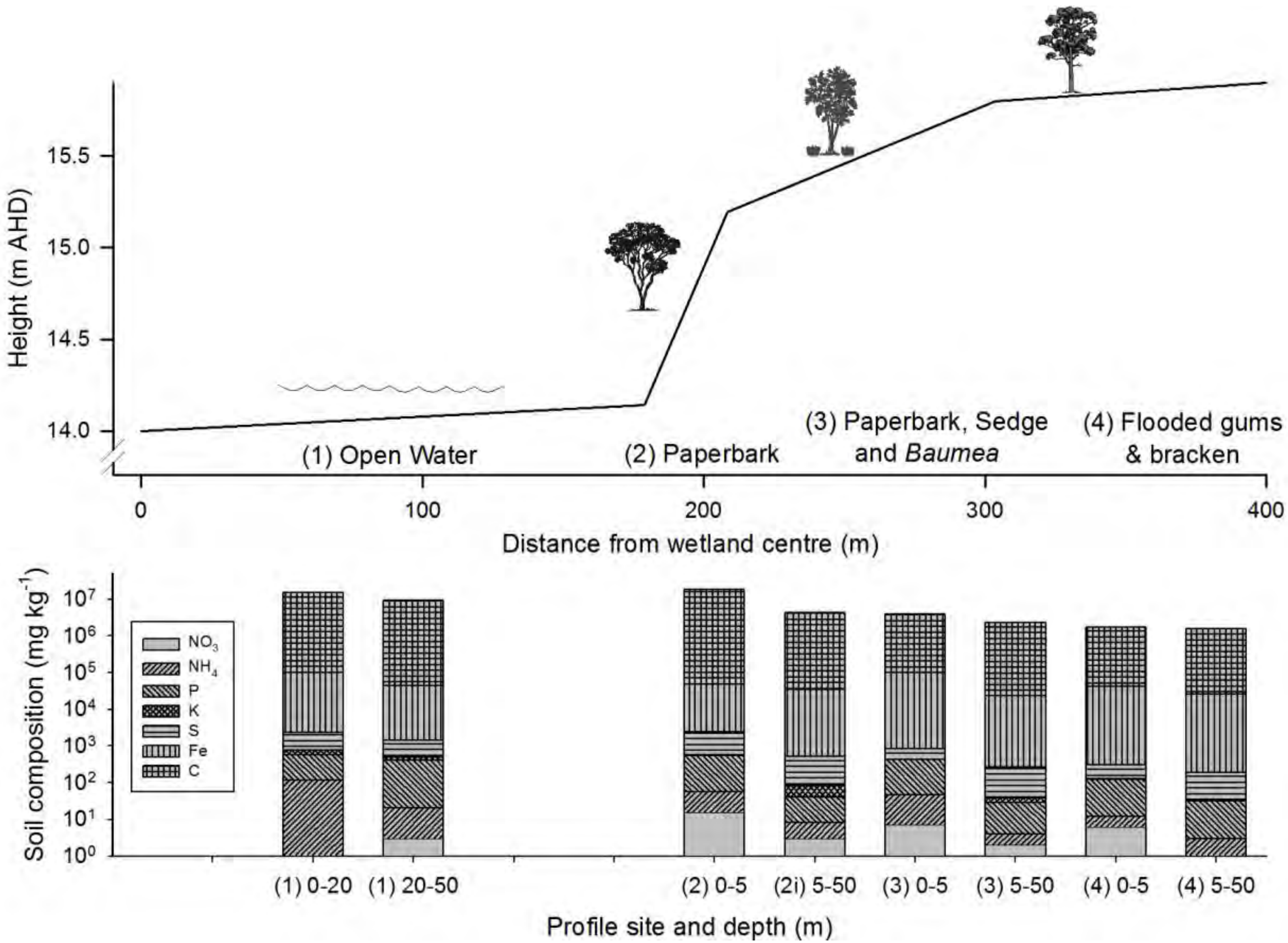

Figure 5. Wetland EPP 7 riparian topographic profile, vegetation structure classification and soil composition.

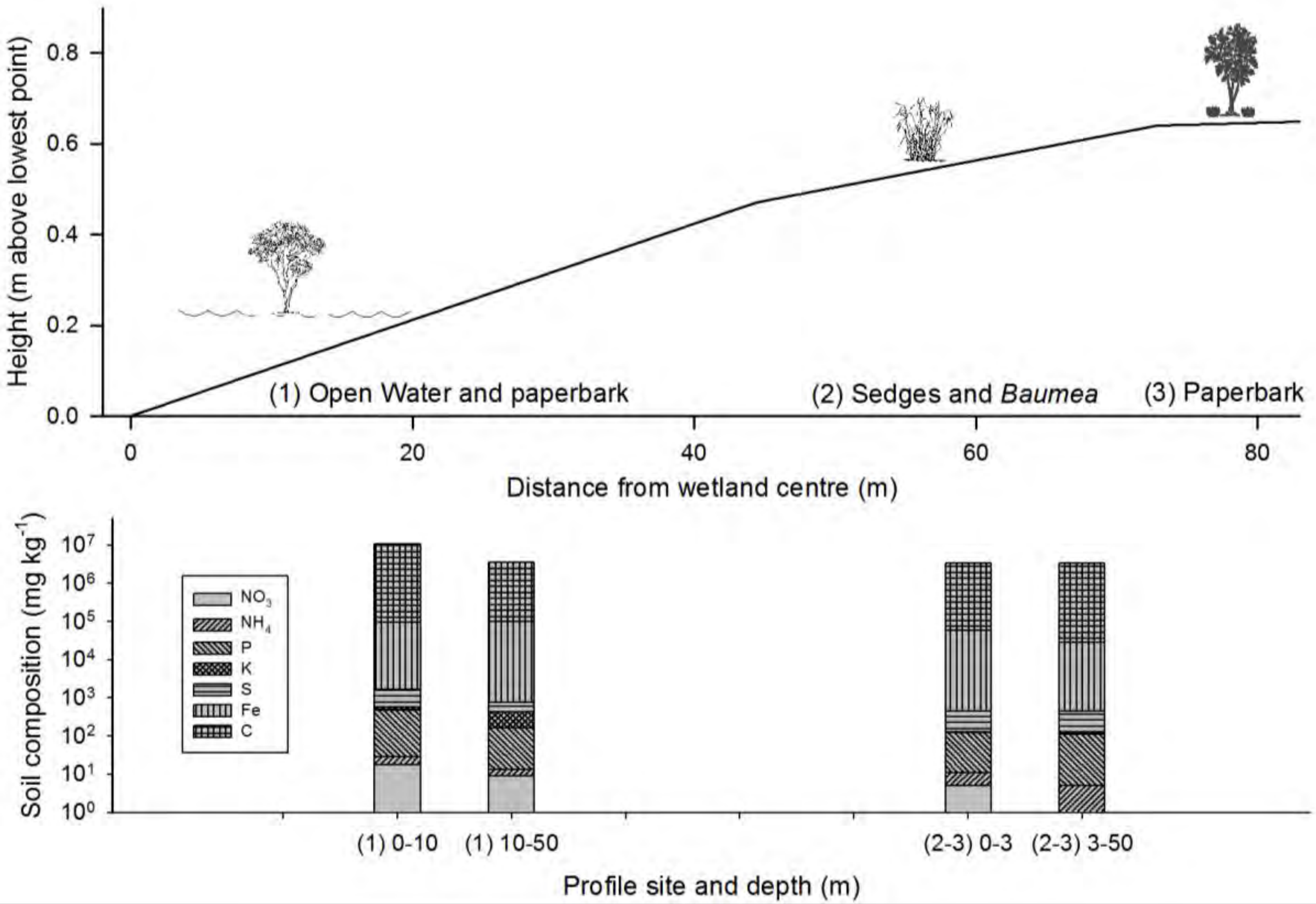

Figure 6. Wetland PD riparian topographic profile, vegetation structure classification and soil composition.

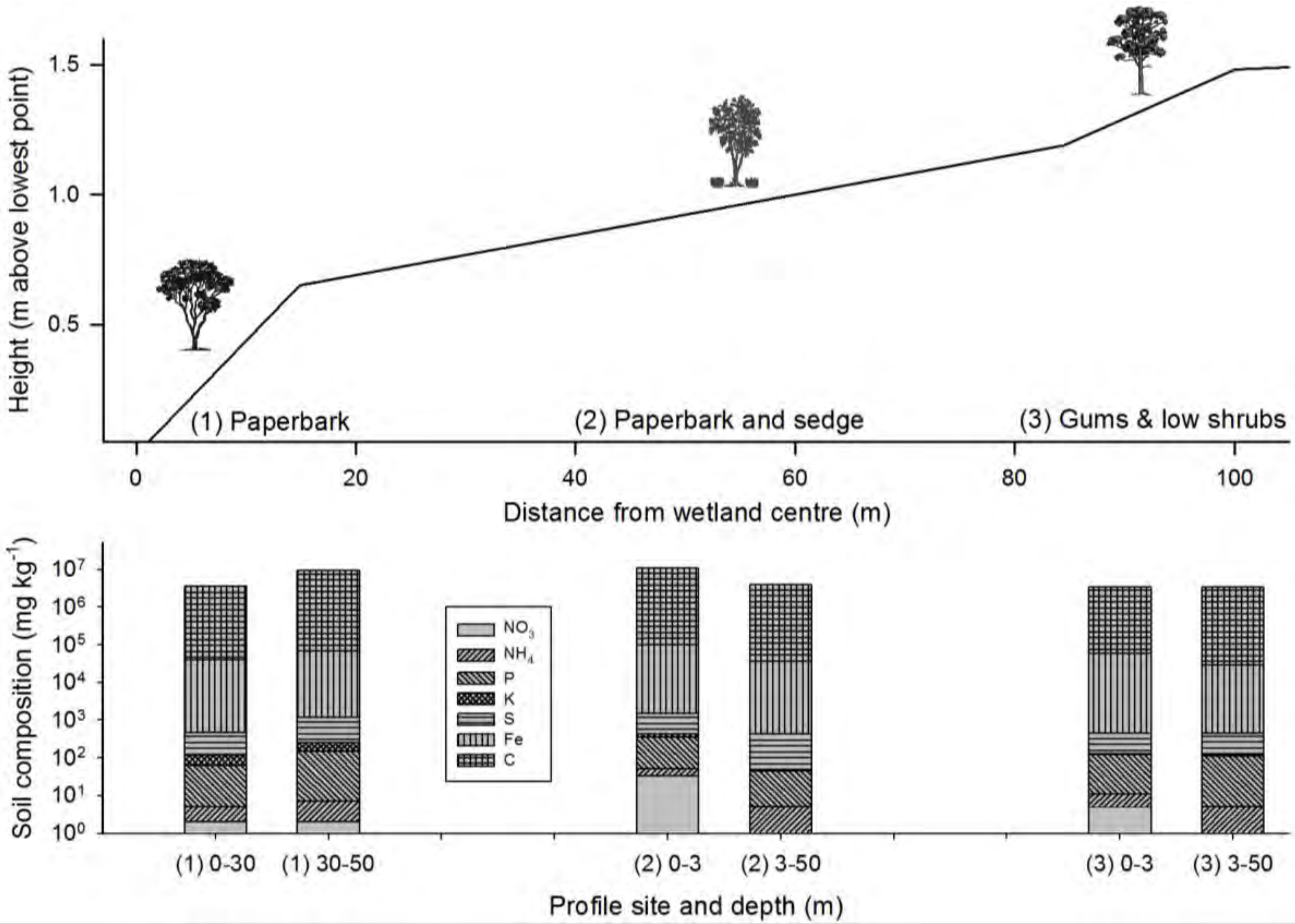

Figure 7. Wetland PS riparian topographic profile, vegetation structure classification and soil composition.

Species richness of riparian plants increased with height above the wetland base, however at EPP 7 this was also associated with an increase in weeds (Table 2).

Table 2. Summary of vegetation communities in natural wetlands areas showing cover of natives, weeds and trees, and the number of native species per relevé. n.a. = not applicable. Closest community based on vegetation mapping of the study area by Mattiske Consulting is also indicated.

EPP Wetland	Community	Description	Cover Native (%)	Cover Weeds (%)	Tree Cover (%)	Native Species Richness	Equivalent Mattiske Community
7	1	Lake Bed with annuals	40	0	1	2	n.a.
	2	Fringing *M. rhaphiophylla*	60	2	60	3	F
	3	Fringing *M. rhaphiophylla* with sedge	100	10	45	5	F
	4	Fringing Eucalypt woodland	100	1	45	13	D
7A	1	Wetland Bed	60	0	30	4	n.a.
	2	Fringing *M. rhaphiophylla* with sedge	60	0	40	4	F
7A-B		Fringing Eucalypt woodland	40	0	25	6	A
7B	1	Fringing *M. rhaphiophylla*	80	0	80	2	F
5	1	Wetland Bed	40	0	10	5	n.a.

	2	*Melaleuca* thicket with sedge and rush	70	0	40	8	E
	3	Fringing *M. rhaphiophylla* with sedge	100+	0	60	10	F
	4	Fringing *Melaleuca* – Eucalypt Transition	100+	0	60	8	A - F
	5	Fringing mixed *Melaleuca*	80	0	60	10	
	6	Fringing Eucalypt woodland	100+	0	30	13	A
4	1	Wetland Bed with *M. laterifolia*	45	0	45	3	n.a.
	2	Fringing mixed Melaleuca	55	0	55	4	E-F
	3	Dampland Community – Melaleuca over heath	65	0	13	13	E-H

Community data for the different transects was examined using ordination, which places them on the graph so as to accurately portray the degree of similarity between the transects (Figure 8). Sites close together on the ordination plot have similar floral community structure. As can be seen in Figure 8, that there is no obvious progression along the transects and that the start and end points were not similar (i.e., 7-1, 4-1 and 5-1 are widely spaced.)

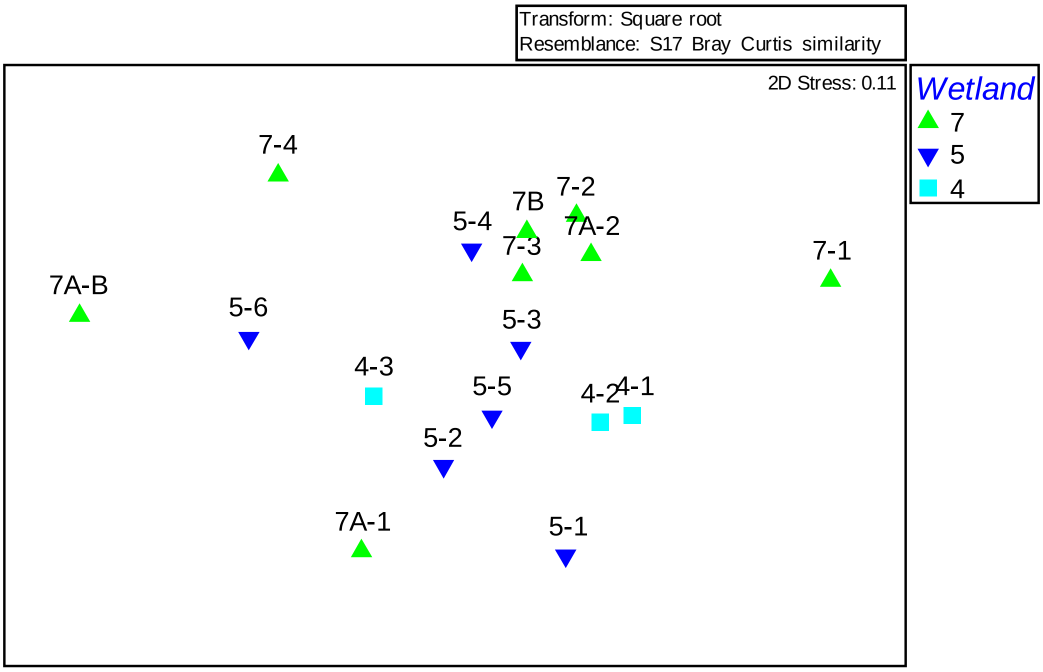

Figure 8. Non-metric multidimensional Scaling of Wetland Communities at Kemerton. Data was relevés of plant species cover (square root transformed) with Bray Curtis measure used to derive similarity matrix. Figure labels indicate wetland transect name_vegetation zone.

The high spatial variability in floral community composition both between and within wetlands might be explainable by soil chemistry, to examine this soil parameters were correlated to their floral communities (Table 3). As seen in Table 3, the maximum rank correlation between floral community and soil composition was only 0.295. This value is very low and suggests that, while soil chemistry may still be important in defining floral community structure of natural KSS project area wetlands, other environmental factors were more likely to be responsible in determining floral community structure.

Table 3. Six highest Spearman rank correlations between floristic similarity and environmental variables.

Variable	Correlation
Depth of ‘A’ horizon	0.295
Topsoil K	0.209
Subsoil pH	0.206
Slope	0.152
Subsoil Fe	0.141
Topsoil Fe	0.117

Soil pH was very variable between the EPP wetlands (Figure 9). Potentially reflecting different proximity to the limestone TEC, EPP 5 was the most alkaline and EPP 7 was slightly acidic.

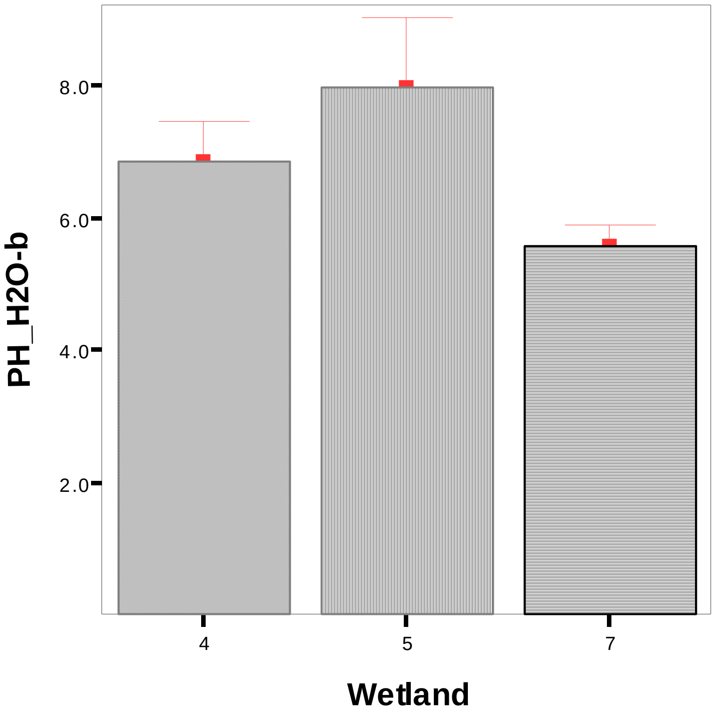

Figure 9. Mean subsoil pH (using H_2O extraction) for each wetland system. Error bars are + 95% confidence intervals.

5 Conclusions

- Of the wetlands studied, only EPP Wetland 4 is close to the original area of mining expansion covered by the P.E.R..
- Wetland EPP 4 appears to be a perched wetland, primarily receiving water inflows from the surrounding CC wetland which effectively acts as a catchment to this EPP wetland. It is therefore important that this catchment area is actively managed to avoid adverse impacts on inflow water quantity and quality.
- The general climate drying trend of the project area over the last decade appears to have resulted in colonisation of paperbark trees in wetland basins. This dynamic can be clearly seen at EPP 4 where a single cohort of ~5 year old paperbark trees have colonised the basin following flooding in 2001–2. Relatively dry conditions since this date have resulted in persistence of these trees which are now likely to survive unless a major and prolonged flooding event occurs or the area is burnt. Other wetlands in the study area (e.g., EPP 9) are already colonised by mature trees and, overall, there is trend across the study area for infill of wetlands by woody vegetation.
- Fringing flora of EPP wetland across the study area are highly variable both spatially and temporally. Key variables responsible for this variation are thought to be hydrology/topography (e.g., depth to groundwater and slope), soil pH (with wetlands in the south-west more alkaline due to limestone layers in nearby soil) and organic carbon content (likely to increase over time since last fire). Iron rich or ‘coffee rock’ layers in soil are also likely to be of importance.
- Given high variability between floral communities of EPP different wetlands on the KSS project lease, it is difficult to establish a single reference or analogue wetland to compare with rehabilitated mine ponds and slopes.
- No declared rare plant taxa were found during survey; although one priority plant taxa was found in dampland adjoining wetland 4 (*Hakea tuberculata*).
- The relationships found here between fringing flora, soil characteristics, topography and hydrology should help improve revegetation practices and overall rehabilitation success. Specifically this information informs that rehabilitation

slopes should be subtle, with varying depth to groundwater and that organic matter levels in new topsoils should be enhanced in rehabilitation attempts.

- There is as a strong need to establish to establish trial/demonstration sites within rehabilitation areas to trial novel wetland rehabilitation techniques that are starting to develop from these studies to date. These trial/demonstration should result in wetlands which more closely resemble the range of natural analogues.

APPENDIX 10:
SYNTHESIS OF EXISTING DATA AND KNOWLEDGE GAPS FOR THE REHABILITATION OF KEMERTON SILICA SAND MINE DREDGE PONDS
FEBRUARY 2007
CENTRE FOR ECOSYSTEM MANAGEMENT
EDITH COWAN UNIVERSITY

SYNTHESIS OF EXISTING DATA AND KNOWLEDGE GAPS FOR THE REHABILITATION OF KEMERTON SILICA SAND MINE DREDGE PONDS

February 2007

Prepared for,

Kemerton Silica Sand Pty Ltd

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CENTRE *for* ECOSYSTEM MANAGEMENT

EDITH COWAN UNIVERSITY

1 Executive Summary

1. The Kemerton Silica Sand Pty Ltd (KSS) mine is located on a 1 600 ha block of land at the northern end of Kemerton Industrial Park. The company mines silica sands following mechanical removal of topsoil, and then extraction of the ore from below the water table by dredging.

2. The Kemerton Industrial Park consists of large areas of remnant or regenerating bushland, with areas of lakes and wetlands, surrounded by cleared farmland. The presence of ecological significant flora, fauna and ecosystems heightens the environmental importance of the area.

3. Lakes with more 1 000 m^2 of standing water on 1/12/91 are protected by the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (EPP). A number of lakes on the project area are protected under this EPP, which restricts mining, discharge to, filling, and other forms of degrading activities without approval. Other wetland types, such as palusplain were being considered for similar protection, however that EPP has been abandoned. KSS transferred 200 ha including 5 EPP lakes to the Department of Environment and Conservation (DEC) and has only one remaining on site and one straddling the project area boundary, although away from current operations.

4. Currently KSS wishes to ensure the longevity of operations by expanding the area that can be mined and is preparing a Public Environmental Review (PER). Given the ecological value of the area, it is important for KSS to be able to adequately demonstrate an ability and willingness to rehabilitate the area post-mining, however no successful rehabilitation, particularly of the dredge ponds has been demonstrated to date.

5. In response to this, KSS commissioned this desktop study to review available literature, primarily in the form of *ad hoc* regulatory reporting by external consultants. Current knowledge was then documented, knowledge gaps identified, monitoring programs to cover the gaps recommended, and potential goals for a rehabilitation program identified. Direction from regulatory bodies and relevant stakeholders was also sourced to guide monitoring and goal development.

6. Apart from a small area of land surrounding each dredge pond, the major feature of the mined areas requiring rehabilitation post-mining are the large and deep dredge ponds.

7. At this stage, the goal for rehabilitation must to enhance existing conservation values and maximise these in novel areas (i.e. dredge ponds). It appears that only once a capacity to achieve this goal has been demonstrated that other potential end uses (alternative uses) for the dredge ponds can be discussed with regulatory agencies.

Frontispiece

Figure 1. Dr. Eddie van Etten standing next to the initial rehabilitation trial area of Lake 1.

This document should be referenced as follows.

McCullough, C. D.; Lund, M. A. & van Etten, E. (2007). *Synthesis of existing data and knowledge gaps for the rehabilitation of Kemerton Silica Sand mine dredge ponds*. Centre for Ecosystem Management Report No. 2007-04, Edith Cowan University, Perth, Australia. 53pp. Unpublished commercial-in-confidence report.

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3 Background

The Kemerton Silica Sand Pty Ltd (KSS) project area is sited on the Swan Coastal Plain, primarily on gently undulating Bassendean Sands (Dames and Moore Pty Ltd, 1993b) in approximately 1 600 ha of land at the northern end of Kemerton Industrial Park. Feldspathic silica sands are extracted from below the water table in a dredge ponds. The resource generally lies beneath <1 m of topsoil and 4 to 7 m of overburden (which contains a band of coffee rock at the inter-phase between high and low groundwater levels). The overburden is removed by surface earth moving equipment. and dredging (below the water table). The resource is then extracted from a 30 m deep superficial aquifer using a surface floating dredge to a maximum permitted depth of 15 m. Once extraction is complete, the dredge pond is approximately 10 m deep. As the dredge pond is essentially an expression of the groundwater, the ponds are permanently inundated features. Fines, overburden and topsoil are available for sculpting and landscaping of the dredge ponds and surrounds.

The shallow depth to groundwater in the inter-dunal depressions has created a number of palusplain, wetland (sumplands) and lake areas (as per the definitions of Semeniuk (1987) within the project area. These become inundated when the groundwater table is at its highest typically at the end of spring. The lakes and some of the wetlands have probably developed an relatively impervious bottom (perched) which allows these areas to retain water for a while after the groundwater recedes. The KSS project area contains examples of remnant, and regrowth native vegetation following destocking of the area (GHD, 2005). Some of these vegetation communities have been identified as threatened. A threatened ecological community ("Shrublands and Woodlands on Muchea Limestone";(English & Blyth 2000)) listed as endangered by the DEC and endangered under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 has been reported as occurring on the eastern side of the existing dredge ponds (Environmental Protection Authority 2005). Ownership of this land (13 ha in total) was transferred from KSS to the conservation estate in 2006 to help protect this TEC.

Six EPP (one crosses the boundary) lakes located in 200 ha of the project area have now been vested with the DEC as the Kemerton (formerly Gwalia) Nature Reserve. One and part of another EPP lakes remain on the project area, but are away from the current operations. One EPP lake has been lost in previous KSS mining activities. Contemporary drainage of surrounding pastoral lands to improve production (Dames and Moore Pty Ltd, 1993b; John Consulting Services, 1997) is likely to continue to impact on the hydrology of these wetlands areas, as will the dredge ponds.

Figure 2. Location of the Kemerton Silica Sand Mine Pty Ltd (KSS) in South West Australia.

KSS are the owners of a large land area of degraded but nevertheless ecologically significant wetland areas and vegetation communities. The ecological significance of the project area is primarily derived from the fact that it still remains in relatively good condition in a landscape which has seen similar areas cleared, drained or filled, rather than from any inherent special significance. Economically, the mine is a very modest operation compared with the perceived ecological value of the project area. It is clear that the previous management of the operation did not fully appreciate this. As a result, only minimal efforts to rehabilitate any parts of the site have previously been undertaken, with a focus instead on handing over more ecologically significant areas to the DEC. Given the limited resources within DEC to rehabilitate and maintain these areas, the land swaps have probably not delivered as much kudos as originally anticipated. As an ongoing operation, KSS is keen to determine the maximum extent of the resource that can ultimately be mined and is in the process of developing a PER towards this end. New management, with different industry background and aspirations, feels that in order for KSS to gain approval to extend the project operation for another 10 to 20 years there needs to be tangible proof that KSS are both capable and willing to rehabilitate the site to regulatory and community/stakeholder expectations (Welker Environmental Consultancy, 2001).

The recent efforts to subdivide the main dredge pond into a series of smaller lakes is a very positive move to facilitate rehabilitation. Although a few hectares of disturbed areas around Lake 1 have been reformed and revegetated, there appear to be problems in achieving revegetation coverage and sustainability (Mattiske Consulting Pty Ltd, 2005). Generally, revegetation success has been mixed (Table 1), with considerable opportunity to learn from past efforts. For instance, observations made on 23/1/07 suggest that topsoiling techniques have worked reasonably well in promoting plant establishment and species diversity, with mulching seeming to enhance survivorship of seedlings. Resprouting of fringing *Melaleuca* and other shrubs from rootstock indicates the benefits of topsoil are not limited to seed stored in the soil. Problems abound however in term of suppressed mature plant growth (related to compaction or some other soil factor), grazing of seedlings, inappropriate species mix in places, as well as water depth fluctuations affecting soil erosion, plant survivorship and species composition in low lying areas. Consequently bare or poorly revegetation patches abound.

Table 1. Summary of revegetation activities and success for the northern dredge pond area.

Date	Activities	Success	Ref
Feb 2001	Contouring, topsoiling and mulching of 2ha of eastern slopes	Poor initial germination; low diversity and cover	(Mattiske Consulting Pty Ltd,

			2004)
May-June 2002	Ripping, herbicide spraying and planting of 3235 seedlings of eastern slopes	Stunted plant growth in north-east corner; otherwise adequate plant cover, although diversity is relatively low. Some weed cover in south-east corner. Sedge death on lower slopes in 2004/5 due to water level decline	(Mattiske Consulting Pty Ltd, 2004, 2005)
April 2003	Contouring and topsoiling of eastern slopes	Progressing well in terms of cover, abundance and diversity. Low weed cover.	(Mattiske Consulting Pty Ltd, 2005); pers. obs.
April 2003	Contouring and topsoiling of overburden stockpile	Adequate vegetation cover, although some shrub deaths in 2005. Over-representation of wetland plants may hinder success.	(Mattiske Consulting Pty Ltd, 2005)
Autumn 2005	Some contouring, mulching and topsoiling of northern slopes	Reasonable plant cover, but relatively low diversity. Evidence of kangaroo &/or rabbit grazing of seedlings. Topsoil washed away at edge.	Pers. Obs.
Autumn 2006	Contouring, topsoiling and mulching of large area on northern and southern slopes	Slow growing plants, but good level of diversity achieved.	Pers. Obs.

State government has yet to decide what completion criteria for most mining operations should be, therefore they can provide little guidance for companies in this regard. There are currently many unknowns in rehabilitation (i.e. what can achieved, the cost and the success), therefore companies have little choice but to be proactive and commence rehabilitation as soon as possible, making sure that they develop proven rehabilitation strategies for their site. Nevertheless, with a the current public perception of mining, current KSS management is also now more focused on triple-bottom-line sustainability of the operation, with a view to maintaining and improving stakeholder perception of the operation. Consequently, autumn

2006 saw more rehabilitation and rehabilitation planning than in the preceding 10 years of operation.

In late 2006, Kemerton Silica Sand Pty Ltd contracted Dr. Mark Lund, Mr. Clint McCullough and Dr. Eddie van Etten of Edith Cowan's Centre for Ecosystem Management as Consulting Ecologists. These researchers visited the site on 31st August 2006 and 24th January 2007. The primary purpose of this contract was to start the rehabilitation planning process, by identifying realistic and achievable outcomes of any rehabilitation plan. A focus of this work was on nature of final pit lake environs formed from dredging of silica sand below the water table and how best to merge these with the natural pristine wetlands of the region. The consultancy proposed development of an effective rehabilitation plan along the following stages:

Stage 1: To determine realistic goals for the rehabilitation of the site.

Stage 2: Implementation of enhanced monitoring program.

Stage 3: Studies commenced to fill in identified knowledge gaps.

Stage 4: Development of the rehabilitation plan.

This current document report fulfils the expectations of Stage 1 of the report, incorporating,

- a review, collation and synthesis of existing data required to establish clearly what is known and what knowledge gaps remain,
- a series of realistic goals for the rehabilitation of the site from consultation with key stakeholders across a range of goals and with an assessment of their ecological feasibility,
- a recommended series of projects/consultancies to fill current knowledge gaps,
- a recommended realistic and cost effective monitoring program that can compliment and enhance existing data collection.

The report is structured in three main sections,

1. Existing knowledge (namely existent information relevant to dredge pond rehabilitation),
2. Knowledge gaps (paucities in these data that would limit successful dredge pond rehabilitation or demonstration of this achievement),
3. Recommended future work (what work is required to supplement and extend current knowledge to enable relinquishment of project area dredge ponds).

Within each of these sections, the three prominent KSS aquatic environments of groundwater (production and monitoring bores), surrounding EPP natural wetlands and the actual dredge ponds (including a 2006 separated section) themselves have been discussed separately.

4 Existing knowledge

There is a significant body of existing knowledge of the environment and ecology of the Kemerton Sand Mine project area. Practically all these data are contained within *ad hoc* regulatory-based reporting. The data has not been databased for easy access and little attention has been given to structuring data collection to facilitate achieving rehabilitation goals. Even less attention has been given to what is the most significant issues for this operation; what are the most significant issues of the final form and nature of the dredge ponds, essentially small scale open-cut pit lakes.

This chapter reviews current knowledge from the available documents, as it relates to these final pit lakes.

4.1 Groundwater

Production bore groundwater pH is near neutral (5.6–7.5) with no apparent trends across the 13 years of data. Salinity is slightly brackish at 450–680 mg L^{-1}, becoming higher with deeper abstractions (Dames and Moore Pty Ltd, 1993b).

Electrical conductivity (EC), pH, Cl (chloride), SO_4 (sulfate), NO_3 (nitrate), Fe (iron), N and P from have been measured from production bores, monitoring bores and wetlands (Rockwater Proprietary Limited, 2005). Monitoring bore NO_3 and P are measured biannually. In 2005, NO_3 was below a detection limit of 0.2 mg L^{-1}, and P ranged from below detection at 0.05 mg L^{-1} to 0.20 mg L^{-1}. However, it is unclear if phosphorus was measured as total phosphorus (TP, the entire phosphorus store, including biologically unavailable forms) or filterable reactive phosphorus (FRP, sometimes also referred to as soluble reactive P or incorrectly as orthophosphate, a more biologically available soluble form). Further work must report these analytes correctly.

Alkali and alkaline earth metals have also been analysed in 1996 and 1997 indicating moderate water hardness (Rockwater Proprietary Limited, 1998). Occasional high sulfate levels in production bores and low pH levels found in monitoring bores as early as 1997 may be indicative of pyrite oxidation (acid sulfate soils, ASS) occurring in the area.

Long-term monitoring indicates seasonal variation in the superficial aquifer is around 1 m (Dames and Moore Pty Ltd, 1993b), however monitoring bores, close to natural wetlands indicate annual water depth fluctuations of up to 2 m. This may be due to these wetlands acting as water sources during winter and water sinks through evapo-transpiration during summer.

4.2 Dredge ponds

Although measurements are taken on a monthly basis, the dredge pond is only assessed for pH and TDS (GHD, 2005). Water levels of the dredge pond appear to show influence on water levels of nearby monitoring bores (Rockwater Proprietary Limited, 2005). With longitudinal and transverse hydraulic conductances of *ca*. 5 m, dredge ponds are very closely tied to the water table (Dames and Moore Pty Ltd, 1993b).

Loss of water from dredge ponds is expected to be around 0.1–0.2 ML year^{-1}, making this water loss a minor concern relative to other project water losses such as loss of water in exported wetted sand (Dames and Moore Pty Ltd, 1993b).

Rockwater Pty Ltd (2005) report that higher salinity and pH occurs in the dredge ponds, relative to the natural wetlands.

Ecologically, dredge pond margin plantings appear to be affected by declining water levels over summer, compacted soils, and erosion (removal and deposition) due to their exposure to prevailing winds (Mattiske Consulting Pty Ltd, 2005). Simple surveying has also observed Gambusia (*Gambusia holbrooki*) in the dredge pond since 2005 (Bamford Consulting Ecologists, 2006).

4.2.1 Active dredge pond water chemistry

A surface water sample was taken from the edge of the active dredge pond on 31st August 2006

Sampling of the active dredge pond in August revealed a moderately low pH of only 5.0, high dissolved oxygen >90%, high turbidity of 128 NTU and elevated Oxidative/Reductive Potential (ORP) (Table 2).

Table 2. Active dredge pond surface water physico-chemistry.

Depth (m)	Temperature (°C)	pH	Electrical conductivity (mS cm^{-1})	Dissolved oxygen (%)	Dissolved oxygen (mg L^{-1})	ORP (mV)	Turbidity (NTU)	Chlorophyll (µg L^{-1})
0	17.12	5.0	1.082	90	8.6	219	128	3.6

4.2.2 Lake 1 water chemistry

The recent separation of part of the dredge pond into Lake 1, provides an insight into future rehabilitation. Lake 1 has featured incomplete rehabilitation attempts of marginal vegetation, but has been landscaped both above and below the waterline. A water column profile of basic physico –chemistry and surface and bottom water solutes were collected from the centre of Lake 1 on 24th January 2007.

The lake profile showed a well-mixed water column with circum-neutral pH and low levels of primary production (*ca.* 5 µg L^{-1}) (Table 1). At levels of 20–30 NTU, turbidity was moderate throughout the water column, as was EC at around 1.5 mS cm^{-1}. Levels of ORP were not unusual at 110–124 mV, although dissolved oxygen levels were depressed throughout, and especially near the lake benthos (<50% saturation) indicating significant groundwater intrusion.

Table 3. Lake 1 physico-chemistry centre profile.

Depth (m)	Temperature (°C)	pH	Electrical conductivity (mS cm^{-1})	Dissolved oxygen (%)	Dissolved oxygen (mg L^{-1})	ORP (mV)	Turbidity (NTU)	Chlorophyll (µg L^{-1})
0	23.9	7.4	1.465	86	7.2	110	28	4.7
1	23.5	7.4	1.463	82	6.9	112	28	5.0
2	22.8	7.3	1.460	79	6.8	115	29	5.0
3	22.1	7.2	1.452	77	6.7	119	29	5.0
4	21.7	7.1	1.449	74	6.5	124	30	5.1
5	21.5	7.0	1.445	<50	4.3	121	37	4.8

Table 4. Lake 1 surface and bottom water chemistry.
Data to come from labs

4.3 Wetlands

Although there is little specific baseline data pertaining to the natural wetlands surrounding the KSS project area, hydrological data have been routinely collected during mine operations (Rockwater Proprietary Limited, 2005). These studies have shown water table variations of up to 2 m occur across the seasonal EPP wetlands within and nearby the KSS project area. Limited monitoring data shows that wetland water pH is slightly acidic to neutral (GHD, 2005). Monitoring also suggests salinities are across a wide range (200–3 800 mg L^{-1} TDS) which become elevated through evapo-concentration at the end of summer (GHD, 2005).

Many significant plant taxa occur in the natural wetland systems surrounding the project area. These are listed as Priority Species by the DEC (Mattiske Consulting Pty Ltd, 2002). However, many of these sightings are single isolated individuals or taxon, with no clear pattern of their resident communities. One Declared Rare Flora (DRF) species was collected by consultants in 1997 and 1998; however its status and distribution is unclear as it has not been collected in subsequent surveys (Mattiske Consulting Pty Ltd, 2002). Six Priority Flora species have been collected on land owned by KSS, with another 7 found in surrounding lands (Mattiske Consulting Pty Ltd, 2002). There is also some uncertainty regarding the presence, actual localities and characteristics of Threatened Ecological Communities (TEC's) mapped as part of the consolidation of flora survey reports (see map 5 of Mattiske Consulting Pty Ltd (2002)). TEC's recognised as "Shrublands and Woodland of the Muchea Limestone" on the eastern boundary have been transferred to the conservation state, but the status of others mapped is unclear.

Vegetation and significant plant species have been mapped over the site at a map scale of 1:20 000 ((Mattiske Consulting Pty Ltd, 2002). Although subjectively determined, the distributions of the 24 plant communities demonstrate a complex mosaic of sandy uplands (generally dominated by woodlands of *Eucalyptus marginata,* and *Banksia attentuata*), lower slopes of *E. marginata – Corymbia calophylla - Agonis flexuosa* woodland, *E. rudis – Melaleuca* woodland fringing lakes and flooded areas, and closed heath of Myrtaceae species (eg *Pericalymma ellipticum*, *Kunzea glabrescens* and *Hypocalymma angustifolium*) on winter-waterlogged palusplain.

Regionally conservation significant freshwater fish also occur in these wetlands (Environmental Protection Authority, 2005). Simple fisheries surveying has revealed populations of the threatened black-striped jollytail (*Galaxias nigrostriata*) (Bamford Consulting Ecologists, 2006). Gilgies (*Cherax* sp.) have also been observed in some of these wetlands, as well western pygmy perch (*Edelia vittata*) and nightfish (*Bostockia porosa*) (Ninox Wildlife Consulting, 1993). Hardyhead (*Atherinosoma* sp.) and Swan River goby (*Pseudogobius olorum*) may possibly also exists in project area and local natural wetlands (Ninox Wildlife Consulting, 1994).

The introduced pest Gambusia (*Gambusia holbrooki*) has also been discovered in some wetlands (Ninox Wildlife Consulting, 1993) and is thought to have possibly entered local natural wetlands from permanent pools in a small agricultural drain linked to major drains that flow into the Wellesley River (Sons of Gwalia Ltd, 2000).

However, surveys of native and introduced fish have only been by sweep-net (Bamford Consulting Ecologists, 2006). This method is usually only used for surveying aquatic insect (macroinvertebrate) communities and is not typically used for sampling or surveying fish communities {Davis, 1999 #19}. Sweep nets are not normally recommended as they are very limited by instream obstacles such as emergent and submerged vegetation and woody debris and access is also limited to the shore in many water bodies, including the singular dredge pond of the time.

4.4 Settling pond tailings fines as benefit to rehabilitation

It has been suggested that settling pond tailings fines be used to line artificial wetlands (Mark Gell, pers. comm. 07/02/2007) and as a soil amendment for terrestrial uplands (Galloway, 1997; John Consulting Services, 1997) to assist in greater water retention. These fines are the product of an organic polymer flocculent added to tailings (better described as settling pond) water (Kemerton Silica Sand Pty Ltd, Unknown). Following flocculation, they are drained and dried on-site in the sun. However, even though planned use of these fines has been postulated for some time, we do not know of any specific study which has examined their suitability for this purpose. Therefore, although an aside to the scope of this current study, the physico-chemical properties of a sample of this material was studied in the ECU Wetland laboratory.

Flocculate density was calculated by known mass displacement in demineralised water. Flocculate moisture content was calculated by drying at 105^{o}C for 24 h, and loss-on-ignition (LOI) by ashing at 550^{o}C for a further 24 h. pH was determined by a 10:1 water:dry sample (w:w) paste test. A simple Net-Acidity-Generation NAG indicator test was followed by the addition of superfluous hydrogen peroxide (H_2O_2) to the paste.

The fines flocculate is a coarse soil-like material, slightly moist and brittle, with a dark centre and a light exterior. Although pre-mining predictions were for a floating to neutral density (Dames and Moore Pty Ltd, 1993b), it is clear from the density data that in this dry form that the flocculate still sinks readily. Although after drying the flocculate still contains a moderate amount of water, its low LOI indicates only a small fraction is organic. Furthermore, upon mixing with water it displays a very low pH of 3.62. When fully oxidised, the paste pH initially falls slowly, until reaching a stable pH of only 1.89 after 30 minutes (Table 3).

Table 5. Physico-chemical properties of tailings (settling pond) flocculate.

Parameter	Value
Density (kg L^{-1})	1.74
Dry mass (%)	84.2

LOI (%)	15.1
pH paste	3.62
pH paste following H_2O_2 treatment	1.89

Given this low pH realised under oxidising conditions, it is likely that the flocculate contains pyritic fines. The small proportion of organic matter contained in the fines further lessen its value for use in rehabilitation, as this was likely to be the most beneficial component of the material. Consequently, our initial assessment is that, although it may represent some value to improving water retention and nutrient capacity of wetland soils (although this needs further investigation), it is advised that this material is not placed in any rehabilitated water that may dry out or become wholly mixed (to prevent oxidation). Given that Lake 1 data indicates that even these larger waterbodies are wholly mixed (Table 3), even over summer months, this would allow this material to oxidise, potentially causing acidity problems (depending on available buffering).

Instead it is recommended that it be stored in a confined area where significant amounts of neither flocculate or tailings pond water will enter waterbodies during heavy rain events. However, further analysis of other chemical properties, and of the buffering capacities of surface and the large volumes of groundwaters (Dames and Moore Pty Ltd, 1993b) of the project area, may yet find this material of useful or at least neutral benefit to rehabilitation of the project area. There are probably few if any concerns with the small contribution of flocculate that ongoing tailing's dam spillage contributes to operational dredge ponds (Gwalia Consolidated Ltd., 1995).

5 Knowledge gaps remaining

Because of the regulatory focus of the studies made to date, it is not surprising that significant gaps exist in the knowledge required for successful dredge pond rehabilitation. Particular knowledge gaps exist with regard to the nature of local aquatic ecology and what trends, if any, that may be apparent in ground and surface water quality and seasonal water depths. This chapter addresses where significant gaps of knowledge remain in the understanding of groundwater, surrounding natural wetlands and the dredge ponds themselves as they pertain to rehabilitation success.

5.1 Groundwater

Fundamental questions relating to potentially acid sulfate soils remain to be directly addressed. For example, is SO_4 and Fe increasing in groundwaters (indicating acidification is occurring)? Does this ground water demonstrated a change in Cl:SO_4 ratios (as Cl is large unaffected by chemical or biological processes, changes in the ratio indicate that SO_4, is actually increasing rather than just evapo-concentrating)? Is an increase in these ions coupled with (that is, potentially caused by) pH decreasing? For instance, some pH values from the 2005 groundwater monitoring have been particularly low and of concern (e.g., 3.7) (Rockwater Proprietary Limited, 2005). This concern is particularly due to a mechanism of potential ASS, namely can it solely be ascribed to general climatic changes (e.g., extended drought periods) or the KSS mining operation.

Groundwater nutrient concentrations are also poorly understood, both in regard to nutrient type (e.g., what partitioning of total nitrogen is ammonia and nitrate/nitrite), and also in detection levels. Current reporting fails to report ecologically significant levels (current detection limits are too high) of nutrient inputs, particularly with regard to phosphorus, which will contribute notably to the final character of the rehabilitated dredge pond lakes.

Previous groundwater reporting also fails to comment upon potentially high concentrations of heavy metals and metalloids such as arsenic through decreased pH leading to higher metal salt solubilities and dissolution of heavy metal containing minerals. The latter is thought to be associated with local geologies as arsenopyrite. This mineral is thought to be a cause of ASS in the area and this acidity generation may be directly releasing arsenic into the water table. However, no data on heavy metal concentrations in either groundwater or surface waters are available.

5.2 Dredge ponds

Although Gambusia have been found in the dredge pond and Lake 1 (Bamford Consulting Ecologists, 2006), it is unknown how long they have been there and whether or not they were deliberately introduced. The dredge ponds are a reservoir for this significant pest species. Modifications to the dredge pond design have been made to prevent pond overflow into the local natural wetlands. There does remain a small risk of Gambusia reaching the natural wetlands from the dredge ponds thorough transfer by water fowl. There is good evidence from around Perth and Australia that Gambusia negatively impact on frog populations (by attacking tadpoles) (Sommer, 1997) and macroinvertebrate communities (McCullough, 1998; Ling, 2004). It is strongly suspected that Gambusia may impact on Jollytail populations, however the significance of this is not known.

Fundamental to the successful rehabilitation of the dredge ponds also is their final form; especially with regards to mean and maximum depth and the extent of the littoral fringe. There needs to be a demonstrable understanding of what is the optimum size and number of potential ponds to ensure environmental benefit while maximising operationally opportunities to complete rehabilitation in an ongoing manner.

Monitoring bore data indicates groundwater potentially contains high levels of nutrients. As a direct relevance to the sustainability of representative ecosystems in rehabilitated dredge ponds, there needs to be an understanding of whether these nutrient levels pose a risk of algal blooms. To this end, the different forms, and concentrations, of nutrients in groundwater entering the dredge ponds need to be seasonally monitored for concentrations and concentration trends.

As with groundwater quality, there has also been no data demonstrated to show concentrations of heavy metals and metalloids in dredge pond water.

Pain (2006) contends that penetrating the superficial aquitade will allow cross contamination of this environmentally significant water resource with that of the deeper groundwater system. Implications of the removal of the coffee-rock layer do not appear to have been specifically investigated in a scientifically defensible manner.

Previous studies have shown that, due to incorrect placement of wetland soils on higher topography than appropriate, wetland vegetation communities have not rehabilitated well. Hence, the viability of this rehabilitation practice (Welker Environmental Consultancy, 2001) is not currently scientifically supported.

The dredge ponds are not like natural lakes on the Swan Coastal Plain, due to their depth and complete domination by groundwater flows. It would be useful to investigate some similar analogues to determine what can potentially be achieved and what should be avoided. Sections of Herdsman Lake (Perth) have been dredged for sand in a similar manner and to a similar depth and might be useful analogues. Unfortunately little is known about these systems, although they have the advantage of being rehabilitated for a number of years.

5.3 Wetlands

There has been very little data collected on the water quality of the natural wetlands. These data are required to provide a baseline against which the dredge ponds and any created wetlands can be compared. The data required includes general physico-chemical parameters (e.g. dissolved oxygen, turbidity, pH, electrical conductivity, etc.), nutrients, metal/metalloid concentrations and biotic data (macroinvertebrates, frogs, birds, plants, fish and plankton).

Due to inconsistencies in the various reported plant communities, palusplain, sumpland, etc. community conservation status e.g., TECs need to be collated and independently verified. These should be incorporated into the MBS mapping exercise. There also needs to be an understanding of the processes leading to development of these communities such as hydrology, geology and topography. Understanding these processes better enables the protection and rehabilitation of these communities.

The presence of ASS within the project area needs to be mapped and the acid generating potential determined. The presence of sulfates and iron in concentrations that are indicative of acidity generated from ASS, needs to be further investigated to determine whether it is due to the activities of the KSS mining, or is a result of a general lowering of water tables resulting from the recent low rainfall. The potential for acidification of natural wetlands needs to determined. It is also unclear whether dredge pond levels may be influencing natural wetland water levels and therefore acidity and salinity. This may be of importance in determining final dredge pond depths in order to minimise water level impacts on surrounding natural wetlands as well as to maximise any possible benefit that the dredge ponds may have in maintaining wetland levels and water quality.

It is also unclear how water level affects both native and introduced fish species and if greater than natural mortalities of threatened native fishes are occurring in these wetlands. If undesirably high mortalities of these species are occurring, it is unknown how best to remedy this situation.

Although *Gambusia* has had a deleterious effect upon similar native fisheries and amphibian populations elsewhere (Barrier & Hicks, 1994; McCullough, 1998; Ling, 2004), the effect of a resident Gambusia in the project area wetlands population is unknown. Nevertheless, expert opinion is that a strong negative association between Gambusia and native freshwater fisheries of south-western Australia exists (Ninox Wildlife Consulting, 1994).

Although recommended as early as 1997 (Galloway, 1997), the macroinvertebrate communities of the project wetlands are undescribed. Consequently, rehabilitation goals for this important wetland community, within the context of this bioregion remain unclear.

It is unclear as to whether maintaining an open dredge pond will reduce wetland drying frequency and extent of drying or not. If maintaining an open dredge pond does reduce wetland drying pattern and extent, it is unclear how significant this impact will be.

Knowledge of existing vegetation patterns and an understanding of the processes controlling them is critical to achieving revegetation success. Generally such natural processes and patterns guide us in terms of species selection, necessary site treatments, key processes which need to be mimicked and so on. Although mapped at a relatively fine scale, there appear to be inconsistencies and disagreement between vegetation units and maps determined by botanical consultants (eg Mattiske Consulting (2002)) and those reported by government scientists (Keighery & Keighery 2003). The latter identified TEC's of Muchea Limestone communities, whereas the former expressed some doubt as to the significance of limestone areas. In addition these studies have little to report on key processes operating to cause such patterns, such as hydrological regimes, soil genesis, sorting and movement, and formation of impermeable layers. Similar work is required on species distributions, particular DRF and other significant taxa, in relation to key environmental variables.

There does not appear to have been any specific study into threats posed by weeds or recommended approach for weed control, particularly in wetlands/lakes and their margins. For instance *Typha* sp. has been reported as a serious threat (especially given potential for seed transport from the around tailings pond area) (Sons of Gwalia Ltd, 2000), with major outbreaks of *Pelargonium* sp. observed (especially around KSS office buildings). Some 53 exotic plant species have been recorded from KSS land (Sons of Gwalia Ltd, 2000). Similarly the current distribution and threat posed by dieback disease (Phytophthora spp.) needs to be clarified.

6 General rehabilitation goal guidelines

The first step in the process of working toward project area relinquishment is planning a series of primary objectives for long term rehabilitation of the KSS project area. Objectives for rehabilitation must include general sustainability principles that the final post-mining landforms are to be safe, stable, durable and non-polluting. If dredge ponds are not rehabilitated appropriately, there are a number of potential risks, as shown in Figure 3.

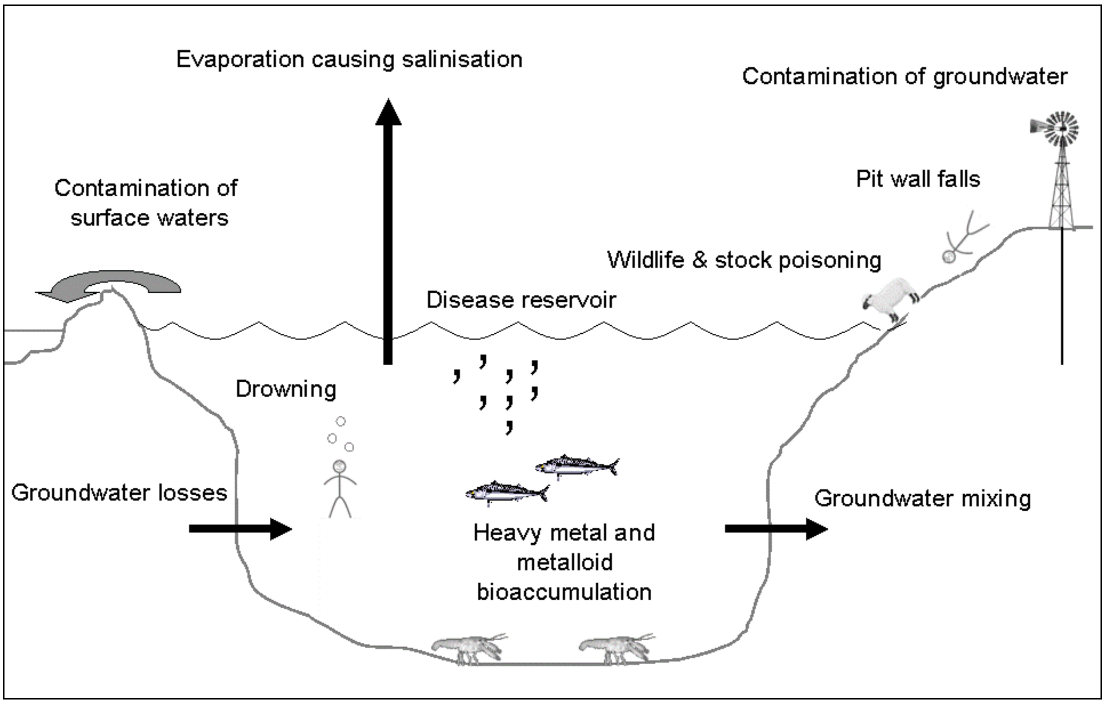

Figure 3. Social and environmental risk and liability which dredge ponds may represent if left inappropriately rehabilitated (after McCullough & Lund (Mattiske Consulting Pty Ltd, 2002)).

There is a wide range of opportunity available for the dredge ponds upon relinquishment (Figure 4). Some of these end uses could be of most benefit to either social or environmental stakeholders whilst some could form a combination of these two main areas.

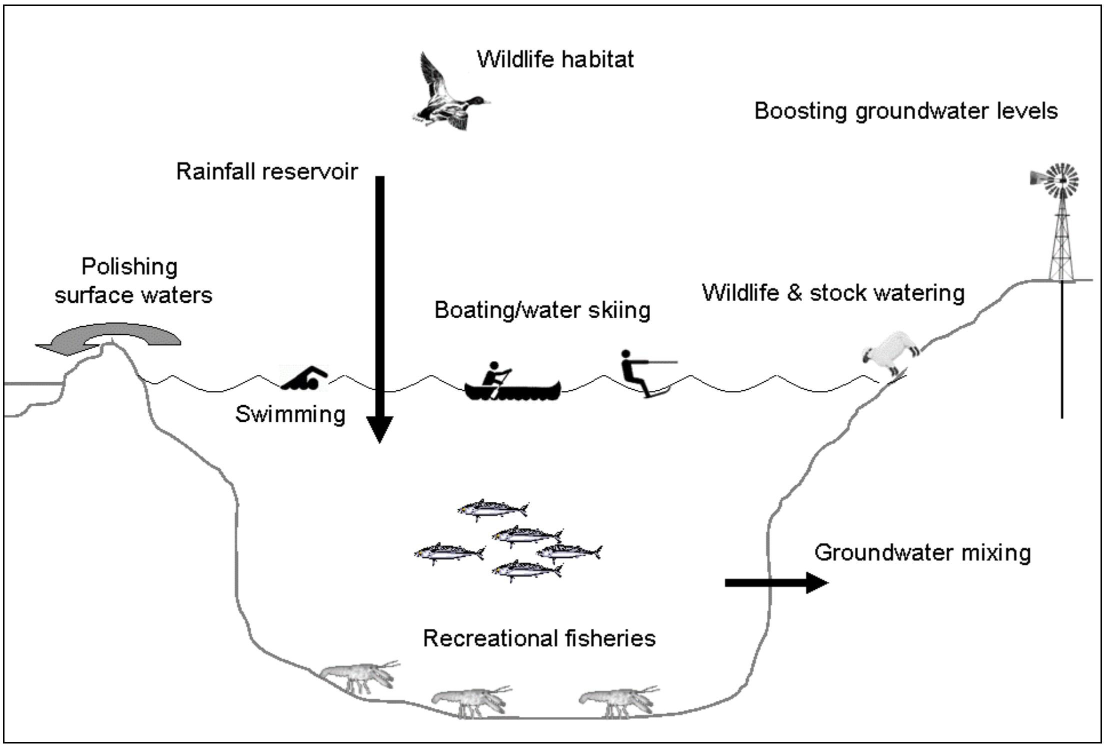

Figure 4. Potential end uses which regulators, community and stakeholders may desire for relinquished dredge pit lakes (after McCullough & Lund (2006a)).

There are many examples of where these different end uses have or are being instigated across Australia (2006a).

The goal for rehabilitation at the KSS project area has to aim to maximise the ecological values of the area. This area will likely be of limited public access, other than to scientific research organisations and special interest groups (Mark Gell, KSS *pers. comm.*). The loss of wetlands and lakes across the Swan Coastal Plain (McCullough & Lund, 2006b), and in the project area due to mining operations provides a rationale to focus rehabilitation on using the dredge pond(s) to expand the quantity of this habitat type. The dominant features of the rehabilitation are the dredge pond(s) and their immediate surrounds. There are opportunities for the reintroduction and maintenance of iconic threatened regional species. These species include water rats (*Hydromys chrysogaster*), black-striped jollytail (*Galaxias nigrostriata*) and various frog and waterfowl species. Protection and enhancement of surviving habitat and populations of these key species may represent an effective component of an offset policy for stakeholders and regulators alike. We recommend that the goal should also be broadened to cover rehabilitating the existing project area, including the Kemerton Reserve. The rationale for this, is that Agencies consider the entire area to be valuable and it would be relatively easy and economical for the Company to quickly boost its rehabilitation credentials by tackling these areas.

However, as per the current KSS Environmental Management System (EMS), regulatory, community and stakeholder consultation is still required to gain support for the proposed goal and to determine how best to incorporate and temper stakeholder expectations. To this end, a registry of key stakeholders for such consultation should be developed (Environmental Protection Authority, 2004).

To effect this high standard of rehabilitation, a policy of progressive rehabilitation should be utilised. This policy will ensure that successful rehabilitation is demonstrable to regulators and stakeholders prior to closure and permits time to develop the techniques needed to successfully rehabilitate the area. This also ensures that only a small amount of rehabilitation will be outstanding across the project area once mining is finished, with consequent savings in plant and labour. As such, an environmental management system (EMS) addressing rehabilitation in addition to current works should be formally instigated.

6.1.1 Systems approach to rehabilitation and closure

As such, it is highly recommended that KSS begin to develop an EMS incorporating a comprehensive rehabilitation plan for closure. This rehabilitation plan should focus primarily upon the rehabilitation of unmined areas and particularly on the dredge pond(s) and surrounds. If the primary ecological habitat of mining activity changes, e.g. to a dry mining system, then the EMS should reflect these changes.

A suggested outline for such a management system, developed using the broad objectives and principles outlined in the ANZMEC/MCA Strategic Framework for Mine Closure (Welker Environmental Consultancy, 2001), would be to adopt a “systems” approach aimed at facilitating progressive mine rehabilitation over the life of the operation to return rehabilitated landforms to functioning ecosystems in the shortest possible time. This Progressive

Decommissioning System for KSS (or KSSPDS, Figure 5) would be a living document which would provide the following tools for the company:

1. a framework for ongoing planning and management of the project area,
2. a reference tool to assist in the costing of ongoing operations,
3. a reference tool for day-to-day operations in rehabilitation planning,
4. basis for documentation to meet regulatory obligations re: decommissioning and closure,
5. and a system for recovering performance bonds as areas are progressively rehabilitated.

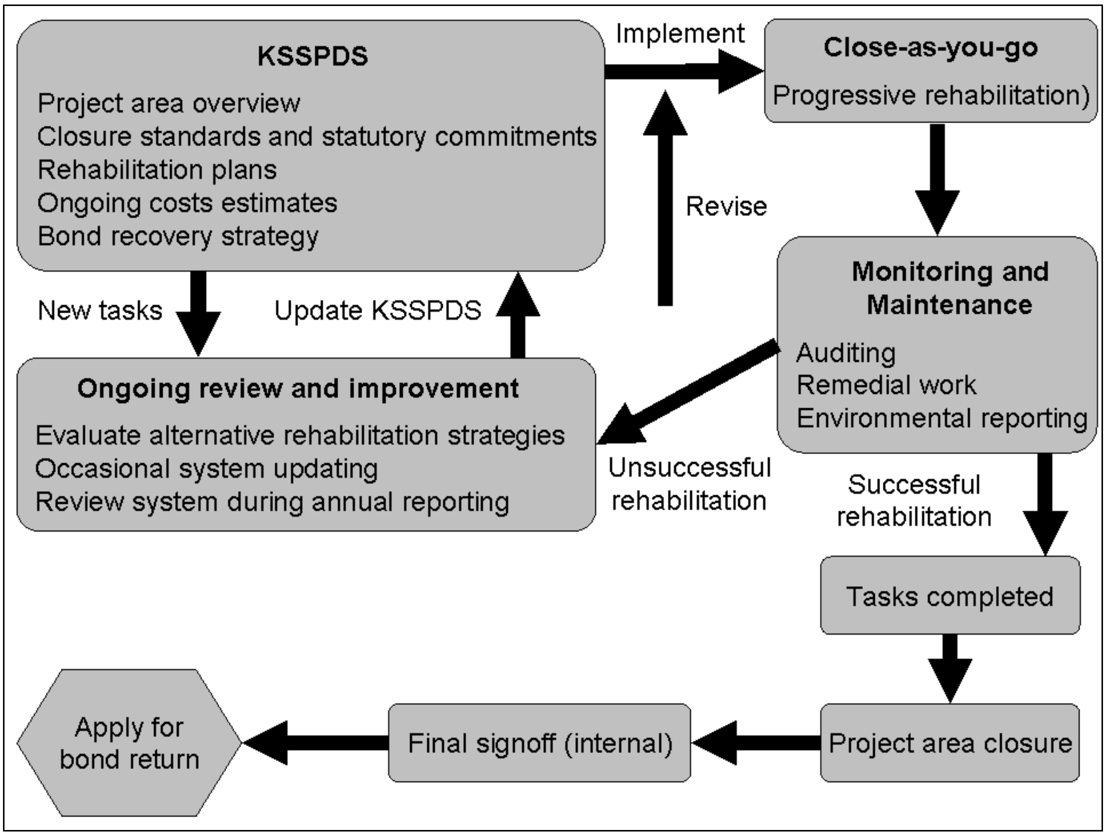

Figure 5. Suggested outline of a Progressive Decommissioning System for Kemerton Silica Sand Mine Pty. Ltd (KSSPDS).

The first step in the process of developing a KSSPDS would be to establish a series of primary objectives to be achieved in planning for long term rehabilitation of the KSS dredge ponds. These objectives must include general sustainability principles that the final post-mining landforms are to be safe, stable, durable and non-polluting. KSSPDS objectives would first need to have clear aims, and would need to be integrated into the general mine planning and provisioning process. The KSSPDS should also be actively implemented and regularly reviewed and updated e.g., as part of annual reporting.

The next step in the process of developing the KSSPDS would involve the compilation of a detailed compliance, commitment and conditions register for the dredge ponds as a baseline for determining minimum completion requirements and to allow for strategic variations of commitments and conditions to better reflect the situation on the ground. Once the dredge pond completion requirements are defined, a comprehensive site audit would be undertaken to identify specific tasks to be undertaken to achieve the required outcomes.

The KSSPDS could consist of the following elements.

***Brief Overview of KSS Project Area* –** description of recent and historical operational activities, location, infrastructure inventory and issues identified through stakeholder consultation;

***Dredge Pond Rehabilitation Objectives and Standards* –** a summary of relevant statutory commitments, standards and guidelines, and stakeholder viewpoints.

***Dredge Pond Decommissioning/Rehabilitation Plan* –** a series of rehabilitation and decommissioning task lists presented for the Dredge Ponds. These tasks lists provide an inventory of sites and identify specific tasks to be undertaken in order to meet rehabilitation criteria.

***Mine Closure Cost Estimates* –** cost tables for upcoming rehabilitation of the KSS project based on known rehabilitation costs including rehabilitation research, earthworks, post-mining monitoring and contingencies for any identified remediation. Options for likely future mining including dry mining cost estimates;

Statutory Commitments and Conditions – series of tables summarising relevant statutory conditions and commitments covering respective parts of the project area.

Commitments to Sustainability and Stakeholders - additionally, it is suggested that sustainability and corporate responsibility, commensurate with investors' expectations, is explicitly addressed.

The KSSPDS would be a dynamic system, designed to be updated on a regular basis to accommodate changes in the operations and completion of tasks which are identified in the system. Other factors taken into account when updating the KSSPDS would include; future developments (e.g., project area extensions), alternative ongoing (post-mining) land use options, rehabilitation success as determined by monitoring, new rehabilitation techniques researched, areas rehabilitated and signed-off by regulator sand stakeholders, the changing state of industry practice and available technology; and changing costs and benefits of a range of decommissioning/closure options.

The development and implementation of the KSSPDS would lead to a reduction in liabilities associated with mine closure which then forms a basis for the progressive recovery of KSS performance bonds. The KSSPDS also would proactively identify areas of high risks as priorities for ongoing research and/or remediation of mined areas. Such a system would maximise ongoing rehabilitation undertaken during the productive phase of mining operations by facilitating the direct involvement of operations personnel in achieving mine rehabilitation outcomes and would facilitate the involvement of key stakeholders in setting priorities for mine rehabilitation.

7 Recommended future studies

The following topics present areas of knowledge relevant to scientifically demonstrable rehabilitation and understanding of the KSS wetland which is currently depauperate. Where relevant specific questions to be addressed in order for successful rehabilitation of aquatic habitats to be achieved.

7.1 Groundwater

1. Measured levels of phosphorus in groundwaters have only been at detection limits of 0.05 mg L^{-1} which is higher than acceptable; water in this range is considered meso-eutrophic (ANZMEC/MCA, 2000). It is also unclear if phosphorus was measured as total phosphorus or filterable reactive phosphorus (FRP).

2. Can increased monitoring bore water sulfate concentrations, adjacent to natural wetlands, be solely ascribed to general climatic changes (e.g., extended drought periods) or could the KSS mining operation be a contributing factor?

3. What are the, scientifically defensible, implications of the removal of the coffee-rock layer allowing mixing of the main groundwater with superficial aquitade water?

7.2 Wetlands and Dredge Ponds

1. The large permanent lakes that will be a legacy of mining provide an opportunity for the conservation of icon species such as the Black-striped Jollytail, migratory birds, marron (and related species), water rats, etc. If water quality is suitable, then islands/specific habitats might be needed to support some of these species.

2. Improving our understanding of hydrological regimes, especially at margins of ponds, and its importance to the establishment and composition of revegetation. More generally, obtaining a better understanding of key links between vegetation pattern and process in unmined areas should help in improving revegetation techniques following mining, as well as clarifying most appropriate reference or analogue sites.

3. What is the likelihood, and what is the environmental effect, of rehabilitated dredge pond water mixing with these natural wetlands following rehabilitation and groundwater rebound? How does this change in relation to annual rainfall patterns and amounts?

4. A survey should be carried out to determine if there are ASS generating solids present in over-burden, particularly from wetland areas. This material may also present in the coffee-rock layer, or in deeper, anoxic ore sediments.

5. More monitoring of wetland water chemistry and ecology is required in order to establish a baseline understanding of what characteristics rehabilitated wetlands should have. It would also be worth a review of data for Herdsman Lakes to provide an analogue for the dredge pond(s). A better understanding of rehabilitated dredge pond water chemistry and ecology may also be required to understand how well these are to emulate natural local or regional waterbodies.

6. Water quality monitoring must also include data on heavy metals and metalloids. Monitoring of these water quality parameters is pertinent to dredge pond relinquishment. These parameters also illustrate the presence and extent of geochemical trends such as ASS amongst the hydraulic continuity of groundwater, the dredge pond and the project wetlands.

7. Water quality reporting for Annual Environmental Reviews and for environmental use areas such as natural wetlands should not use irrelevant NHMRC/ARMCANZ

(Wetzel, 2001) drinking water guidelines (e.g., GHD (1996)). Rather, environmental guidelines (i.e., ANZECC/ARMCANZ (2005)) should be cited, which will better inform mine management of performance to current environmental criteria.

8. Nominated nearby project wetland drawdown is estimated from less than 1 m (2000) to 0.5–1.5 m (Dames and Moore Pty Ltd, 1993b). This may be a significant depth for these seasonal shallow wetlands that means the difference between high and low ecological values but there is currently insufficient understanding. Hydrological fluctuations at lake margin also need to be within specified limits.

9. There also appears to have been little consideration as to the potential drawdown effects of rehabilitated dredge ponds on deeper aquifer habitats e.g. phreaophytic vegetation communities. Although any reductions may not directly affect natural partially groundwater perched wetlands, rehabilitated wetlands (such as sumplands) tied to this deeper aquifer may face greater fluctuations than before.

10. As it is also unclear how water level affects both native and introduced fisheries, fisheries surveying over different seasons of different years, tied to different years may help explain the importance of this variable which is closely tied to mining operations.

11. Some amphibian surveying has been carried out, with three native frog species recorded (Dames and Moore Pty Ltd, 1993a). Specific amphibian surveying may reveal icon species which wetland rehabilitation may benefit.

12. Macroinvertebrate surveying would also prove useful; both to determine whether rare species are present and also to determine rehabilitation criteria for these communities and as indicators of chronic water quality.

13. Environmental assessment of wetlands as a habitat type require a higher degree of the surveying intensity and quality to be acceptable to regulatory authorities than does surveying of many other habitat types (Ninox Wildlife Consulting, 1993, 1994). As such, specific regulatory guidance should be sought where possible. In the case of surveying of freshwater fisheries, this advice is not available, and increase an approach of following best scientific practice is therefore recommended as a defendable protocol.

14. The presence of native and introduced fisheries in project area wetlands would be more scientifically and appropriately ascertained through the more effective use of electric fishing/and or nocturnal spotlighting (Environmental Protection Authority, 2004) coupled with trapping where access was found to be difficult.

15. Should NAG tests be done on over-burden (particularly from wetland soils) prior to disturbance? Does some over-burden have to be handled differently?

16. How successfully can wetland topsoil be used to rehabilitate to natural floral communities of wetlands? E.g., what is the viability of wetland seed banks over extended periods of placement outside of their hydrological norm? What topography is it appropriate to rehabilitate?

17. What are the benefits of separating topsoil according to vegetation/soil and matching to final landforms, and, what are the economic and technical impediments to achieving this?

18. Although expert opinion is that a strong negative association between Gambusia and native freshwater fisheries of the south-western Australia is likely to exist, is this hypothesis able to be scientifically tested?

19. What opportunity for conservation of aquatic icon species could the rehabilitated wetlands and dredge ponds present? How would stakeholders perceive the value of these species?

20. What are the macroinvertebrate communities of the project wetlands? Do they include rare taxa or taxa of limited distribution? Are their measures important indicators of rehabilitated wetland ecosystem function, and hence wetland rehabilitation success?

7.3 Revegetation

1. Clarification of the conservation significance of species and vegetation types and their distribution in unmined areas as previously mentioned.

2. What species of weeds might need to be controlled for in all post-mining landscape habitats, including woodland, wetlands, lakes and their margins. How would this weed control be effected; especially without impacting upon water body vegetation communities and water quality.

3. The degraded nature of some of the existing vegetation may mean a depauperate (or at least sub-optimum) seed store is being utilised, so studies of seed store potential, as well as appropriate topsoil collection, storage and spreading protocol, may be worthwhile for different plant communities.

4. What key species (such as dominant trees & *Melaleuca*) are absent from or diminished in the rehabilitation to date, and how can these be specifically introduced into the restoration process?

5. Reasons for stunted growth of older plantings is still unclear (compaction or some other soil factor?) – specific soil profile studies may shed light on these factors;

21. It is also suggested that wetland margin soils be tested for N and P availability. Being newly exposed soils, these are likely to be quite low in nutrients, particularly phosphorus. The high flow rate of shallow groundwater through these soils may contribute some nutrients (particularly reduced forms of nitrogen) however is likely to be depauperate in phosphorus, of significance to root growth of establishing wetland margin plants.

8 Recommended baseline monitoring

Given the nature of surrounding threatened systems, and also the original project area landscape, it is highly likely that relinquishment of KSS dredge ponds will be in the form of an environmental end use. Consequently, baseline monitoring for dredge pond rehabilitation primarily needs to seek to increase understanding of what environmental (ecological and physico-chemical) conditions prevailed in the project area prior to mining, and how mining has changed these conditions.

Initial aquatic habitat monitoring should more frequent for 1–2 years before a reduction in frequency to twice annually–annually once general trends have been established (Table 6).

Although there are permanent monitoring transects in place for terrestrial revegetation monitoring, there is scope for more regular and detailed monitoring of wetland and lake margin habitats as these are areas of current rapid succession and change.

Table 6. Recommended environmental monitoring of KSS waterbodies. All surveying as habitat is available.

	Fisheries		Aquatic macroinvertebrates		Physico-chemical*	
	Survey method	Frequency	Survey method	Frequency	Survey method	Frequency
Reference wetlands	Electric-fishing and trapping	Annually (September)	Semi-quantitative sweep net. For 1 m^2 three replicates per major habitat	Quarterly	Temperature, DO, pH, ORP, EC, Chlr *a*. Metal suite. TN, NH3, NOx, TP, SRP	Monthly
Rehabilitated wetlands	Electric-fishing and trapping	Annually (September)	Semi-quantitative sweep net. For 1 m^2 three replicates per major habitat	Quarterly	Temperature, DO, pH, ORP, EC, Chlr *a.* Metal suite TN, NH3, NOx, TP, SRP	Monthly
Rehabilitated lakes	Trapping	Annually (September)	Semi-quantitative sweep net. For 1 m^2 three replicates per major habitat	Quarterly	Temperature, DO, pH, ORP, EC, Chlr *a.* Metal suite TN, NH3, NOx, TP, SRP	Monthly

- Physico-chemical parameters must have levels-of-detection appropriate to relevant environmental guidelines.

9 Conclusions

Although rehabilitation objectives for closure are still in the planning stages, KSS have been informed by regulatory authorities that general public access such as for recreation will likely not be the chosen end use. Rather access will be intended for specific interest parties such as environmental interest groups. Therefore, the best outcome for KSS will most likely be for a wetland and lake based nature reserve, where endangered species and locally significant communities can be protected.

Broad aims of successful rehabilitation are to provide a stable and self-sustaining landform representative of the habitats lost to mining and of value to the region. Additionally, the rehabilitation should also be to standards consistent with the conservation values of the area. This landform should blend into remaining natural landforms, yet provide no ongoing liability to these undisturbed communities.

Although dredge ponds are the most prominent feature in the post-mining KSS landscape, rehabilitating these land forms as representative wetlands of the area both minimises environmental impacts and enhances the existing ecological values of the area.

Acknowledgement must be given to the previously degraded state of mined areas. Consequently, it is likely that scientifically-directed rehabilitation attempts of significant effort will provide for wildlife habitat superior to this previous degraded state. The ability to demonstrate this rehabilitation *improvement* upon previous ecosystem quality is both in line with the current KSS (EMS) (Galloway, 1997) and will also facilitate relinquishment (Arbotech Pty Ltd, 1997). Therefore, good baseline data and ongoing rehabilitation matched with appropriate and quality monitoring will be a tool to facilitate future aspirations of either project area relinquishment or extension.

Previous and current extraction activity has been based around shallow wetland areas where less over burden removal is required. These areas are consequently less expensive to mine than other areas where overburden depths are greater (Environmental Protection Authority, 2005). However, mining of this area does not take rehabilitation expenses into account. The inclusion of expenses to rehabilitate arguably more complex and less sustainable wetland systems (with potential risks of ASS) may mean that mining of wetland areas is less profitable than previously envisaged.

Consequently, “dry” mining under 3–5 m high dune systems (Dames and Moore Pty Ltd, 1993b) is both likely to have lower ecological impact due to the lower ecological values of this habitat (Rust PPK Pty Ltd, 1997) and also to be easier to rehabilitate (Welker Environmental Consultancy, 2001). Local markets are also often available for this coarser sand fraction helping to recoup excavation costs, furthermore usage of this resource reduces the need for quarrying of sand elsewhere in the Bunbury region. Once the dry mining is complete, KSS could then continue to mine ore below the water table. Thus, remaining project area wetlands would be unmined, and dune systems could be rehabilitated into open water lakes and wetlands. Mining dune systems would also supply overburden for contouring of rehabilitated areas.

A cost-benefit analysis of the relative expense of both mining types, including costs and likely success of rehabilitation endeavors, local water resource impact and stakeholder perception should be conducted to best address this possibility. Recognition and acceptance of the inability to rehabilitate to pre-European landforms is a concept that is often not accepted by companies undertaking rehabilitation activities. Consequently the value of replacing lower ecologically valuable communities such as dunelands with higher ecological habitats such as shallow wetlands should always be a valid consideration as an offset.

10 References

ANZECC/ARMCANZ (2000). *Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4*. Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

ANZMEC/MCA (2000). *Strategic Framework for Mine Closure*. Australian and New Zealand Minerals and Energy Council/Minerals Council of Australia, Canberra. 27pp.

Arbotech Pty Ltd (1997). *Annual Environmental Report*. Arbotech Pty Ltd, Perth, Australia. 39+pp.

Bamford Consulting Ecologists (2006). *Kemerton Silica Sands Mine Report on fauna monitoring programme: 2005*. Bamford Consulting Ecologists, Perth, Australia. 7pp.

Barrier, R. F. G. & Hicks, B. J. (1994). Behavioural interactions between black mudfish (Neochanna diversus) and mosquitofish (Gambusia affinis Baird & Girard 1854). *Ecology of Freshwater Fish* 3: 93-99.

Dames and Moore Pty Ltd (1993a). *Additional groundwater considerations, Kemerton Silica Sand Project*. 21377-007-366/1. Perth, Australia. Dames and Moore Pty Ltd,17+pp.

Dames and Moore Pty Ltd (1993b). *Hydrogeological and geotechnical study, Kemerton Silica Sand Project*. Dames and Moore Pty Ltd, Perth, Australia. 15+pp.

English, V. & Blyth , J. (2000). *Shrublands and woodlands on Muchea Limestone - interim recovery plan 2000-2003*. Department of Conservation and Land Management, WA Threatened Species and Community Unit, Perth, Australia.

Environmental Protection Authority (2004). *Guidance for the assessment of Environmental Factors: terrestrial biological surveys for Environmental Impact Assessment*. No. 56. Environmental Protection Authority, Perth, Australia. 45pp.

Environmental Protection Authority (2005). *Kemerton silica sand mining revised proposal - additional mining areas and trasnfer of land for conservation*. Bulletin 1183. Perth, Australia. 10pp.

Galloway, R. (1997). *Gwalia Consolidfated Ltd. Kemerton Silica Sand Pty Ltd, proposal for the monitoring and rehabilitation program*. Arbotech Pty Ltd, Perth, Australia. 7pp.

GHD (2005). *Kemerton Silica Sand Annual Environmental Review 2004/2005*. 61/10572/9022. GHD, Perth, Australia.

Gwalia Consolidated Ltd. (1995). *Kemerton Silica Sand Project groundwater monitoring and management programme*. Gwalia Consolidated Ltd., Perth, Australia. 3+pp.

John Consulting Services (1997). *Kemerton Silica Sand Pty Ltd, Kemerton Silica Sand Project - Western Extension*. John Consulting Services, Perth, Australia. 17pp.

Kemerton Silica Sand Pty Ltd (Unknown). *Kemerton Silica Sand Project, Section 46 Western Extension (980): response to proponent from public submissions*. Kemerton Silica Sand Pty Ltd, Perth, Australia.

Ling, N. (2004). *Gambusia* in New Zealand: really bad or just misunderstood? *New Zealand Journal of Marine and Freshwater Research* 38: 473-480.

Mattiske Consulting Pty Ltd (1993). *Gwalia Consolidated Limited - Kemerton Sand Project, flora and vegetation studies*. GWA001/02/93. Mattiske Consulting Pty Ltd, Perth, Australia. 23pp.

Mattiske Consulting Pty Ltd (2002). *Flora and vegetation, Gwalia Consolidated Limited, Kemerton Sand Project*. SOG0203/020/02. Mattiske Consulting Pty Ltd, Perth, Australia. 23pp.

Mattiske Consulting Pty Ltd (2004). *Assessment of rehabilitated wetland areas 2004 - Kemerton Silica Sands Limited - Kemerton operations*. KSS0401/025/03. Mattiske Consulting Pty Ltd, Perth, Australia. 15pp.

Mattiske Consulting Pty Ltd (2005). *Assessment of rehabilitated wetland areas 2005 - Kemerton Silica Sands Limited - Kemerton operations*. KSS0501/166/05. Mattiske Consulting Pty Ltd, Perth, Australia. 14pp.

MBS Environmental (2003). *Scoping document, Kemerton Silica Sand, extension to dredge pond operation*. MBS Environmental, Perth, Australia. 33pp.

McCullough, C. D. (1998). The voracious mosquitofish: *Gambusia* or Damnbusia? Forest & Bird.

McCullough, C. D. & Hicks, B. J. (2002). Estimating the abundance of banded kokopu (*Galaxias fasciatus* Gray) in small streams by nocturnal counts under spotlight illumination. *New Zealand Natural Sciences* 27: 1-14.

McCullough, C. D. & Lund, M. A. (2006a). Opportunities for sustainable mining pit lakes in Australia. *Mine Water and the Environment* 25: 220-226.

McCullough, C. D. & Lund, M. A. (2006b). *Pit lake sustainability; what is it, and how do I get it?* Proceedings of the 2006 Australasian Institute of Metal and Metallurgy (AUSIMM) Water in Mining conference. Brisbane, Australia 24th - 26th November, Australasian Institute of Mining and Metallurgy, 323-330 pp.

NHMRC/ARMCANZ (1996). *Australian drinking water guidelines*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra. 359pp.

Ninox Wildlife Consulting (1993). *Vertebrate fauna assessment of the Kemerton Silica Sands project*. Ninox Wildlife Consulting, Perth, Australia. 33pp.

Ninox Wildlife Consulting (1994). *Kemerton Silica Sands Project Area, vertebrate fauna assessments: December 1992 - December 1993*. Ninox Wildlife Consulting, Perth, Australia. 27pp.

Pain, G. (2006). *Advice to the communities around Kemerton on the 3c technical and siting considerations for a potential Hazardous Industrial Waste Treatment Precinct at Kemerton Industrial Park*. Elder Market Research, Perth, Australia. 160pp.

Regulatory Impact Assessment Panel for the Swan Coastal Plain Wetlands EPP (2005). *Regulatory Impact Assessment - Revised Draft Swan Coastal Plain Wetlands Environmental Protection Policy (2004)*. Minister for the Environment, Perth, Australia. 24pp.

Rockwater Proprietary Limited (1998). *Groundwater monitoring review for July 1997 to June 1998 (GWL No. 60367)*. 258.0/98/1. Perth, Australia. 17pp.

Rockwater Proprietary Limited (2005). *Groundwater monitoring review for July 2004 to June 2005 (GWL No. 60367)*. 258.0/05/01. Perth, Australia. 17pp.

Rowe, D. K. & Champion, P. D. (1994). *Biomanipulation of plants and fish to restore Lake Parkinson: a case study and its implications*. Restoration of aquatic habitats, selected papers from the second day of the New Zealand Limnological Society 1993 Annual Conference. Wellington Collier, K. J. (ed.) Department of Conservation, 53–65 pp.

Rust PPK Pty Ltd (1997). *Kemerton Silica Sand Groundwater Well Licence No. 54445 borefield monitoring review.* Rust PPK Pty Ltd, Environmental and Infrastructure, Perth, Australia. 9+pp.

Semeniuk, C. A. (1987). Wetlands of the Darling system - a geomorphic approach to habitat classification. *Journal of the Royal Society of Western Australia* 69: 95-112.

Sommer, B. (1997). *Predation by Gambusia holbrockii (Girard) (Pisces: Poecillidae) on tadpoles: feeding trials and microhabitat utilisation in two contrasting wetlands on the Swan Coastal Plain.* BSc (hons) thesis, Edith Cowan University, Perth, Australia.

Sons of Gwalia Ltd (2000). *Kemerton silica Sands Pty Ltd Annual Environmental Report*. 22/02/01. Sons of Gwalia Ltd, Perth, Australia. 163pp.

Welker Environmental Consultancy (2001). *Environmental strategy for S46 assessment of silica sands project extension*. Report no. SOG11. Welker Environmental Consultancy, Perth, Australia. 7pp.

Wetzel, R. G. (2001). *Limnology - Lake and river Ecosystems.* 3rd edn, Academic Press, San Diego, USA. 1006 p.

11 Appendix 1 — Plates

Plate 1. The confining layer of coffee rock overlaying the quartzite ore body.

Plate 2. Removal of coffee-rock confining layer following prior removal and stock piling of top-soil (1 m) and over-burden.

Plate 3. Final dredging to 7–10 m of quartzite ore.

Plate 4. Erosion of topsoil, accumulation of coarse woody debris and coffee rock along western shores of Lake 1.

Plate 5. Accumulation of coarse woody debris and coffee rock along western shores of Lake 1.

Plate 6. Naturally regenerating shrubby vegetation being smothered by blown sands along eastern shores of Lake 1.

Plate 7. Kangaroo paw being smothered by blown sands along eastern shores of Lake 1.

12 Appendix 2 — Considerations for aquatic habitat and fringing vegetation rehabilitation

Rehabilitation criteria and goals must take into account that areas of the wider Kemerton project area have previously been subjected to historic logging and clearing, and also more recently to the fungal disease *Phytophthora cinnamomi* (McCullough & Hicks, 2002). Consequently, the project area land was in an already impacted state prior to mining approval.

However, given that both the highest value habitat and a significant component of habitat lost to date is seasonal wetlands, creation of new such habitats should be the primary target for rehabilitation. To make any new water bodies as shallow as possible. However, given the abstractive nature of the industry in question, some large lakes that are deeper than regional analogues will be an inevitable consequence.

The damage of wind erosion from easterly and westerly prevailing winds is increased by the open water of large lakes lengthening wind fetch. Orientating larger lake morphology so that the greatest linear dimension is in a north-south axis will reduce this fetch and consequent wind and wave exposure and erosion (Figure 1).

The previous approved strategy for rehabilitating dredge ponds was for a 100 m wide annulus of 2 m shallow margins around a centre dredge pond (Mattiske Consulting Pty Ltd, 2002). However, this design would also cause a high degree of wind fetch and consequent exposure. To further reduce wind velocities, and to buffer effects of potentially degraded ecology and water quality of these unavoidable large water bodies on nearby natural wetlands, they should be circled with an annulus of smaller, shallower seasonal "satellite" lakes that will dry in summer months (Figure 1).

Although long term eradication of Gambusia has been achieved before (Arbotech Pty Ltd, 1997; Sons of Gwalia Ltd, 2000) a first requirement for the management of this pest fish is to ensure reinvasion does not occur. Hence, drains from surrounding agricultural land leading into the project area wetlands that have been identified as potential sources of Gambusia (Welker Environmental Consultancy, 2001) should be diverted or bunded to prevent Gambusia ingress via this path.

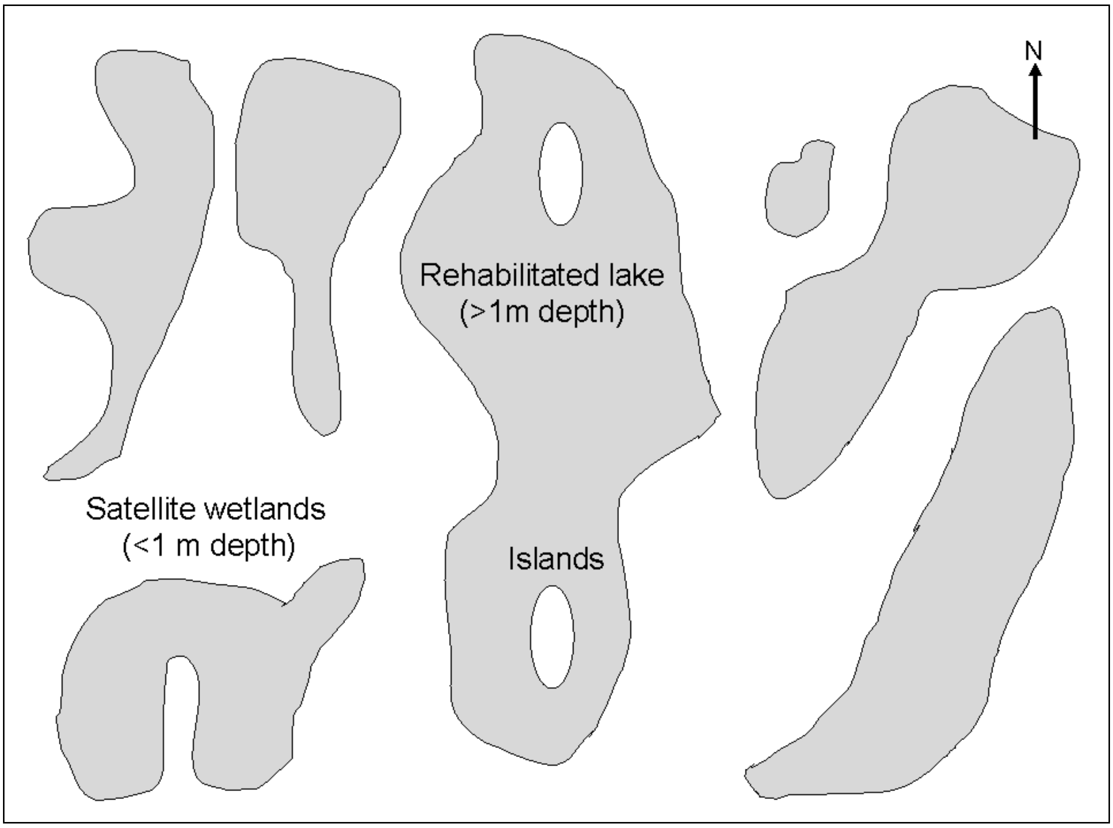

Figure 6. Suggested lake rehabilitation morphology and setting.

To provide for a geotechnically stable margin, rehabilitated lake margins are advised to be battered to at least 24^{o} (Sons of Gwalia Ltd, 2000). However, greater battering to a lower angle should be encouraged to prevent lake margin erosion and loss of establishing vegetation there. This may be achieved by spelling (resting) the lake, following battering, for at least a year prior to planting.

As recommended at the initiation of the mining project, there should be an attempt to maintain as much existing undisturbed flora as possible (Dames and Moore Pty Ltd, 1993b), particularly the high ecological value and difficult to rehabilitate wetland habitats (Mattiske Consulting Pty Ltd, 1993). These floral communities are the basis of both bird habitat, but also wetland habitat for fish, mammals and amphibians (Welker Environmental Consultancy, 2001) , as well as providing potential for natural regeneration. Mining will not only directly remove this valuable habitat, but will also degrade remaining vegetation communities through introduction of pathogens and diseases and the changing of local hydrological, light and wind environments.

Results from spreading topsoil and mulch onto reformed land has been encouraging and this should be the primary mode of revegetation. However key species (dominant trees, fringing Melaleuca spp.) appear to be absent or poorly represented in the rehabilitation to date and these should be targeted via planting, establishment via rootstock and other means. However, as previously mentioned, topsoils need to be more carefully defined and replaced as appropriate not only to topography and soil type, but also to depth to water table.

Instead of using fines for improving topsoil nutrient and water retention properties, mulching chips from cleared woody vegetation should be tilled into topsoils when ripping for rehabilitation (Regulatory Impact Assessment Panel for the Swan Coastal Plain Wetlands EPP, 2005). This organic matter will provide for improved soil water and nutrient retention in these extremely low-carbon virgin topsoils. Depending on the degree of decomposition of the mulch at the time of application, then to prevent nitrogen depletion some nitrogen fertilisers might be required.

Seeing as the coffee rock pan of this lake has not been disturbed, natural EPP lake “Lake 3” should be rehabilitated this winter 2007 with wetland topsoil to a partially groundwater perched wetland. This lake rehabilitation also then goes some way as a good trial and demonstration of the capacity to rehabilitate wetlands with top soils.

A variety of water depths has been suggested to provide for the greatest diversity of waterfowl. Deep areas of the lakes will be of value to diving waterfowl that feed on fish and crustacea. However, it has also been acknowledged that water depths over 1 m are less desirable waterfowl habitat as their food of water plants and aquatic macroinvertebrates are sparser and less accessible in these deeper waters (MBS Environmental, 2003).

Although islands are an important feature in providing waterfowl predator refuge, constructed solely of sand, such structures are unlikely to be stable over time. Consequently, the use of stabilising structures such as gabion baskets and whole trees should be considered to render these development viable over a long-term.

Constructing peninsulas as an alternative to islands may also assist in providing long-term viable predator refuge. Alternatively, wholly artificial floating islands may be constructed as a means of providing longer-term viable structures for waterfowl roosting (Ninox Wildlife Consulting, 1993).

Some islands may be left bare as they are seasonally inundated. However, as for lake fringes, some constructed islands and peninsulas will also require active revegetation to stabilise sediments and provide for habitat e.g. roosting sites within a shorter time span.

Fire management, although already discussed as a maintenance of rehabilitated areas requirement (Galloway, 1997), should also be included as part of the wetland and fringing vegetation sustainability strategy.

APPENDIX 11:
AQUATIC MACROINVERTEBRATES IN SEASONAL AND REHABILITATED WETLANDS OF THE KEMERTON SILICA SAND
DECEMBER 2008
CENTRE FOR ECOSYSTEM MANAGEMENT
EDITH COWAN UNIVERSITY

Centre for ecosystem management

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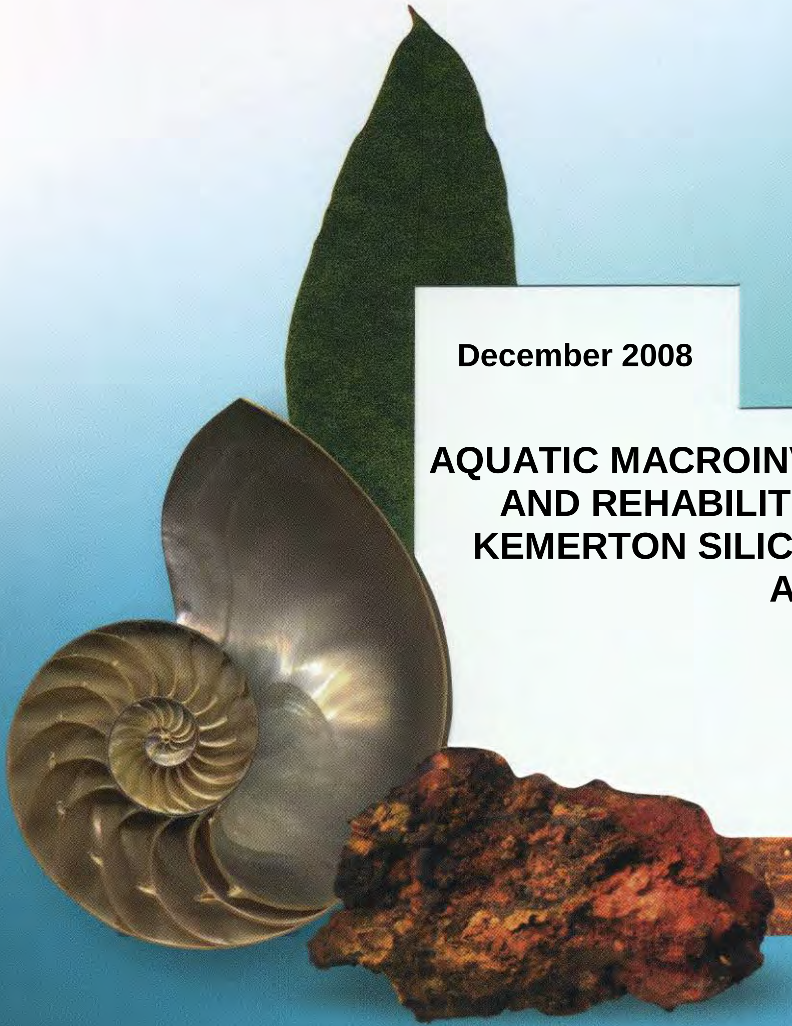

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AQUATIC MACROINVERTEBRATES IN SEASONAL AND REHABILITATED WETLANDS OF THE KEMERTON SILICA SAND PTY LTD PROJECT AREA (2007)

By, Dr. Clint McCullough
Assoc. Prof. Mark Lund

CENTRE FOR ECOSYSTEM MANAGEMENT

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AQUATIC MACROINVERTEBRATES IN SEASONAL AND REHABILITATED WETLANDS OF THE KEMERTON SILICA SAND PTY LTD PROJECT AREA (2007)

***By*, Dr. Clint McCullough**
Assoc. Prof. Mark Lund

Mine Water and Environment Research/Centre for Ecosystem Management Report

No. 2008-16

Prepared for,

Kemerton Silica Sand Pty Ltd

Dr. Clint McCullough BSc, MSc (Hons), PhD (Aquatic Ecotoxicologist),

Assoc. Prof. Mark Lund BSc (Hons), PhD (Aquatic Ecologist).

Frontispiece

Figure 1. Assoc. Prof. Mark Lund collecting an aquatic macroinvertebrate sample from EPP Wetland 5.

This document should be referenced as follows.

McCullough, C. D. & Lund, M. A. (2008). *Aquatic macroinvertebrates in seasonal and rehabilitated wetlands of the Kemerton Silica Sand Pty Ltd project area (2007)*. Mine Water and Environment Research/Centre for Ecosystem Management Report No. 2008-16, Edith Cowan University, Perth, Australia. 72pp. Unpublished report to Kemerton Silica Sand Pty Ltd.

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2 Executive Summary

1. The Kemerton Silica Sand Pty Ltd (KSS) mine is located on a 1 600 ha block at the northern end of Kemerton Industrial Park. The company mines silica sands following mechanical removal of topsoil, and then extraction of the ore from below the water table by dredging.

2. KSS are seeking approval to expand their current operations to the west of the current operations. To support the approval process, a Public Environmental Review (PER) is currently being prepared.

3. KSS commissioned the authors to report on aquatic macroinvertebrate communities within the project area and Kemerton Nature Reserve. The wetlands were sampled on 26–28th September and 12th October 2007 when the wetlands were expected to be at their deepest. The authors visited all the EPP (Environmental Protection Policy) listed wetlands and the majority of the wetland areas identified on aerial photographs. A particular focus was the conservation category wetlands (CCW) that lie in the proposed expansion area.

4. Seventeen wetlands were sampled for water quality and macroinvertebrate communities. A further eight potential wetland sites were visited, but were dry. A number of new wetland areas were identified, although as conditions were dry, it is believed that a number of small wetland areas remain to be described on the project area.

5. This report contains a listing of all wetlands visited, along with brief descriptions of possible geomorphic classifications and other features (although the dry conditions limited what could be done). It is also likely that in wetter conditions some of these wetlands have the potential to merge together.

6. In response to preliminary recommendations from this study, the CCW surrounding EPP4 has been excluded from the proposed expansion area. The CCW was dry on our visit, but appeared to be the catchment for the EPP4 wetland. Given the unique characters of EPP4, we recommend that this

wetland would be best protected by excluding the entire surrounding CCW wetland from any proposed expansion of the mining area.

7. The CCW to the north of EPP 4 lies in the PER area but already has a drain from previous mine operations running through it. On our visit the drain was wet but the CCW was dry. The CCW is likely to be negatively impacted by the drain.

8. The last CCW in the PER area lies to the west of EPP 4, it was dry on our visit and located on a gentle slope. Bennett Environmental Consulting (2004) considered this area to be palusplain. Near the western border of this CCW lie two small damplands (they were dry). The condition of these wetlands appears good.

9. We recommend the proposed expansion area be modified to better protect the sumpland at Site 7. This would involve exclusion of the dampland areas south of Site 7 to where the dunes nearly join (north of Site 6).6. It is possible that the scale and nature of wetlands located on the KSS project area and KNR have been overstated by Hill *et al.* (1996), having been mainly assessed by aerial imagery. We recommend that there is a need to integrate the wetlands (and complexes) identified in Bennett Environmental Consulting (2004), this study, and those on the DEC database (as per Hill *et al.*, 1996) into a common meaningful set.

10. A total of 147 taxa of aquatic macroinvertebrate were collected across all sites, the majority of species had distributions limited to a single wetland; only one species occurred across all sites (*Necterosoma* sp. larvae). The most di*verse* sites were EPP1 and EPP5. EPP1 appears to be relatively permanent and has water quality similar to the North Lake suggesting that it might be a suitable reference for natural macroinvertebrate communities.

11. The rehabilitated dredge pond and newly *c*reated wetland (CCX) were less species diverse than the majority of natural wetlands but CCX showed good species diversity, particularly as it had only just been established.

12. KSS project area wetlands containing water were generally of similar temperature. Natural wetlands were generally slightly acidic, however, artificial water bodies were slightly alkaline. Specific conductance was

moderate and typical of seasonal wetlands of the SCP. Dissolved oxygen was slightly super-saturated in artificial water bodies, and around 80% in natural water bodies. ORP was generally moderately oxidising in all wetlands bar CC5P where it was slightly reducing. This may be due to feral animal bioturbation of the soil during drier periods. Turbidity was low in all EPP wetlands, but moderate in artificial water bodies and CC wetlands.

13. Macroinvertebrate communities of EPP wetlands were numerically dominated by zooplankton, chironomid larvae and beetles and bugs. EPP4, particularly, was dominated by and contained a high abundance of conchostrocans.

14. Nevertheless, the aquatic macroinvertebrate community of EPP 4 appeared to be typical of other KSS project area wetlands in both number of animals and taxa and also in community composition.

15. There appeared to be no difference between littoral and open water aquatic macroinvertebrate communities. This finding suggests riparian vegetation may not be significant contributors to aquatic macroinvertebrate community structure *within* each wetland.

16. Recommendations are provided for future monitoring of macroinvertebrates in the KSS project area and Kemerton Nature Reserve.

3 Background

The Kemerton Silica Sand Pty Ltd (KSS) project area occupies some 1 600 ha of land at the northern end of Kemerton Industrial Park, 20 km north of Bunbury (Figure 2). The KSS Project Area is located in the Swan Coastal Plain, primarily on gently undulating Bassendean Sands, with vegetation comprising *Eucalypt-Banksia* woodland on uplands and wetlands on lower parts of the landscape.

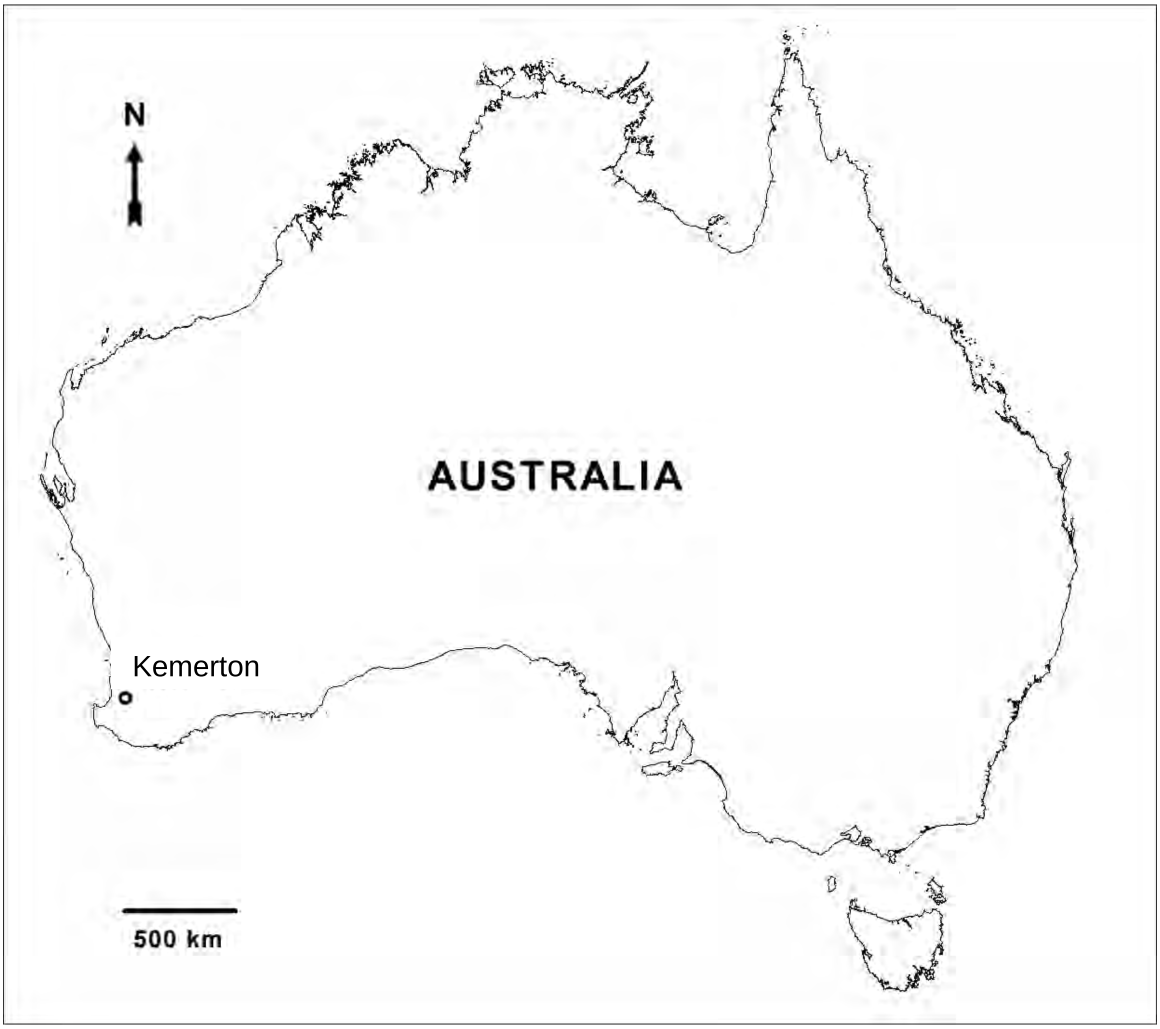


Figure 2. Location of Kemerton wetlands in south-western Australia.

Feldspathic silica sands are extracted from below the water table using dredge ponds. The resource generally lies beneath <1 m of topsoil and 4 to 7 m of overburden (which generally contains a band of coffee rock at the inter-phase between high and low groundwater levels). The overburden is removed by earth moving equipment. The ore resource is then extracted from a 30 m deep superficial aquifer using a surface floating dredge to a maximum permitted depth of 15 m. Once ore extraction is complete, the dredge pond is approximately 10 m deep. As the dredge pond is essentially an expression of the groundwater, the results are permanently inundated lakes. Washing fines, overburden and topsoil are available for sculpting and landscaping of the dredge ponds and surrounds.

Shallow depth to groundwater in the inter-dunal depressions results in numerous wetland areas of palusplain, damplands, sumplands and lakes (as per the definitions of Semeniuk (1987) within the project area. These wetlands become inundated from rainfall or the rising groundwater table, typically from July to November. Some of the wetlands are perched above the water table and so are dependent on rainfall for inundation. Six EPP wetlands (one crosses the project boundary) located across 200 ha of the project area have now been vested with the Department of Environment and Conservation (DEC) as the Kemerton (formerly Gwalia) Nature Reserve (KNR). One and part of another EPP lake remain in the project area, but are away from the current operations. One EPP lake has been lost in previous KSS mining activities. The KSS project area contains examples of remnant and regrowth native vegetation following selective logging and stocking in the past (GHD, 2005). Some of these vegetation communities have been identified as threatened. A threatened ecological community ("Shrublands and Woodlands on Muchea Limestone" (English & Blyth 2000)) listed as endangered by the DEC and under the Commonwealth Environment and Biodiversity Conservation Act 1999 has been reported as occurring on the eastern side of the existing dredge ponds (Environmental Protection Authority, 2005). Ownership of this land (13 ha in total) was transferred from KSS to the conservation estate in 2006 to help protect this Threatened Ecological Community (TEC).

According to Hill *et al.* (1996) the KSS project area and KNR contained on Map 2031 I SW (Harvey SW) damplands (57, 58, 59, 65, 68, 76) and sumplands (64, 67, 90, 100106, 130 (which includes 100 and 154)) and on Map 2031 I NW (Harvey NW) damplands (12 and 76, which are part of 57 on the previous map; 5, 36, 88, 120, 153, 175), sumplands (57, 99, 149 which are all part of 130 on the previous map; 170, 139, 55, 78, 202, 132, 147) and palusplain (316) (Figure 3). These wetlands are also listed on 'WetlandBase' (Western Australian Wetlands Database website, DEC). More recently, Bennett Environmental Consulting (2004) conducted a wetland survey of the KSS Project area (but not KNR). This study clarified the extent and linkages between some of the wetlands identified by Hill *et al*.a. (1996).

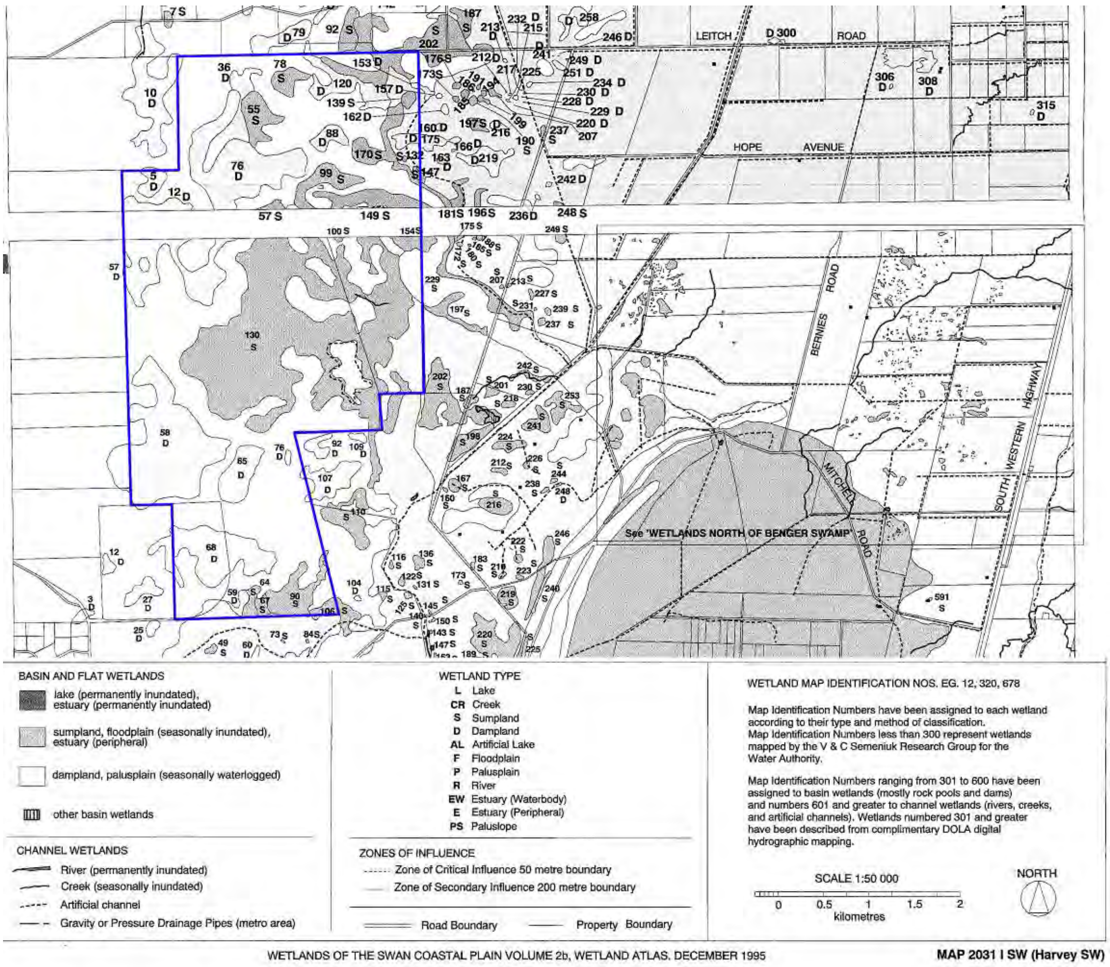


Figure 3. Combined map (2031 I NW and 2031 I SW) showing the wetlands identified by Hill *et al.* (1996) for the Project area and KNR (highlighted in blue).

In late 2006, Kemerton Silica Sand Pty Ltd contracted Doctor Clint McCullough and Associate Professor Mark Lund of Edith Cowan University's Centre for Ecosystem Management as Consulting Ecologists. As part of gathering the data for a Public Environmental Review (PER) document to support an application to expand the current mineable lands on the site, these researchers were contracted to examine the aquatic macroinvertebrates of all wetlands within the project area and KNR in 2007.

Benthic macroinvertebrates are typically the most popular biological community chosen to assess aquatic impacts. Internationally, analysis of benthic macroinvertebrate communities has been the foremost tool for biological assessment of aquatic ecosystems due to the availability of good taxonomy, a speciose community and extensive literature of pollutant effects (Havens *et al.*, 1996; Schofield & Davies, 1996; ANZECC/ARMCANZ, 2000). Although historically biological methods have been slow to be accepted in Australia, water managers now rely heavily upon aquatic macroinvertebrate communities for day-to-day assessment of water quality across the country (Norris & Norris, 1995; Norris *et al.*, 1995).

The objectives of this study were to;

- assess aquatic macroinvertebrate communities and water quality within wetlands in the PER area, project area and KNR,
- assess the condition and conservation status of as many wetlands on the PER area, project area and KNR as possible in the time available.

4 Methods

The KSS project area and KNR were visited on 26–28 September and 12 October 2007. Early spring was chosen to sample, as this season generally represents peak water levels for wetlands on the Swan Coastal Plain. Based on examination of aerial photographs and previous ground work, 21 sites were visited in addition to the 8 EPP wetlands (1, 3, 4, 5, 6, 7, 8, & 9). In total, 16 (13 natural) wetlands contained water and were sampled for water quality and macroinvertebrate communities. At each site, the wetland was walked around and notes taken on habitat type, condition and water depth, if appropriate (Figure 4).

4.1 Physico-chemical sampling

Wetlands were sampled in a stratified design where habitat heterogeneity was apparent. Different aquatic habitat types were identified as shallow and deep open water, and vegetated and bare littoral edge. Each wetland habitat type was sampled in replicate (3–5 concomitant with wetland size) for basic physico-chemistry parameters of temperature, dissolved oxygen (DO as % and $mg\,L^{-1}$), specific conductance (conductivity, EC), pH, Oxidation-Reduction Potential (ORP), turbidity and chlorophyll *a*[1] concentration with a Hydrolab Datasonde 4a. Single water samples for nutrients and metals were also taking by pooling across all water body habitats and replicates.

[1] The Hydrolab Datasonde 4a uses fluorescence to measure chlorophyll *a*, this proved to be impacted by the high colour of the water (gilvin) which rendered these results meaningless.

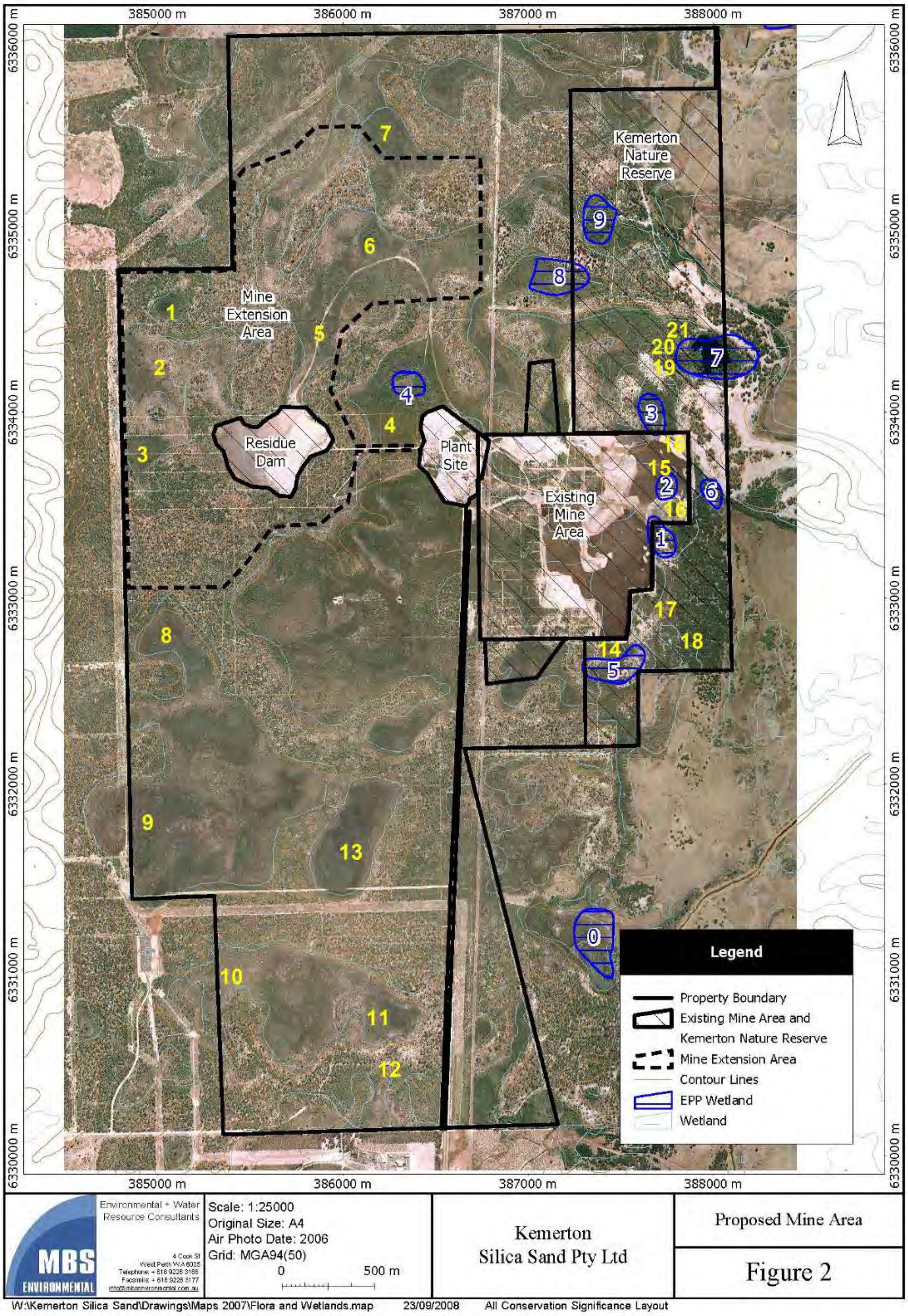


Figure 4. Kemerton Silica Sand project area and Kemerton Nature Reserve with EPP wetlands (blue numbers; wetland 2 no longer exists) and sites visited (yellow numbers; the two site 16's were considered as one wetland type) shown. PER area indicated by dashed black line). After MBS (2008).

Upon collection, each water sample was split into a 250 mL aliquot of unfiltered and two aliquots filtered through glassfibre filterpaper (0.5 µm Pal Metrigard) and stored in acid washed high-density polyethylene bottles. All nutrient samples were frozen prior to analysis. Metals samples were acidified with reagent grade HNO_3. Filtered samples were analysed for ammonium, NO_2^-/NO_3^- (NO_x), and filterable reactive phosphate (FRP) after APHA (1998), SO_4^{2-} by ion chromatograph (Dionex ICS-1000) and dissolved organic carbon as gilvin$_{440}$ by absorbance on a spectrophotometer (Schimadzu) at 440 nm. Unfiltered samples were persulfate digested and then analysed for total P and N according to APHA (1998). Selected metals/metalloids were analysed by Inductively Coupled Plasma Atomic Emission Spectrophotometry (ICP-AES; Al, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, Mn, Na, Ni, Sb, Sn and V) (Varian).

4.2 Aquatic macroinvertebrate community sampling

Aquatic macroinvertebrates were collected with a 250 µm mesh sweep net along a 10 m transect through each habitat. Each wetland macroinvertebrate sample was replicated at least three times, with up to five replicate for very large water bodies (Table 1). Macroinvertebrate sorting began with a big-pick from the 2 mm fraction. The sample filtrate was then placed into a four-channel Bogarov tray and sorted by two passes with an Olympus SZ-STU2 stereo microscope. Macroinvertebrates from both the larger fraction CPOM sieving and from the smaller fraction sorting tray were also identified and counted under this same microscope. Initially all uncommon (<200 individuals) were sorted, identified and counted. The remaining sample was then 20% subsampled for common taxa (>200 individuals) which were sorted, identified and counted. Subsampling was by volumetric dilution in beakers after Wrona *et al.* (1982). Prior to removal, samples were well shaken in the subsampler to break up organic clumps and increase the random nature of particle settling (Lund, 1999).

Table 1. Wetlands surveyed for aquatic macroinvertebrates and their names.

Site	Wetland code	Description of wetland	Replicates/ habitat
17	CC5	Series of small sumplands	3
18	CC5P	Paperbark dominated sumpland area immediately south-east of dredge pond	3
14	CCX	Rehabilitated wetland next to CC5	3
	EP1	EPP wetland 1	3
	EP3	EPP wetland 3	4
	EP4	EPP wetland 4	3
	EP5	EPP wetland 5	5
	EP6	EPP wetland 6	4
	EP7	EPP wetland 7	5
	EP8	EPP wetland 8	3
	EP9	EPP wetland 9	3
15	NL	North Lake - rehabilitated old dredge pond	5
12	NO	Old unrehabilitated pond* in south of project area	1
16	NS	Satellite lake of rehabilitated North Lake	3
21	PD	'Paperbark deep' - deep wetland nor-north west of EPP wetland 7	3
19	PN	'Paperbark new' - large shallow wetland north-west of EPP wetland 7	3
20	PS	'Paperbark new' - small shallow wetland north-west of EPP wetland 7	3

*Pre-dates mining operations on the KSS project area.

4.2.1 Data analysis

Univariate analyses were by one-way ANOVA in SPSS (2004) with a Type I error of 0.05. Prior to analysis data were $\log_{10}(x+1)$ transformed to improve normality. Data were also checked for parametric assumptions (McGuiness, 2002). Multivariate data analyses were made using PRIMER v6 software (Clarke, 1993) and followed a procedure of data transformation, graphical exploration and then statistical hypothesis testing. The key to these techniques is that the software attempts to represent on a graph (usually 2 to 3 dimensions) the degree of similarity between sites based on either their macroinvertebrate communities or water quality so that this similarity is equal to relative distances between sites on the plot. Therefore on the graphs similar sites group closely together. Ln(x+1) transformations of abundance data for multivariate analysis were used to reduce contributions to community dissimilarity by abundant taxa, and consequently to increase the contribution to analyses of less abundant taxa (Faith *et al.*, 1987; Austen & Somerfield, 1997; Stark, 1998). Biotic data transformations were chosen as those which gave the greatest returns of most statistically powerful ANalysis-Of-SIMilarity (ANOSIM) results (Olsgard *et al.*, 1997).

Principal Components Analysis (PCA) was used to produce ordinations of water quality (environmental) data. Two-dimensional nMDS ordinations of multivariate data were constructed for taxa frequency data using 100 iterations, based on the Bray-Curtis dissimilarity matrix (Faith *et al.*, 1987). Differences between *a priori* treatment groups were tested using the ANOSIM permutation routine with 9 999 iterations (all other variables default) (Clarke & Gorley, 2001). Environmental variables and taxa most contributing to differences between control and ASS mesocosms were determined using the SIMilarity-PERcentages (SIMPER) routine (all default settings) (Clarke, 1999). A transformation matching that of the ordination and consequent ANOSIM analysis was made for SIMPER analysis of biological variables with Bray-Curtis dissimilarity. Euclidean distance of untransformed data was used prior to SIMPER analysis of environmental variables. The BIO-ENV procedure was used to determine the combination of environmental variables best rank correlating with associated biological communities (Clarke & Ainsworth, 1993). Prior to BIO-ENV analysis, environmental variables were normalised to the maximum value encountered (Olsgard *et al.*, 1997; Clarke & Warwick, 2001). Draftsman plots were also examined to determine which variables were highly, (i.e., 95% or greater, Bob Clarke, Plymouth Marine Laboratory UK pers. comm.), Spearman rank correlated together leaving only a single dummy variable to represent correlated variables. Environmental data were always $\log_{10}$ transformed.

5 Results and Discussion

5.1 Wetlands of the Project Area and Kemerton Nature Reserve

5.1.1 Sites 1–3

Site 1, was a small dry dampland, in relatively good condition, surrounded by paperbarks. This site was listed by Hill *et al.* (1996) as D5 (SW) and in Lund *et al.* (1998) as CCW3. The wetland as seen in Figure 5 is circular (centred 'on the '1') and does not appear to extend northwards.

Site 2 had low scrub type vegetation; it appeared to occur on a slight slope (downwards to the west). There was no obvious sign of it being a dampland. This and Site 3 form D57 (SW) on the map of Hill *et al.* (1996). It is possible that the Residue Dam has blocked water flows that might have occurred though this site in the past. Site 3 was a distinct dampland, surrounded by paperbarks similar to Site 1. Site 3 was also dry and showed no sign of recent water logging.

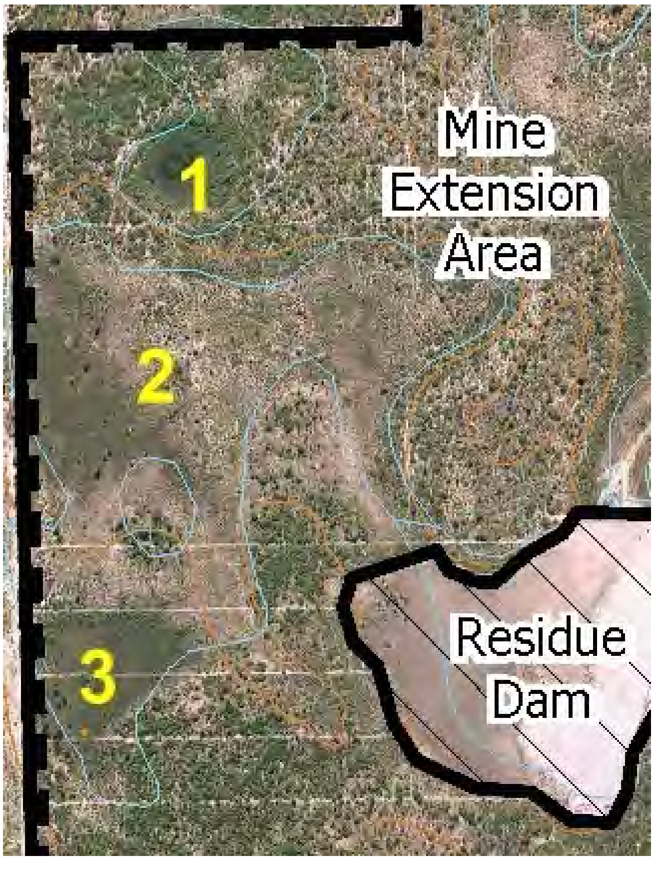


Figure 5. Aerial photograph (after MBS) showing Sites 1 to 3.

5.1.2 Site 4 and EPP4

Site 4 is a dampland located in the wetland that surrounds the EPP4 sumpland (Figure 6). Van Etten *et al.* (in prep) and McCullough *et al.* (2007) have found EPP4 is unique on the KSS project site as a perched wetland with distinct flora and fauna. EPP4 appears to be in good condition. As such, it appears that the dampland is the catchment for EPP4. Although dry at the time of our visit, anecdotal evidence from KSS staff suggest that in the past the wetland has flooded. EPP4 wetland habitat appears to be in very good condition.

EPP4 Site 4 (CCW1)

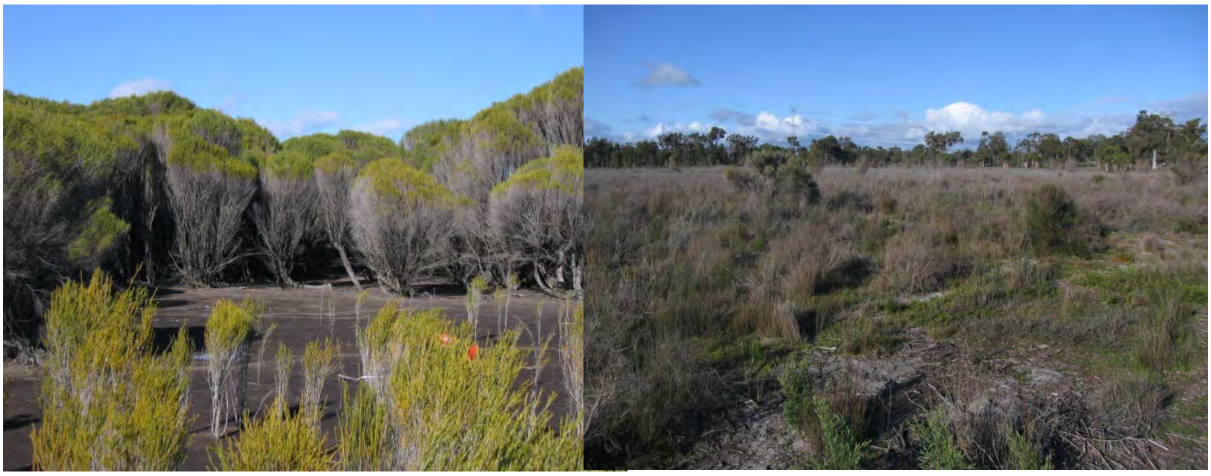


Figure 6. Photographs of EPP4 (June 2007) and Site 4.

In order to protect the unique aquatic ecological values of EPP4, we recommend that EPP4 and the surrounding dampland be excluded from the proposed expansion area.

Hill *et al.* (1996) identifies the dampland as part of a large sumpland (S120; SW), however the plant site (Figure 7), effectively splits this larger wetland into sections of which Site 4 and EPP4 form one. It appears unlikely that the link (indicated with a red line on Figure 7) between this wetland and EPP8 is ever connected by surface water. This supports the findings of Bennett Environmental Consulting (2004) who also identified these wetlands as separated.

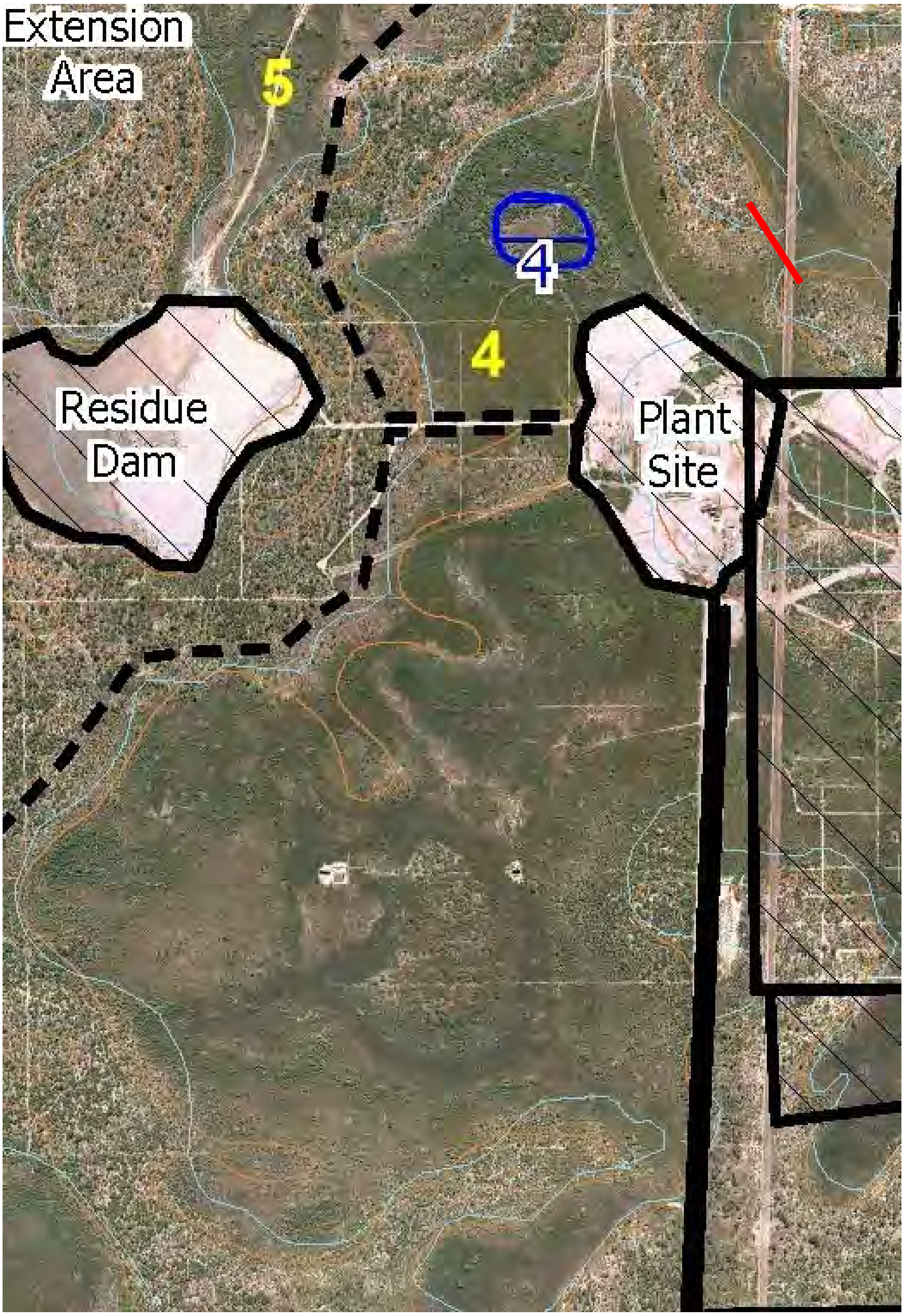


Figure 7. Aerial photograph (after MBS) showing Sites 4 and EPP4 (blue 4).

5.1.3 Sites 5–7

Sites 5 and 6 form part of dampland D76 (NW; Hill *et al.* 1996), and in Lund *et al.* (2008) was referred to as conservation category wetland CCW2 (Figure 8). This wetland was dry at the time of visiting. This dampland (CCW2) extends northwards out of the proposed expansion area. A key feature of the wetland is the old drain which links the evaporation pond to an area close to current operations. At the time of our visit the drain was wet, presumably draining the wetland surrounding it. Site C (Figure 8) was a deeper part of the dampland, which had peaty soils and stands of paperbarks and rushes and was likely to have surface water on occasion. The northern arm (Site B on Figure 8) of the dampland appeared to be terrestrial rather than dampland. Hill *et al.* (1996) identified a dampland to the north called D36, this is indicated as Site A on Figure 8. This dampland also appeared to be terrestrial. Below D36, Hill *et al.* (1996) identified a sumpland S55 (NW), in this study this sumpland was Site 7. During the study it was found to contain a small area of water. The water was located in a closed canopy paperbark woodland, surrounded by patches of rush. However, there was insufficient water to sample for aquatic macroinvertebrates. We recommend that this sumpland be investigated further in wetter conditions.

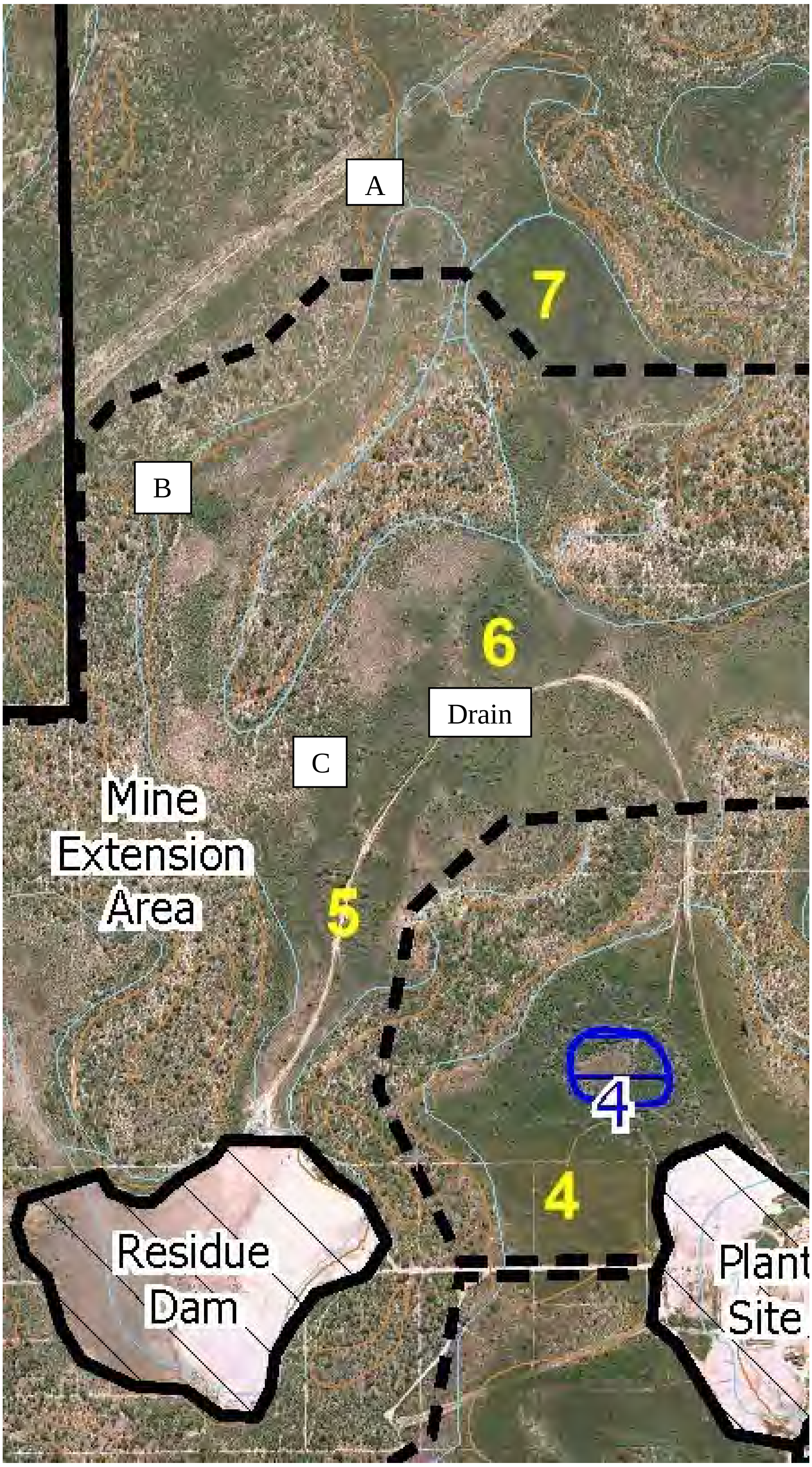


Figure 8. Aerial photograph (after MBS) showing Sites 5 to 7.

Site 5

Site 6

Drain

Drain

Site 7

Site C

Figure 9. Photographs of the wetland habitats in CCW2 dampland.

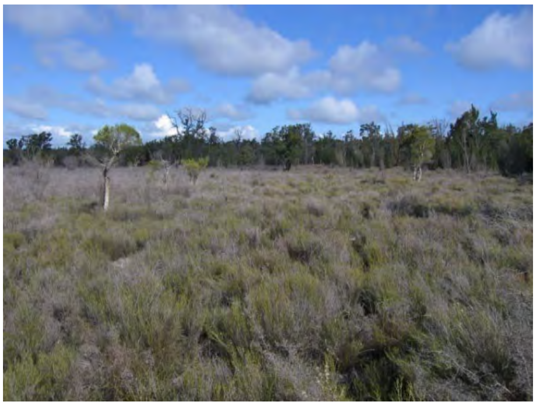
5.1.4 Sites 8, 9 and 13

Sites 8 and 9 lie in dampland D58 (SW) in Hill *et al.* (1996). They were dry at the time of the study. Aside from the western sections separated by the fire break (along the property boundary) the wetland appeared in good condition.

Figure 10. Aerial photograph (after MBS) showing Sites 8, 9 and 13.

Site 13 lies within dampland D65 in Hill *et al.* (1996) and was also in good condition and dry (Figure 11).

Site 9



Site 8

Site 13

Figure 11. Photographs of sites 8, 9 and 13.

5.1.5 Sites 10, and 11

Sites 10 and 11 are listed in Hill *et al.* (1996) as dampland D68 (SW). Dampland was dry, but appeared in good condition (Figure 12, Figure 13).

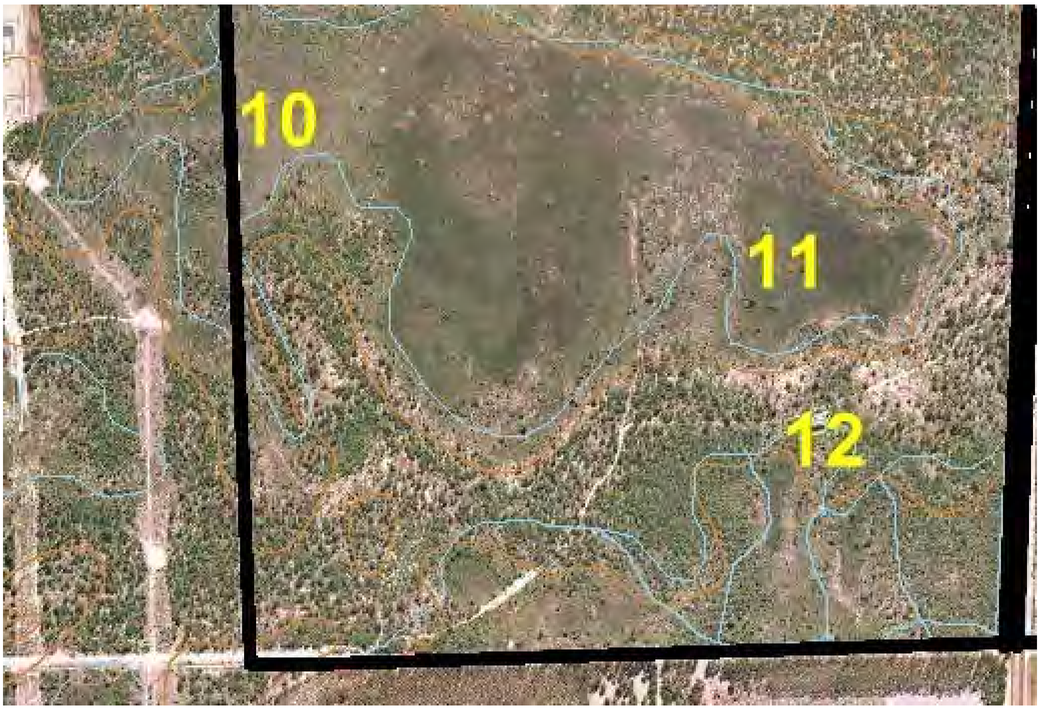


Figure 12. Aerial photograph (after MBS) of Sites 10 and 11.

Site 10 Site 11

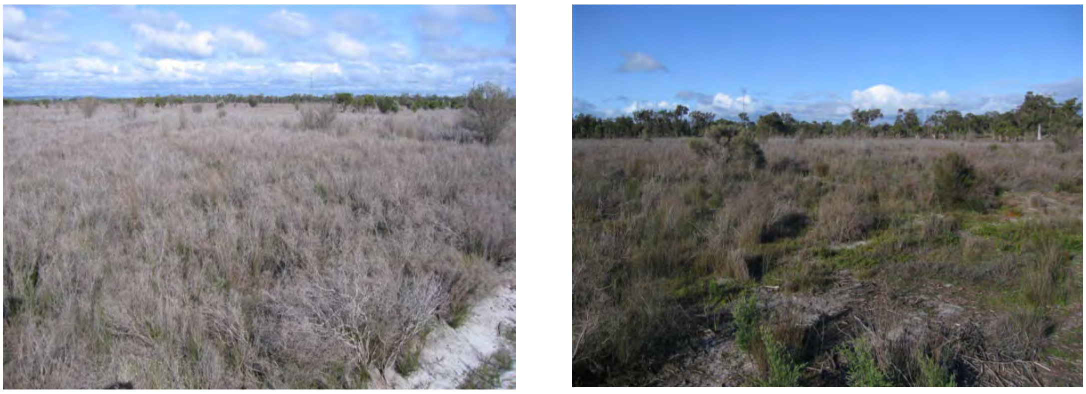


Figure 13. Photographs of Sites 10 and 11.

5.1.6 Sites 14, 17, 18 and EPP5

All these wetlands form part of sumpland S120 (SW) as listed in Hill *et al.* (1996). However, these wetlands are certainly not part of a giant sumpland but rather a series of distinct sumplands surrounded by damplands which in particularly wet years connect the sumplands with surface water (Figure 14). All these sites contained water at the time of sampling. Site 14 (CCX) is a new sumpland created by KSS, it has a base of wetland top soil and has a number of logs scattered over the surface to provide habitat. 2007 was the first year of filling after rehabilitation. EPP5 is a large sumpland, that has been heavily impacted by feral animals (in particular pigs and rabbits), although wetland vegetation remains relatively intact.

Site 14 (CCX)

EPP5

Site 17 (CC5)

Site 18 (CC5P)

Figure 14. Photographs of EPP5 and Sites 14 (CCX), 17 (CC5) and 18 (CC5P).

Site 17 (CC5) is located on a slight slope and represents a series of shallow pools (<0.2 m deep) that during wet conditions can interlink and flow down towards Site 18. The shallow pools could be considered mini sumplands. Site 18 (CC5P) is located at the bottom of the valley and is a predominantly closed canopy paperbark sumpland. The degree of connectedness CC5P has to EPP5 is not known.

5.1.7 EPP1

Rather than a wetland, EPP1 is a lake, as it appears to have almost permanent water. However, in wet conditions it expands outwards to the south almost doubling in area (Figure 15). It is located on the Muchea limestone TEC. The lake appears to be receiving seepage from North Lake.

Figure 15. Photographs of EPP1 (left –main lake, right – overflow area).

5.1.8 Sites 12, 15 and 16

These sites are all former dredge ponds. Site 12 (NO) is a small, probably test dredge site with no rehabilitation (Figure 16). Site 15 is the large rehabilitated lake, referred to by Lund *et al.* (2008) as North Lake (NL). To the north-east and south-east of Site 15 are two small satellite wetlands identified as Site 16 (NS). These satellite wetlands are shallow and at times of high water are joined to North Lake. However, in summer they separate from the main lake.

Site 12 (NO)

Site 15 (North Lake)

Site 16 (north-east)

Figure 16. Photographs of Sites 12, 15 and 16.

5.1.9 Sites EPP7, 19, 20 and 21

EPP7 is the largest sumpland in the study area (Figure 17). To the east, are three smaller sumplands. Site 19 (PN) is the largest, with the smaller and very shallow Site 20 (PS) further to the north. It is possible that in wet conditions that these wetlands are joined, although this did not appear to be the case during our study. Separated from PS is Site 21 (PD) which is a small circular wetland consisting of deeper water with old *Melaleuca* in the centre.

EPP7

Site 19 (PN)

Site 20 (PS)

Site 21 (PD)

Figure 17. Photographs of EPP7 and Sites 19, 20 and 21.

5.1.10 Sites EPP3, 6, 8 and 9

EPP3, 6, 8 and 9 are medium sized sumplands. EPP6 is surrounded by paperbarks but has fairly clear open water, EPP3 is similar but the water is filled with rushes with few open patches. EPP8 is a closed canopy paperbark wetland and EPP9 has old paperbarks around the edge, with young *Melaleuca* (similar to EPP4) growing densely across the middle (Figure 18).

EPP3

EPP6

EPP8

EPP9

Figure 18. Photographs of EPP3, 6, 8 and 9.

5.2 Aquatic Chemistry

Temperature varied across and within wetlands from 13.9 to 28.2°C affected by water depth and shading, the mean temperature across all sites was 19°C (Figure 19). However, pH was much more variable with the TEC wetland EPP1 and dredge ponds (NL, NO and NS) with a pH>7 up to 8.5. Most EPP wetlands tended towards being acidic with pH<7 down to 4.6. The EC of wetlands ranged from 0.15 to 2.06 mS cm^{-1} but was very variable within and between wetlands. EPP7 EPP1, the dredge ponds (NS, NL) and PN were the highest with EC >1.1 mS cm^{-1}. Interestingly one of replicates of NS and NO had low EC <0.4 mS cm^{-1}, probably showing a lack of connection with the deep groundwater. EPP3, EPP4, EPP5 and PS all had EC <0.6 mS cm^{-1}. Dissolved oxygen concentrations ranged from super-saturated to 120% in the dredge ponds (NS, NO and NL) to 60% in EPP9. Generally, oxygen saturation across most natural wetlands was around 80%. ORP was very variable but positive across all wetlands, except CC5P, at around 100 mV (Figure 19). CC5P has a highly variable, but had a mean ORP of only -6 mV. The highest ORP was measured in EPP9 at 230 mV, in spite of it having the lowest oxygen saturation. Turbidity was close to 0 NTU across all EPP wetlands, ranged from 0.5 to 43.8 NTU in CC5, CC5P and CCX wetlands and from 0.5–36 NTU (one replicate had a turbidity of 187 NTU, although this is probably due to stirring of the sediment during measurement) in dredge ponds (NO, NS and NL).

NPOC and gilvin were highly correlated (r=0.94) indicating that most of dissolved organic carbon in the water was in the form of coloured humic and fulvic acids and unlikely to very available for bacterial use (Table 2). EPP1 and EPP4 and the dredge ponds (NL and NO) had the lowest gilvin concentrations. The likely reasons are EPP1 and NL have high Ca concentrations, and this will precipitate humic and fulvic acids. EPP4 and NO are probably dominated by rainwater which is low in gilvin. All other sites have relatively high gilvin, sufficient to limit algal productivity, the source is groundwater and is typical of Bassendean sand dunes (Lund & Ryder 1998).

All undisturbed natural KSS project area wetlands showed $Cl:SO_4$ molar ratios >5 (Table 2). However, North Lake showed a $Cl:SO_4$ ratio of only 1.3 and CCX, which had been disturbed by scraping, showed a $Cl:SO_4$ ratio of only 3.8. $Cl:SO_4$ values less than four indicate the presence of ASS and values less than two indicate severe contamination (Department of Local Government and Planning, 2002). Low $Cl:SO_4$ ratios in North Lake and also in CCX may indicate some AMD/ASS-type oxidation from disturbance of the intermediate 'coffee rock' layer which may contain PASS (McCullough *et al.*, 2007). CCX was just acidic at approximately pH 5.6. While buffering with high Ca concentrations prevents acidification in the other wetlands with $Cl:SO_4$ ratios <3, the comparatively low Ca concentrations of CCX, suggest that this wetland needs to be monitored to determine if acidification is going to become a problem. KSS have informed the authors that these PASS soils will be removed which may eliminate this problem. The high pH (8.0) of the North Lake, however, is likely due to calcareous sediments in the lower aquifer neutralising acidity generated by ASS. Natural seasonal wetland sediments on the project area are unlikely to contain PASS due to the high frequency of drying remobilising sulfur (Baldwin *et al.*, 2007) and they demonstrate this by high $Cl:SO_4$ ratios. Interestingly, Fe levels are generally low across all waterbodies, suggesting oxidative or secondary mineralisation processes are responsible for its removal.

Wetlands which dry have much higher levels of NH_3 than permanent wetlands indicating breakdown of organic matter in the sediment while the wetland is dry. This NH_3 will be converted to NOx by nitrification and NOx is utilized heavily by plants and algae. EPP6 had particularly high NOx concentrations at 339 μgL^{-1}, this was also accompanied by high FRP at 36 μgL^{-1} which suggests that the wetland might be receiving fertiliser runoff from the nearby paddocks. Otherwise all other wetlands had typical nutrient concentrations, with the exception of PD which had elevated FRP concentrations of 297 μgL^{-1}. These FRP concentrations may be natural but warrant further investigation.

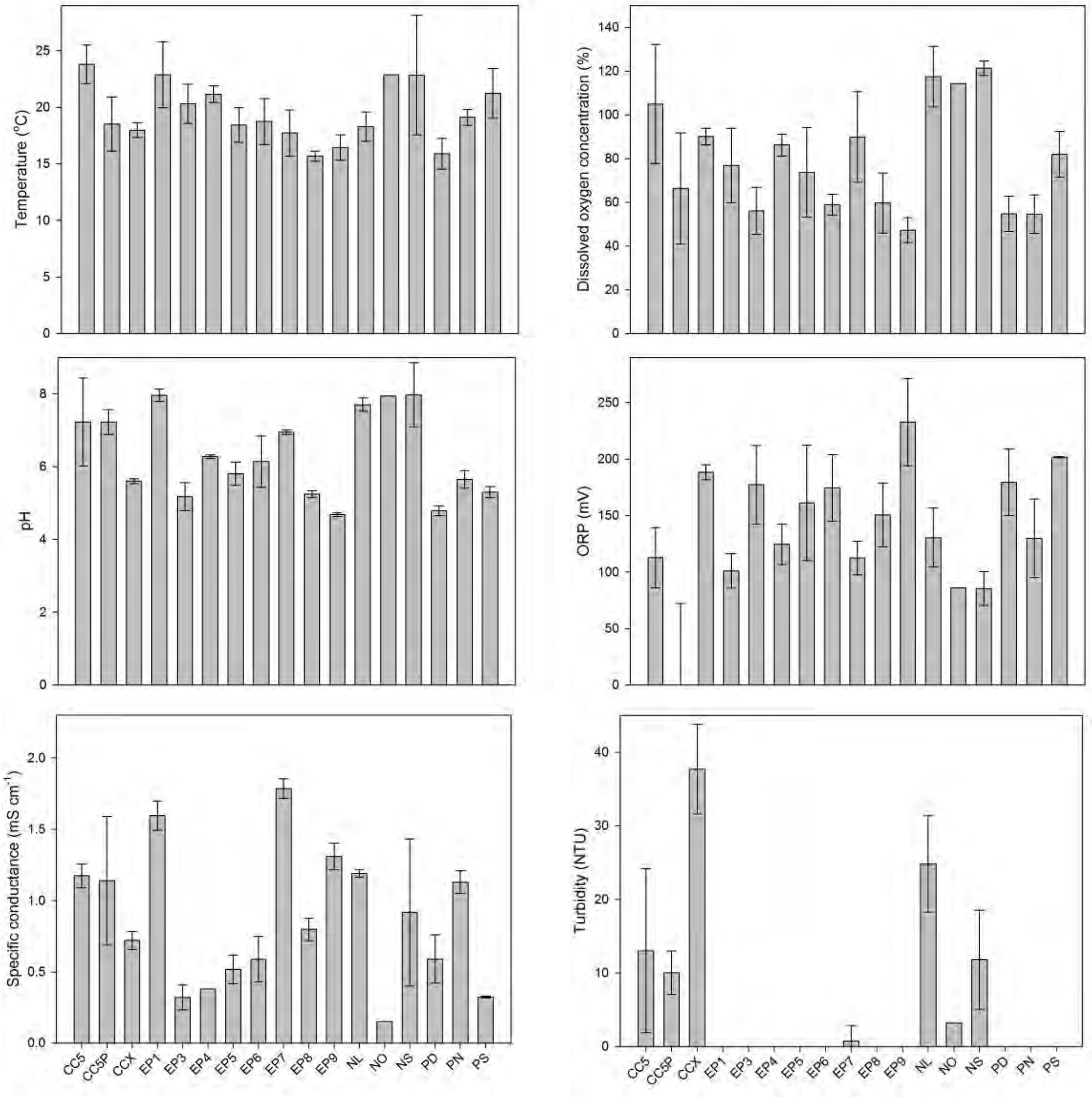


Figure 19. Mean physico-chemical parameters of KSS project area wetlands. Error bars are single standard deviations of the mean.

Table 2. Cl, SO4 and Cl:SO_4 ratios of KSS project area waterbodies.

Waterbody	Cl	SO_4	Cl:SO_4
CC5P	216	65	9.1
CC5	277	74	10
CCX	145	103	3.8
EP1	252	125	5.5
EP3	55	10	15
EP4	89	23	10
EP5	131	13	28
EP6	136	49	7.5
EP7	486	75	18
EP8	190	30	17
EP9	302	79	10
NL	138	296	1.3
NO	36	10	10
PD	115	23	13
PN	277	31	24
PS	63	16	11

A PCA of all the physico-chemical variables is shown in Figure 20. It should be noted that the degree of similarity between replicates within a wetland is enhanced as each replicate possesses identical nutrient and metal data from the pooled water sample. KSS wetlands were significantly different (Global $R = 0.991$, $p = 0.01$) and possessed a distinct chemical signature, with greatest within chemical variability shown by the shallow satellite wetlands of North Lake. Across KSS wetlands, EC was generally positively correlated with solute concentrations of Na, K, Fe, Cl and Mg. Surprisingly, concentrations of Fe were not correlated with concentrations of SO_4.

There appeared to be similarities in water quality of nearby wetlands, with adjacent wetland pairs such as EPP5 and EPP6, CCX and CC5P, and PD and EPP3 very similar to each other. EPP7 was unusual in having much higher solute concentrations of Na, Cl, K, Fe, TN and NPOC, with the closest wetland being PN indicating either a similar source of water or recent connection.

EPP4 appeared to have distinct water chemistry from other natural wetlands in having low EC, nutrients and solute concentrations of Na, Cl, Fe, Mg and K. Intriguingly, the closest wetland was NO, this perhaps indicates that the predominate source of water in these sites is rainwater.

Dredge ponds and satellite lakes had significantly different water chemistry to natural KSS wetlands (Global $R = 0.991$, $p = 0.01$). Relative to natural KSS wetlands, rehabilitated dredge pond North Lake had higher water temperatures, turbidity, DO, pH and SO_4 concentrations (Figure 21). North Lake also had lower NPOC, ammonia and total nitrogen. North Lake water chemistry was very similar to that of the TEC wetland EPP1, albeit more extreme in all water quality variables leading to differences from the other natural wetlands.

There was no significant difference between water quality between the different habitat types of deep and shallow open water, and vegetated and bare littoral edges (

Figure 22, Global $R = -0.007$, $p = 0.578$).

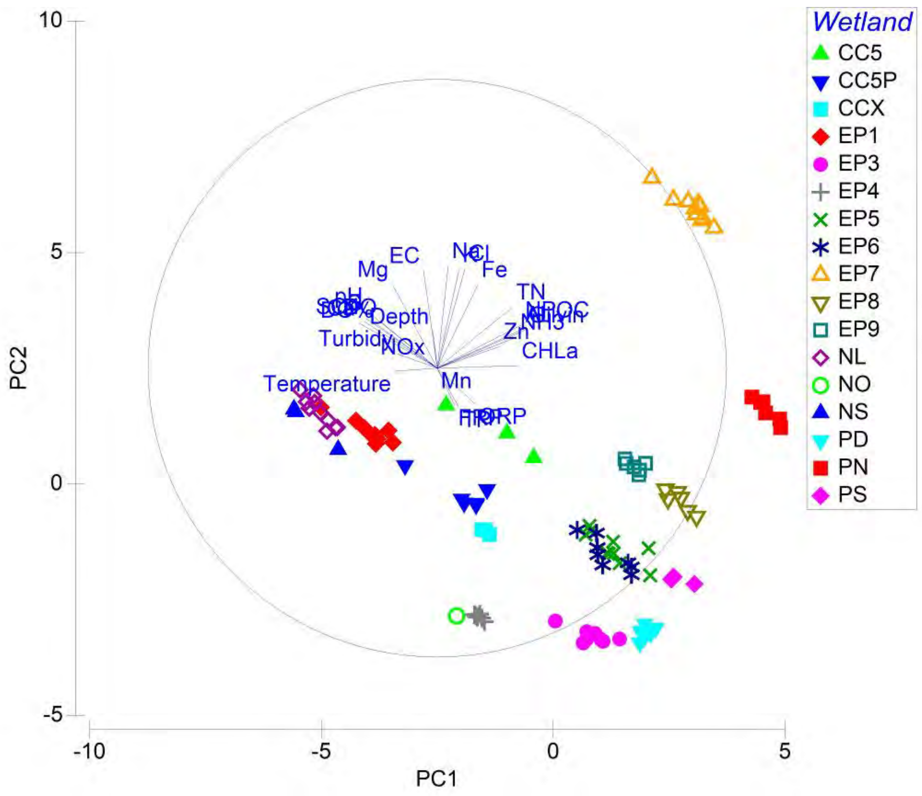


Figure 20. PCA of physico-chemical parameters of KSS project area wetlands. PC1 = 33.9%, PC2 = 25.5%.

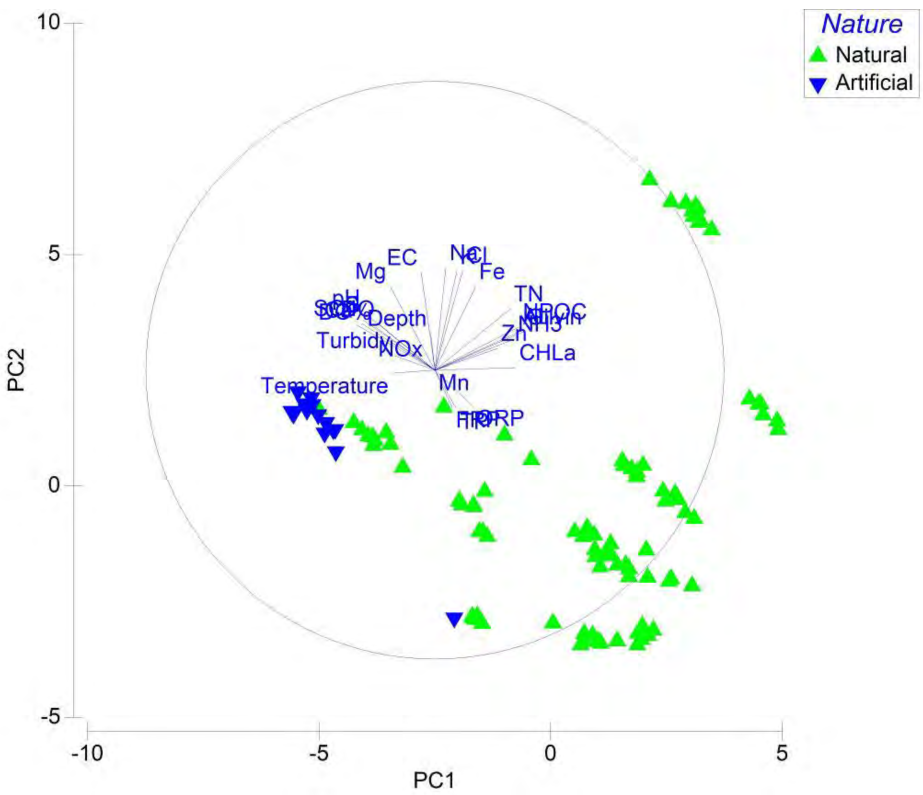


Figure 21. PCA of physico-chemical parameters of KSS project area waterbodies as natural or artificial. PC1 = 33.9%, PC2 = 25.5%.

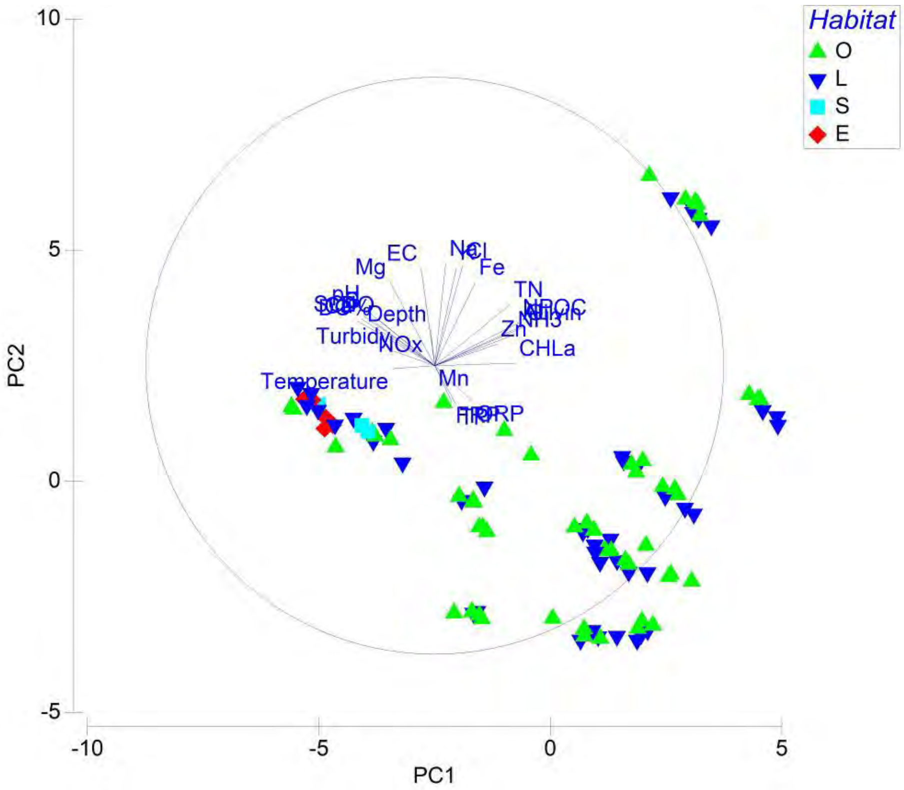


Figure 22. PCA of physico-chemical parameters of KSS project area wetland habitats. PC1 = 33.9%, PC2 = 25.5%.

5.3 Aquatic Macroinvertebrate Communities

There was a diverse range of 147 taxa encountered in the KSS project area survey. Aquatic macroinvertebrate communities were generally dominated by zooplankton, then chironomid larvae (an order of magnitude less abundant) and beetle, mosquito and hemipteran larvae. Aquatic macroinvertebrates of natural wetlands were abundant in most samples with an overall mean of 309±49 (standard error of the mean) macroinvertebrates per sample and a mean of 850 macroinvertebrates per sample recorded from PD. Samples rich in animals were dominated by zooplankton crustaceans including daphnid and other cladoceran families, calanoid copepods and ostracods. Dominance by other taxonomic groups was less common, with a high diversity of rarely sampled taxa such as mayfly (Baetidae) and riffle beetle (Elmidae) larvae. Natural wetland macroinvertebrate samples were also moderately diverse, with an overall mean of 9±0.0 taxa per sample found across natural wetlands to a maximum of 19 taxa per sample encountered in EPP1 and 4. Macroinvertebrate community abundance and diversity was lower in artificial water bodies, with the NO and North Lake and NS showing only a mean of 24±10 macroinvertebrates per sample and a mean of 4±1 taxa per sample.

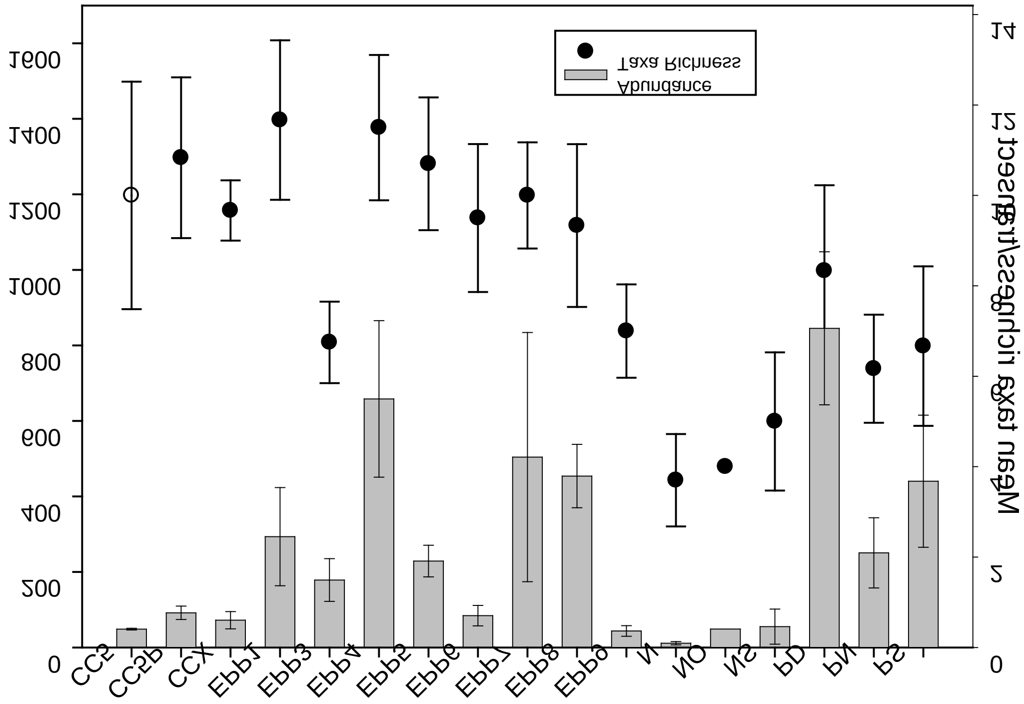


Figure 23. Mean aquatic macroinvertebrate abundance and diversity per transect in KSS project area wetlands.

Total taxa per wetland are shown in Appendix 2[2], with EPP1 and EPP5 the most diverse (with 58 and 55 taxa respectively). EPP7, EPP4, EPP6 and CC5P had similar diversity ranging from 47 to 40 taxa. This illustrates that CC5P is a significant wetland in terms of biodiversity. EPP9 and EPP8 have 30 and 28 taxa respectively which is interesting given their proximity to each other. EPP3, PD, CC5, NL, PN and CCX all had taxa richness between 23 and 19. Of particular note is the richness of CCX which is high considering the wetland had only just been created. The result shows than compared to the other permanent wetland EPP1, NL still had a long way

[2] Total taxa per wetland is a function of amount of sampling. In this study the number of replicates was weighted to the size of the wetland, so while direct comparison should be treated cautiously it provides insight into the distribution of biodiversity.

to go to develop its full biodiversity. The low richness of PS is surprising at 13 while NO had a richness of only 5 which can be partially attributed to only a single sample being collected. Only one taxon (*Necterosoma* larvae) was common across all wetlands and only 10% of taxa were found in over half of the wetlands. Forty percent of taxa only occurred in one wetland with all wetlands except PS and NO had unique species. This result suggests that either more sampling was required at each wetland to get a complete taxa list or that as wetlands may have filled at different times that there is temporal species variation.

An nMDS ordination of KSS macroinvertebrate communities showed outliers for a replicate of North Lake and EPP6 littoral. When these outliers were removed the ordination still showed a high stress of 0.23 as a result of the large number of data points collected (Figure 24).

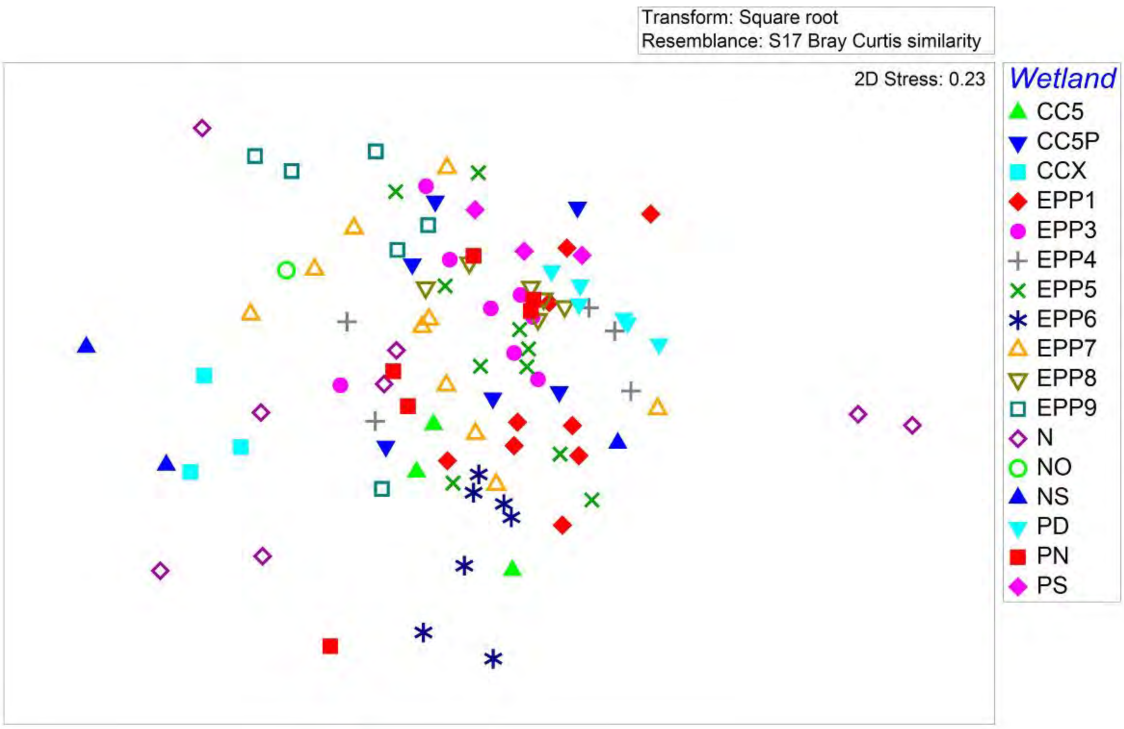


Figure 24. nMDS ordination of aquatic macroinvertebrate communities in KSS project area wetlands. Different colours indicate different wetlands.

There were some consistency between wetland transects for some natural wetlands such as CCX, EPP6 and PD. However, many wetland macroinvertebrate communities were highly spatially variable and showed great overlap between each other. For example, EPP1 and EPP5 showed a range of community overlap with most other waterbodies. Macroinvertebrate communities of KSS wetlands were often quite variable between replicates. Macroinvertebrate community structure of dredge ponds and NS were highly significantly different to those of natural water bodies (Global $R = 0.536$, $p << 0.01$, Figure 25). These differences were primarily due to dominance by zooplankton in natural wetlands and dominance by chironomid larvae in the dredge ponds and NS (Table 3).

Table 3. SIMPER analysis showing macroinvertebrate community structure differences between natural and artificial water bodies on the KSS project area (values contributing >5% to inter-treatment dissimilarities). 'Contribution %' indicates proportion of total dissimilarity between treatments which each taxon contributed in a diminishing order. Mean inter-treatment dissimilarity = 88%. All data square root transformed.

Species	Natural wetland Abundance	Artificial waterbody Abundance	Average Dissimilarity	Dissimilarity/SD	Contribution %	Cumulative %
Calanoida	5.80	1.03	14.31	1.02	16.20	16.20
Ostracoda	5.68	0.78	12.31	1.12	13.94	30.13
Daphniidae	5.42	0.81	11.84	0.75	13.40	43.53
Chironomidae larvae	0.75	1.72	4.89	0.78	5.54	49.07

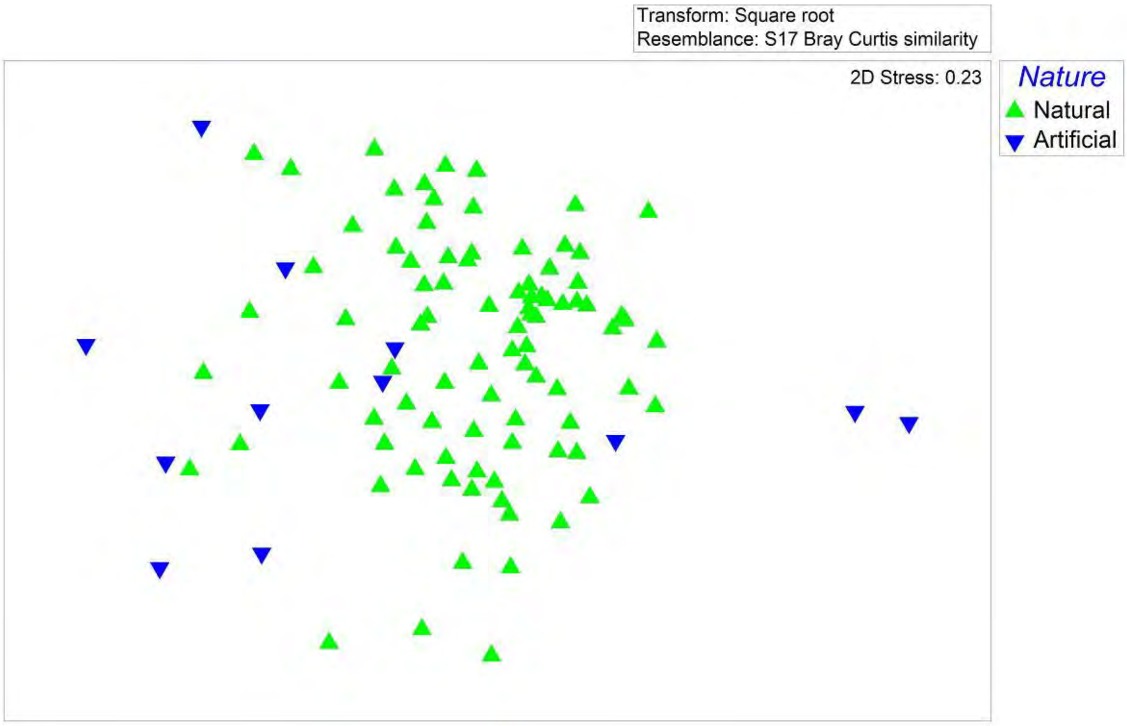


Figure 25. nMDS ordination of aquatic macroinvertebrate communities in KSS project area wetlands. Different colours indicate either natural or artificial waterbody type.

Although macroinvertebrate community structure of the habitats of deep and shallow open water and vegetated and bare edge appeared to be similar when ordinated, the large sample size permitted some differences to be detected (Figure 24). Macroinvertebrate community structures of some different wetland habitats were significantly different to each other (Global $R = 0.129$, $p = 0.02$). Macroinvertebrate community structure of bare edge littoral habitat was significantly different to all other habitat types ($p < 0.05$). Macroinvertebrate community structure of vegetated littoral habitat was also significantly different to that of open water ($p << 0.01$).

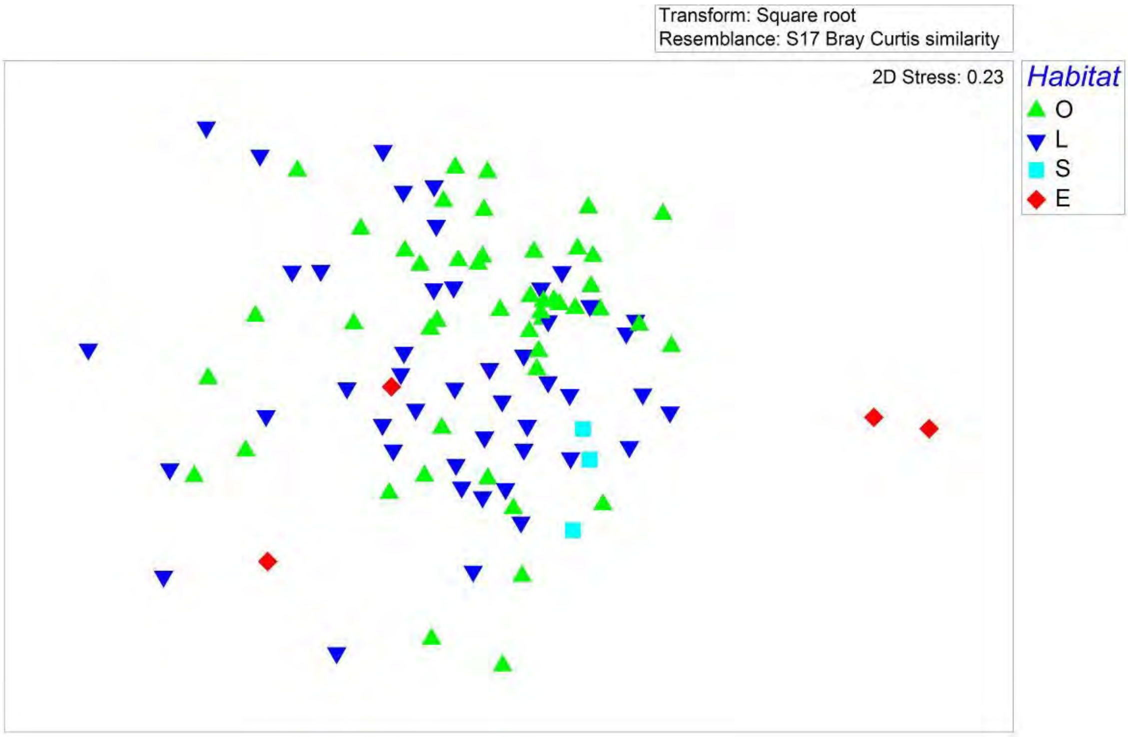


Figure 26. nMDS ordination of aquatic macroinvertebrate communities in KSS project area wetlands. Different colours indicate vegetated littoral (L), bare edge (E), open water (O) and shallow open water (S) site sampled.

All KSS project area water bodies considered, turbidity and NOx explained most macroinvertebrate community structure variation (0.484, Table 4). S/SO_4, Mn and DO (%) only slightly increased correlation between macroinvertebrate communities and water quality. Considering only natural wetlands of the KSS project area, turbidity and NOx again explained most macroinvertebrate community structure variation (0.413, Table 5).

Table 4. BIO-ENV results for all KSS project area macroinvertebrate communities. Biotic data square-root transformed, environmental data normalise but untransformed. X indicates inclusion of this environmental variable in the explanatory subset, while highest rank correlation coefficient (ρ) indicates best explanatory environmental variable subset.

Number of variables	ρ	Turbidity	NOx	S/SO_4	Mn	DO (%)
2	0.484	X	X			
3	0.487	X	X	X		
3	0.484	X	X		X	
4	0.489	X	X	X		X
4	0.487	X	X	X	X	

Table 5. BIO-ENV results for natural wetland project area macroinvertebrate communities. Biotic data square-root transformed, environmental data normalise but untransformed. X indicates inclusion of this environmental variable in the explanatory subset, while highest rank correlation coefficient (ρ) indicates best explanatory environmental variable subset.

Number of variables	ρ	Turbidity	NOx	S/SO_4	Mn	DO (%)	Fe
2	0.413	X	X				
3	0.413	X	X		X		
3	0.398	X	X			X	
3	0.381	X	X	X			
3	0.375	X	X				X

6 Conclusions

Seventeen wetlands were sampled, three of which were dredge ponds that had been rehabilitated (NL and NS) and not rehabilitated (NO). Given the size of NO it was not possible to clearly demonstrate the benefits of rehabilitation. A total of 149 taxa were collected across the study area, with EPP1 and EPP5 the most diverse. As EPP1 is relatively permanent, receiving seepage from the dredge pond and is located on a limestone TEC it has similar water quality to the rehabilitated dredge pond. EPP1 may therefore be useful for indicating potential macroinvertebrate community structure that might be achieved in the dredge ponds. Satellite wetlands off the dredge pond did have in at least one case different water quality to that of the dredge pond. While diversity of NS was relatively low, this does not exclude the potential benefits of creating shallow wetlands around the dredge pond as evidenced by the high diversity in CCX only months after construction.

Habitats within natural wetlands did not appear to demonstrate either significantly different water quality or significantly different macroinvertebrate communities. This may be because many of the taxa encountered in these seasonal wetlands are cosmopolitan and do not have narrow ecological niches that would separate them across the habitats sampled. There also appeared to be no difference between littoral and open water aquatic macroinvertebrate communities suggesting riparian vegetation is not significant for aquatic macroinvertebrate community structure *within* these natural wetlands. Establishment of the simple sedgeland margin in the more successfully rehabilitated areas has also appeared to significantly alter macroinvertebrate structure to that of a more natural community. Early-succession riparian sedge vegetation was very important for the rehabilitated dredge pond North Lake as macroinvertebrate community structure was very different to that of the rest of the lake and natural wetlands in 60% of samples (including an outlier where no macroinvertebrates were found).

However, although habitats within wetlands were not significantly different, riparian vegetation does appear to be important for the natural wetlands of the KSS project area by contributing wetland bank and water column stability, water surface shading and contribution of organic carbon as both dissolved and particulate forms.

Although this study has established aquatic macroinvertebrate community baselines of the KSS project area, it is still unclear as to how this community varies between years. For instance, is there a consistent aquatic macroinvertebrate community that needs to be targeted for rehabilitation, or is the community more opportunistic. Similarly, seasonal wetland communities may show a predictable succession from initial wetting to final drying (Tripodi, 1997). Therefore, seasonal changes within KSS study area also require understanding in order to understand annual variations.

The only sumpland that was not sampled as it was too dry was Site 7; however this wetland should form part of any regular sampling program. Sites 1-6, 8-12 and 13 all represented damplands, although Site 2 was potentially too dry to still be considered a wetland. The damplands appeared rarely wetted e.g., showing little development of wetland type soils. It is suspected that these areas rarely have surface waters but are more often waterlogged (better fitting the definition of palusplain/dampland), although this was not the case in 2007. CCW2 (Sites 5 and 6) was thought to be drained by the drain leading back from the evaporation pond, so was probably drier than it would normally have been. CCW1 (Site 4) was dry, although we were informed by Mr. Paul Williams at KSS that it had been inundated in previous years. As such, it is difficult to separate CCW1 from EPP4 (as it is effectively the catchment of EPP4).

- The wetlands in KNR and KSS Project area have all been assessed for extent through the use of aerial photography, with little apparent ground-truthing. It is unclear whether the extent of wetland area identified in Hill *et al.* (1996) has declined or was incorrectly designated as wetland. Furthermore, some damplands may have dried as a response of climate change over the drying period of the last few years. Global warming predictions over a longer-term are that drying is likely to continue, however exact nature of long-term precipitation in the KSS area is still speculative. Nevertheless, we would recommend that all the wetlands be reassessed to determine whether these palusplain and damplands remain once a wetter year eventuates or are in fact undergoing terrestrialisation. If so, then habitat assessments should be made on terrestrial rather than aquatic values.

7 Recommendations

- A regular annual monitoring program for macroinvertebrates be established, that includes all the wetlands sampled in this study and Site 7. The number of times per year to sample, sampling times should be based on a more intensive sampling frequency over one year.
    - Initially we recommend species level taxonomy (where possible), although in future regular monitoring a simpler family level taxonomy will probably be sufficient.
    - KSS has committed to fund a two-year research Masters by Research project commencing in 2009 to examine seasonal and interannual variability in macroinvertebrate communities in the KSS in the study wetlands. At the end of this project a suitable macroinvertebrate monitoring program will be developed for 2010 onwards. Mr. Niall Somesan, who was partly responsible for sorting and identifying the macroinvertebrates from this study will be contracted to undertake this Masters project.
    - Macroinvertebrate samples were collected in 2008 (except from Site 7). This will ensure a thorough annual macroinvertebrate data collection from 2007 through to 2009.
- To further enhance the values of the CCW (Site 4) surrounding EPP4 we recommend that the section of drain (from the Residue Dam) that crosses this wetland be filled and vegetation rehabilitated. Being a perched wetland it is important that the Wetland EPP 4 catchment area (Site 4) is actively managed to avoid adverse impacts on inflow water quantity and quality.
- Establishment of a representative riparian margin around rehabilitated dredge ponds appears to be important, not just from a value in its own right, but also to help achieve water quality that will better mirror that of surrounding natural wetlands. EPP1 appears to be a potential useful reference wetland for rehabilitated dredge ponds.

- Satellite wetlands around the dredge ponds should be explored and trialled further given the success of CCX. Furthermore it is recommended that the two satellite wetlands be monitored separately in future as there is evidence of different water quality in the north east wetland from the main dredge pond.
- There is a need to integrate the wetlands (and complexes) identified in Bennett Environmental Consulting (2004), this study, and those on the DEC database (as per Hill *et al.*, 1996) into a common set.
- The rehabilitation of CCX is on target, however monitoring is required to ensure potential acidification as indicated through low $Cl:SO_4$ ratios does not occur. Removal of known ASS from the site is recommended.
- Establishment of even a simple sedgeland margin around rehabilitated areas e.g., *Schoenoplectus validus* appears to significantly improve macroinvertebrate structure to that of a more natural community.
- We recommend that the proposed mine extension area be modified by following the dunal ridges southwards towards Site 6 to better protect the Site 7 sumpland,.

8 Acknowledgements

Thanks to Research Assistants Niall Somesan and Lisa Edward of the MiWER laboratories for assistance with macroinvertebrate sorting and identification, and Senior Laboratory Technician Mark Bannister at Edith Cowan University for assistance with chemical analyses.

9 References

ANZECC/ARMCANZ (2000). *Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4*. Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Austen, M. C. & Somerfield, P. J. (1997). A community level sediment bioassay applied to an estuarine heavy metal gradient. *Marine Environmental Research* 43: 315-328.

Baldwin, D. S.; Hall, K. S.; Rees, G. N. & Richardson, A. J. (2007). Development of a protocol for recognizing sulfidic sediments (potential acid sulfate soils) in freshwater wetlands. *Ecological Management and Restoration* 8: 56-60.

Bennett Environmental Consulting (2004). Kemerton: Significant flora and wetlands. Report for Martinick Bosch Sell Pty Ltd, West Perth.

Clarke, K. R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117–143.

Clarke, K. R. (1999). Non-metric multivariate analysis of changes in community-level ecotoxicology. *Environmental Toxicology and Chemistry* 18: 118-127.

Clarke, K. R. & Ainsworth, M. (1993). A method for linking multivariate community structure to environmental variables. *Marine Ecology Progress Series* 92: 205-219.

Clarke, K. R. & Gorley, R. N. (2001). *PRIMER v5. User Manual*. PRIMER-E, Plymouth. 91pp.

Clarke, K. R. & Warwick, R. M. (2001). *Change in marine communities: an approach to statistical analysis and interpretation.* 2nd edn, Plymouth Marine Laboratory, Plymouth. 144pp.

Department of Local Government and Planning, D. o. N. R. a. M. (2002). *State Planning Policy 2/02 Guideline: Planning and Managing Development involving Acid Sulfate Soils*. Indooroopilly Brisbane, QLD, Australia.

English, V. & Blyth , J. (2000). *Shrublands and woodlands on Muchea Limestone - interim recovery plan 2000-2003*. Department of Conservation and Land Management, WA Threatened Species and Community Unit, Perth, Australia.

Environmental Protection Authority (2005). *Kemerton Silica Sand mining revised proposal - additional mining areas and transfer of land for conservation.* Report and recommendations of the Environmental Protection Authority Bulletin 1183. Environmental Protection Authority, Perth, Australia.

Faith, D. P.; Minchin, P. R. & Belbin, L. (1987). Compositional dissimilarity as a robust measure of ecological distance. *Vegetation* 69: 57–68.

GHD (2005). *Kemerton Silica Sand Annual Environmental Review 2004/2005*. 61/10572/9022. GHD, Perth, Australia.

Havens, K. E.; Bull, L. A.; Warren, G. L.; Crisman, T. L.; Phlips, E. J. & Smith, J. P. (1996). Food web structure in a subtropical lake ecosystem. *Oikos* 75: 20-32.

Hill, A. L.; Semeniuk, C. A.; Semeniuk, V. & Del Marco, A. (1996). *Wetland mapping, classification and evaluation*. Wetlands of the Swan Coastal Plain Volume 2 Perth, Australia.

Lund, M. A. (1999). Modification of a Bogarov Tray to allow *in situ* subsampling of preserved macroinvertebrate and zooplankton samples. *Journal of Freshwater Ecology* 14: 417-421.

Lund, M. A. & Ryder, D. S. (1998). Can artificially generated gilvin (g440 m^{-1}, Glebstoffe) be used as a tool for lake restoration? *Verhandlungen der Internationale Vereinigung fur Theoretische und Angewandte Limnologie* 26:

McCullough, C. D.; Lund, M. A. & van Etten, E. (2007). *Synthesis of existing data and knowledge gaps for the rehabilitation of Kemerton Silica Sand mine dredge ponds*. Report number 2007-04. Centre for Ecosystem Management, Edith Cowan University, Perth, Australia. 53pp. Unpublished report to Kemerton Silica Sand Pty Ltd.

McGuiness, K. A. (2002). Of rowing boats, ocean liners and tests of the assumptions of the ANOVA homogeneity of variance. *Austral Ecology* 27: 681-688.

Norris, R. H. & Norris, K. R. (1995). The need for biological assessment of water quality: Australian perspective. *Australian Journal of Ecology* 20: 1-6.

Norris, R. H.; T., H. B.; Finlayson, M. & Norris, K. R. (1995). Use of biota to assess water quality. *Australian Journal of Ecology* 20: 12-27.

Olsgard, F.; Somerfield, P. J. & Carr, M. R. (1997). Relationships between taxonomic resolution and data transformations in analyses of a macrobenthic community along an established pollution gradient. *Marine Ecology Progress Series* 149: 173-181.

Schofield, N. J. & Davies, P. E. (1996). Measuring the health of our rivers. *Water* May-June 1996: 39-43.

Semeniuk, C. A. (1987). Wetlands of the Darling system - a geomorphic approach to habitat classification. *Journal of the Royal Society of Western Australia* 69: 95-112.

SPSS Inc. (2004). SPSS. 13.0, SPSS Inc., Chicago.

Stark, J. S. (1998). Heavy metal pollution and macrobenthic assemblages in soft sediments in two Sydney estuaries, Australia. *Marine and Freshwater Research* 49: 533-540.

Tripodi, E. (1997). *Temporal and spatial variations in the macroinvertebrate communities of the seasonally flowing portions of Magela Creek, Northern Territory*. Internal report Supervising Scientist, Canberra.

van Etten, E.; McCullough, C. D. & Lund, M. A. (in prep). *Evaluation of rehabilitation efforts at the Kemerton Silica Sands Pty. Ltd. project area, June 2007*. Report number 2008-10. Centre for Ecosystem Management, Edith Cowan University, Perth, Australia. 88pp.

Wrona, F. J.; Culp, J. M. & Davies, R. W. (1982). Macroinvertebrate subsampling: a simplified apparatus and approach. *Canadian Journal of Fisheries and Aquatic Sciences* 39: 1051-1054.

10 Appendices

Appendix 1. Nutrients and metals from Kemerton Project area and Nature Reserve.

Site	NPOC	Gilvin	Cl	SO_4	Al	Ca	Fe	K	Mg	Na	Pb	S	Zn	NH_3	NOx	Total N	FRP	Total P
	mgL^{-1}	g440	mgL^{-1}	mgL^{-1}	mgL^{-1}	mgL^{-1}	mgL^{-1}	mgL^{-1}	mgL^{-1}	mgL^{-1}	mgL^{-1}	mgL^{-1}	mgL^{-1}	μgL^{-1}	μgL^{-1}	μgL^{-1}	μgL^{-1}	μgL^{-1}
CC5P	32	24	216	65	<0.1	33	<0.05	4	38	145	<0.1	26	<0.05	66	14	792	6	<20
CC5	56	56	277	74	0.6	31	0.7	5	40	174	0.1	29	0.33	98	21	1300	<2	<20
CCX	41	34	145	103	0.5	21	0.1	5	32	106	<0.1	44	<0.05	78	99	1060	2	20
EPP1	28	15	252	125	<0.1	84	<0.05	4	69	215	<0.1	59	<0.05	13	90	692	6	<20
EPP3	48	45	55	10	0.7	4	0.0	3	10	43	<0.1	3	0.25	96	19	936	2	58
EPP4	16	15	89	23	0.1	7	<0.05	4	11	60	<0.1	8	0.21	27	14	399	2	35
EPP5	66	68	131	13	0.8	7	0.5	4	15	89	<0.1	4	0.30	137	24	1358	2	20
EPP6	75	81	136	49	0.5	17	0.3	2	23	90	<0.1	21	0.33	200	339	1397	36	<20**
EPP7	111	130	486	75	1.3	21	1.9	13	53	317	<0.1	36	0.32	272	67	4643	2	30
EPP8	101	90	190	30	0.9	10	<0.05	7	23	126	0.2	14	0.26	222	24	2659	2	20
EPP9	108	79	302	79	0.7	19	<0.05	6	51	211	0.1	34	0.30	22	104	1780	5	<20
NL	22	11	138	296	0.1	67	0.1	6	58	136	<0.1	126	0.15	22	98	573	2	20
NO	15	3	36	10	<0.1	2	<0.05	1	8	22	<0.1	3	<0.05	38	<2	559	2	41
PD	49	75	115	23	0.5	8	<0.05	4	25	110	<0.1	14	<0.05	132	17	2632	297	416
PN	135	157	277	31	1.8	11	0.6	6	37	176	<0.1	17	0.31	356	28	4375	2	44
PS	88	124	63	16	1.0	4	0.1	2	10	63	<0.1	6	0.25	300	29	2608	2	64

*Ni, Cu, As (except PD= 0.08) and B (except EPP7=0.09) were <0.05 mg L^{-1}
Mn, Co and Cr were <0.01 mg L^{-1}
Hg was <0.1 mg L^{-1}
Se was <0.2 mg L^{-1}
**Total P must be >FRP, therefore this result indicates that the majority of Total P was as FRP and the discrepancy is due to the lower resolution of Total P.

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands.

Wetland	Habitat	Nature	*Acritoptila*	*Agraptocorixa*	*Amphiops*	Amphipoda	Ancylidae	*Allodessus*	*Anisops*	*Anopheles*	*Anophelini*
CC5	Open	Natural	1	0	0	0	0	0	1	0	0
CC5P	Mixed	Natural	1	0	0	0	0	0	1	0	0
CCX	Open	Natural	0	0	0	0	0	0	1	0	0
EPP1	Mixed	Natural	0	1	0	0	1	0	1	1	0
EPP3	Mixed	Natural	0	0	0	0	0	0	1	1	0
EPP4	Mixed	Natural	0	0	0	0	1	0	1	0	0
EPP5	Mixed	Natural	1	0	0	1	1	0	1	0	1
EPP6	Mixed	Natural	0	0	0	1	1	0	0	0	0
EPP7	Mixed	Natural	0	1	1	1	0	1	1	1	0
EPP8	Mixed	Natural	0	0	0	0	1	0	0	1	0
EPP9	Mixed	Natural	0	0	0	0	0	0	0	0	0
N	Mixed	Natural	0	0	0	0	0	0	0	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	1	0	0
NS	Littoral	Artificial	0	0	0	0	0	0	0	0	0
PD	Mixed	Natural	0	0	0	0	0	0	0	1	0
PN	Mixed	Natural	0	0	0	0	0	0	0	0	0
PS	Open	Natural	0	0	0	0	0	0	0	1	0

Appendix 2Error! Reference source not found.. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	*Antiporus*	*Antiporus*	*Austrolestes*	*Austrogammarus*	Baetidae	*Bagous*	*Batracomatus*	*Berosus*	Calanoida
CC5	Open	Natural	0	0	1	0	0	0	0	0	1
CC5P	Mixed	Natural	0	0	1	0	0	0	0	1	1
CCX	Open	Natural	0	0	1	0	0	0	0	0	1
EPP1	Mixed	Natural	0	1	1	0	0	0	0	0	1
EPP3	Mixed	Natural	0	0	1	0	0	0	0	0	1
EPP4	Mixed	Natural	0	1	1	0	0	0	0	1	1
EPP5	Mixed	Natural	0	0	1	1	0	0	1	1	1
EPP6	Mixed	Natural	0	0	1	0	0	1	0	0	1
EPP7	Mixed	Natural	0	1	1	0	0	0	0	1	1
EPP8	Mixed	Natural	0	0	0	0	0	0	0	0	1
EPP9	Mixed	Natural	1	1	1	0	0	0	0	0	1
N	Mixed	Natural	0	0	0	0	1	0	0	0	1
NO	Littoral	Artificial	0	0	0	0	0	0	0	0	1
NS	Littoral	Artificial	0	0	0	0	0	0	0	0	1
PD	Mixed	Natural	0	0	0	0	0	0	0	0	1
PN	Mixed	Natural	0	0	0	0	0	0	0	0	1
PS	Open	Natural	0	0	0	0	0	0	0	0	1

Appendix 2Error! Reference source not found.. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Ceinidae	Ceratopogonidae	*Chaetarthria*	Chaoborinae	*Cherax*	Chironomidae	Chironominae	*Chostonectes*
CC5	Open	Natural	1	0	0	0	0	0	1	0
CC5P	Mixed	Natural	0	1	1	0	0	1	1	0
CCX	Open	Natural	0	0	0	0	0	1	1	0
EPP1	Mixed	Natural	1	0	0	0	0	1	1	0
EPP3	Mixed	Natural	0	0	0	0	0	1	1	0
EPP4	Mixed	Natural	1	0	0	0	0	1	1	0
EPP5	Mixed	Natural	1	1	0	0	1	1	1	1
EPP6	Mixed	Natural	1	0	0	0	1	1	1	0
EPP7	Mixed	Natural	0	1	0	0	0	1	1	1
EPP8	Mixed	Natural	0	1	0	0	1	1	1	0
EPP9	Mixed	Natural	1	0	0	0	0	1	0	0
N	Mixed	Natural	0	1	0	0	0	1	1	0
NO	Littoral	Artificial	0	0	0	0	0	0	1	0
NS	Littoral	Artificial	0	1	0	0	0	1	1	0
PD	Mixed	Natural	0	1	0	0	1	1	1	0
PN	Mixed	Natural	0	0	0	0	0	1	1	0
PS	Open	Natural	0	0	0	1	0	0	1	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Ceinidae	Ceratopogonidae	*Chaetarthria*	Chaoborinae	*Cherax*	Chironomidae	*Chostonectes*	Chydoridae
CC5	Open	Natural	1	0	0	0	0	1	0	1
CC5P	Mixed	Natural	0	1	1	0	0	2	0	0
CCX	Open	Natural	0	0	0	0	0	3	0	0
EPP1	Mixed	Natural	1	0	0	0	0	3	0	1
EPP3	Mixed	Natural	0	0	0	0	0	3	0	0
EPP4	Mixed	Natural	1	0	0	0	0	3	0	0
EPP5	Mixed	Natural	1	1	0	0	1	3	1	0
EPP6	Mixed	Natural	1	0	0	0	1	3	0	0
EPP7	Mixed	Natural	0	1	0	0	0	3	1	0
EPP8	Mixed	Natural	0	1	0	0	1	2	0	0
EPP9	Mixed	Natural	1	0	0	0	0	1	0	0
N	Mixed	Natural	0	1	0	0	0	3	0	0
NO	Littoral	Artificial	0	0	0	0	0	1	0	0
NS	Littoral	Artificial	0	1	0	0	0	2	0	0
PD	Mixed	Natural	0	1	0	0	1	2	0	0
PN	Mixed	Natural	0	0	0	0	0	3	0	0
PS	Open	Natural	0	0	0	1	0	1	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Cladocera	Collembola	Conchostraca	*Coquillettidia*	Corixidae	Corixidae	*Corynoneura*	Culicidae
CC5	Open	Natural	0	1	0	0	0	0	1	0
CC5P	Mixed	Natural	1	1	0	1	0	0	0	1
CCX	Open	Natural	0	0	0	1	0	0	0	0
EPP1	Mixed	Natural	1	1	1	1	0	0	0	0
EPP3	Mixed	Natural	0	1	0	1	0	0	1	1
EPP4	Mixed	Natural	1	1	1	1	1	0	0	1
EPP5	Mixed	Natural	1	1	0	1	1	0	1	0
EPP6	Mixed	Natural	1	1	0	0	0	0	1	1
EPP7	Mixed	Natural	1	1	0	0	1	1	1	0
EPP8	Mixed	Natural	1	1	0	1	0	0	0	0
EPP9	Mixed	Natural	1	1	0	1	0	0	0	1
N	Mixed	Natural	0	0	0	0	1	1	1	0
NO	Littoral	Artificial	0	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	0	0	0	0
PD	Mixed	Natural	0	1	0	1	0	0	0	0
PN	Mixed	Natural	1	1	0	0	0	0	0	0
PS	Open	Natural	1	0	1	1	0	0	0	0

Appendix 2Error! Reference source not found.. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Culicidae	Culicini	Curculionidae	Curculionidae	Cyclopoida	Daphniidae	Dasyheleinae	*Daternomina*
CC5	Open	Natural	0	0	0	0	0	1	0	0
CC5P	Mixed	Natural	0	0	0	0	0	1	0	0
CCX	Open	Natural	0	0	0	0	0	0	0	0
EPP1	Mixed	Natural	0	1	0	0	0	1	0	1
EPP3	Mixed	Natural	0	1	0	0	0	1	0	0
EPP4	Mixed	Natural	0	1	0	0	0	1	0	0
EPP5	Mixed	Natural	0	0	0	0	0	1	0	0
EPP6	Mixed	Natural	0	0	1	0	0	0	0	0
EPP7	Mixed	Natural	0	0	1	0	0	1	0	0
EPP8	Mixed	Natural	0	1	0	1	0	1	0	0
EPP9	Mixed	Natural	0	1	0	0	0	1	0	0
N	Mixed	Natural	0	0	0	0	1	1	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	1	1	1	0
PD	Mixed	Natural	0	0	0	0	1	1	0	0
PN	Mixed	Natural	1	0	0	0	0	1	0	0
PS	Open	Natural	1	1	0	0	0	1	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Diptera	Dytiscidae	*Ecnomus*	Elmidae	Elmidae	Empiolidae	Ephydridae	*Eulimnadia*	*Ferrissia*
CC5	Open	Natural	0	0	0	1	0	0	0	0	1
CC5P	Mixed	Natural	0	0	0	0	0	0	0	0	0
CCX	Open	Natural	0	0	0	0	0	0	0	0	0
EPP1	Mixed	Natural	0	0	0	1	0	0	0	0	1
EPP3	Mixed	Natural	0	0	1	1	1	0	0	0	0
EPP4	Mixed	Natural	1	1	0	0	0	1	0	1	0
EPP5	Mixed	Natural	0	0	0	0	0	0	0	0	0
EPP6	Mixed	Natural	0	0	0	0	0	0	0	0	0
EPP7	Mixed	Natural	1	0	1	0	0	0	1	0	0
EPP8	Mixed	Natural	0	0	0	0	0	0	0	0	0
EPP9	Mixed	Natural	0	0	0	0	1	0	0	0	0
N	Mixed	Natural	0	0	0	0	0	0	0	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0	0	0
NS	Littoral	Artificial	1	0	0	0	0	0	0	0	0
PD	Mixed	Natural	1	0	0	0	0	0	0	0	0
PN	Mixed	Natural	0	0	0	0	0	0	0	0	0
PS	Open	Natural	1	0	0	0	0	0	0	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	*Georissus*	*Glyptophysa*	Haliplidae	*Haliplus*	Haplotaxidae	Hebridae	*Helisoma*	*Hemicordulia tau*
CC5	Open	Natural	1	0	0	0	0	0	1	0
CC5P	Mixed	Natural	0	1	0	0	0	1	1	0
CCX	Open	Natural	0	0	0	0	0	0	0	0
EPP1	Mixed	Natural	0	1	0	1	0	0	0	1
EPP3	Mixed	Natural	0	0	0	0	0	0	0	0
EPP4	Mixed	Natural	0	0	1	0	0	0	0	0
EPP5	Mixed	Natural	0	0	1	0	0	0	0	0
EPP6	Mixed	Natural	0	1	1	0	1	0	0	0
EPP7	Mixed	Natural	0	0	0	0	0	1	0	0
EPP8	Mixed	Natural	0	0	0	0	0	0	0	0
EPP9	Mixed	Natural	0	0	0	0	0	0	0	0
N	Mixed	Natural	0	0	0	0	0	0	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	0	0	0	0
PD	Mixed	Natural	0	0	0	0	0	0	0	0
PN	Mixed	Natural	0	0	0	0	0	0	0	0
PS	Open	Natural	0	0	0	0	0	0	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	*Homeodytes*	*Hydaticus*	Hydracarina	Hydrachnoidea	Hydrochidae	Hydromidae	Hydrophilidae	Hydrophilidae
CC5	Open	Natural	0	0	0	0	0	0	0	0
CC5P	Mixed	Natural	0	0	1	0	0	0	0	1
CCX	Open	Natural	0	0	0	0	0	0	0	1
EPP1	Mixed	Natural	0	0	1	0	0	0	0	0
EPP3	Mixed	Natural	0	0	0	0	0	0	0	0
EPP4	Mixed	Natural	0	1	1	1	0	0	0	0
EPP5	Mixed	Natural	0	0	0	0	0	0	0	1
EPP6	Mixed	Natural	1	0	1	0	0	0	0	0
EPP7	Mixed	Natural	0	0	1	0	0	0	0	1
EPP8	Mixed	Natural	0	0	0	0	0	0	0	0
EPP9	Mixed	Natural	0	0	0	0	0	0	1	0
N	Mixed	Natural	0	0	1	0	1	0	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	0	0	0	0
PD	Mixed	Natural	0	0	0	0	0	1	1	0
PN	Mixed	Natural	0	0	1	0	0	0	0	0
PS	Open	Natural	0	0	0	0	0	0	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Hydrophiloidea	Hydroptilidae	Hydyphantidae	Hypogastruridae	Ilyocryptidae	Isidorella	Isopoda	Isotomidae
CC5	Open	Natural	0	0	0	0	0	0	1	0
CC5P	Mixed	Natural	0	1	0	0	0	1	0	1
CCX	Open	Natural	0	0	0	0	0	0	0	0
EPP1	Mixed	Natural	0	0	0	1	0	0	0	1
EPP3	Mixed	Natural	0	0	0	0	0	0	0	1
EPP4	Mixed	Natural	1	0	0	0	0	0	0	0
EPP5	Mixed	Natural	0	1	0	0	0	0	1	0
EPP6	Mixed	Natural	0	0	0	0	0	0	1	1
EPP7	Mixed	Natural	0	0	0	0	0	0	0	0
EPP8	Mixed	Natural	0	0	0	0	0	0	1	1
EPP9	Mixed	Natural	0	0	0	0	1	0	0	1
N	Mixed	Natural	0	0	0	0	0	0	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	0	0	0	0
PD	Mixed	Natural	0	0	1	0	0	0	0	1
PN	Mixed	Natural	0	0	0	0	0	0	0	0
PS	Open	Natural	0	0	0	0	0	0	0	0

Appendix 2Error! Reference source not found.. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	*Lancetes*	*Lectrides*	Lestidae	Lepidoptera	Leptoceridae	Libellulidae	*Limbodessus*	*Limnoxenus*
CC5	Open	Natural	0	0	1	0	0	0	0	0
CC5P	Mixed	Natural	0	0	0	0	1	0	0	1
CCX	Open	Natural	0	0	0	0	1	0	0	0
EPP1	Mixed	Natural	0	1	0	1	0	1	0	0
EPP3	Mixed	Natural	0	0	0	0	0	0	0	0
EPP4	Mixed	Natural	0	0	1	0	0	0	0	0
EPP5	Mixed	Natural	0	0	0	1	0	0	1	0
EPP6	Mixed	Natural	0	1	1	0	0	0	0	0
EPP7	Mixed	Natural	1	0	0	0	0	0	0	1
EPP8	Mixed	Natural	0	0	0	0	0	0	0	0
EPP9	Mixed	Natural	0	0	0	0	0	1	0	0
N	Mixed	Natural	0	0	0	0	0	0	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	0	0	0	0
PD	Mixed	Natural	0	0	0	0	0	0	0	0
PN	Mixed	Natural	0	0	0	1	0	0	0	0
PS	Open	Natural	0	0	0	0	0	0	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	*Liodessus*	Lymnaeidae	*Macrothrix*	*Megaporus*	*Megaporus*	*Micronecta robusta*
CC5	Open	Natural	0	0	0	0	0	0
CC5P	Mixed	Natural	0	0	0	0	0	0
CCX	Open	Natural	0	0	0	0	0	1
EPP1	Mixed	Natural	1	0	0	0	1	1
EPP3	Mixed	Natural	0	0	0	0	0	0
EPP4	Mixed	Natural	0	0	0	0	1	0
EPP5	Mixed	Natural	0	1	0	0	1	1
EPP6	Mixed	Natural	0	0	0	1	0	0
EPP7	Mixed	Natural	0	0	0	0	1	1
EPP8	Mixed	Natural	0	0	0	0	1	0
EPP9	Mixed	Natural	0	0	1	0	0	0
N	Mixed	Natural	0	0	0	0	0	1
NO	Littoral	Artificial	0	0	0	0	0	1
NS	Littoral	Artificial	0	0	0	0	0	0
PD	Mixed	Natural	0	0	0	0	0	0
PN	Mixed	Natural	0	0	0	0	1	0
PS	Open	Natural	0	0	0	0	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	*Microvelia*	Mites	*Nannophya australis*	*Necterosoma*	*Necterosoma*	*Neoplea halei*	*Notalina*
CC5	Open	Natural	0	0	0	0	0	0	0
CC5P	Mixed	Natural	0	0	0	0	0	0	0
CCX	Open	Natural	0	0	0	0	1	0	0
EPP1	Mixed	Natural	1	0	0	0	1	0	0
EPP3	Mixed	Natural	0	0	0	0	0	0	0
EPP4	Mixed	Natural	0	1	0	0	0	0	0
EPP5	Mixed	Natural	0	1	0	1	1	0	0
EPP6	Mixed	Natural	1	1	0	0	0	0	1
EPP7	Mixed	Natural	0	0	0	1	0	1	0
EPP8	Mixed	Natural	0	1	0	0	0	0	0
EPP9	Mixed	Natural	1	1	0	0	0	0	0
N	Mixed	Natural	0	0	0	0	1	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	1	0	1	0	0
PD	Mixed	Natural	0	0	0	1	0	0	0
PN	Mixed	Natural	0	1	0	0	0	0	0
PS	Open	Natural	0	0	0	0	0	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Notonectidae	Notonectidae	Odonata	Oligochaeta	Orthocladiinae	Ostracoda	*Palemonetes australis*	*Paracymus*
CC5	Open	Natural	0	0	0	0	0	1	0	0
CC5P	Mixed	Natural	0	0	0	1	0	1	0	1
CCX	Open	Natural	0	0	0	0	0	0	0	0
EPP1	Mixed	Natural	0	0	0	0	1	1	0	1
EPP3	Mixed	Natural	0	0	0	0	0	1	0	0
EPP4	Mixed	Natural	1	0	0	0	1	1	0	1
EPP5	Mixed	Natural	0	0	0	1	1	1	0	0
EPP6	Mixed	Natural	0	1	0	0	1	1	0	0
EPP7	Mixed	Natural	1	1	0	0	1	1	0	0
EPP8	Mixed	Natural	0	0	1	0	1	1	0	0
EPP9	Mixed	Natural	0	0	0	1	0	1	1	0
N	Mixed	Natural	0	0	0	1	1	1	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	0	1	0	0
PD	Mixed	Natural	0	0	0	0	1	1	0	0
PN	Mixed	Natural	0	0	0	0	1	1	0	0
PS	Open	Natural	0	0	0	0	0	1	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	*Paralimnophyes pullulus*	*Paramerina levidensis*	*Paranisops*	*Paramphisopus palustris*	*Paroster*	*Perthia*
CC5	Open	Natural	0	0	0	1	0	0
CC5P	Mixed	Natural	0	0	0	1	0	0
CCX	Open	Natural	0	0	1	0	0	0
EPP1	Mixed	Natural	0	0	1	1	0	1
EPP3	Mixed	Natural	0	0	0	0	0	0
EPP4	Mixed	Natural	0	0	0	0	0	0
EPP5	Mixed	Natural	0	0	0	1	1	1
EPP6	Mixed	Natural	0	0	0	0	0	0
EPP7	Mixed	Natural	1	1	0	0	0	0
EPP8	Mixed	Natural	0	0	0	0	0	1
EPP9	Mixed	Natural	0	0	0	1	0	0
N	Mixed	Natural	0	0	0	0	0	1
NO	Littoral	Artificial	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	0	0
PD	Mixed	Natural	0	0	0	0	0	1
PN	Mixed	Natural	0	0	0	0	0	0
PS	Open	Natural	0	0	0	0	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Perthiidae	*Peza ops*	Philorheithridae	*Phreatoicidea*	*Phreatoicidea*	Phreodrilidae	*Physastra*
CC5	Open	Natural	0	0	0	1	0	0	1
CC5P	Mixed	Natural	0	0	0	1	1	0	0
CCX	Open	Natural	0	0	1	0	0	0	0
EPP1	Mixed	Natural	0	0	0	1	0	1	1
EPP3	Mixed	Natural	0	0	0	0	0	0	0
EPP4	Mixed	Natural	0	0	0	0	0	0	0
EPP5	Mixed	Natural	1	1	0	0	0	0	0
EPP6	Mixed	Natural	1	0	0	0	0	0	0
EPP7	Mixed	Natural	0	0	0	0	0	0	0
EPP8	Mixed	Natural	0	0	0	0	0	0	0
EPP9	Mixed	Natural	0	0	0	0	0	0	0
N	Mixed	Natural	0	0	0	0	0	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	0	0	0
PD	Mixed	Natural	0	0	0	0	0	0	0
PN	Mixed	Natural	0	0	0	0	0	0	0
PS	Open	Natural	0	0	0	0	0	1	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Pionidae	Planorbidae	*Platynectes*	Podonominae	Porohalacaridae	*Pseudomoera*	*Rhantus*	Sciomyzidae
CC5	Open	Natural	0	0	0	0	0	0	0	0
CC5P	Mixed	Natural	1	0	0	0	1	0	0	0
CCX	Open	Natural	0	0	0	0	0	0	0	0
EPP1	Mixed	Natural	0	1	0	0	0	0	0	0
EPP3	Mixed	Natural	0	0	0	1	0	0	0	0
EPP4	Mixed	Natural	0	1	1	0	0	0	0	0
EPP5	Mixed	Natural	0	1	0	0	0	0	0	0
EPP6	Mixed	Natural	0	1	0	0	0	1	0	0
EPP7	Mixed	Natural	0	1	0	0	0	0	1	0
EPP8	Mixed	Natural	0	0	0	0	0	0	0	1
EPP9	Mixed	Natural	0	0	0	0	0	0	0	0
N	Mixed	Natural	0	0	0	0	0	0	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	0	0	0	0	0
PD	Mixed	Natural	0	0	0	0	0	0	0	1
PN	Mixed	Natural	0	1	0	0	0	0	0	0
PS	Open	Natural	0	0	0	0	0	0	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Scirtidae	*Sigara*	*Spencerhydrus*	*Sternolophus*	*Sternopriscus*	*Sternopriscus*	*Symphitoneuria*
CC5	Open	Natural	0	0	0	0	0	1	0
CC5P	Mixed	Natural	1	0	1	1	0	0	0
CCX	Open	Natural	0	0	0	1	1	1	0
EPP1	Mixed	Natural	1	1	1	0	0	1	1
EPP3	Mixed	Natural	0	0	0	0	0	0	0
EPP4	Mixed	Natural	0	0	0	0	0	1	0
EPP5	Mixed	Natural	1	0	1	0	0	1	0
EPP6	Mixed	Natural	1	1	1	0	0	0	1
EPP7	Mixed	Natural	0	1	0	0	0	1	0
EPP8	Mixed	Natural	1	0	0	1	0	0	1
EPP9	Mixed	Natural	1	0	0	1	0	0	1
N	Mixed	Natural	0	0	0	0	0	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	0	1	0	0	0
PD	Mixed	Natural	1	0	0	0	0	0	0
PN	Mixed	Natural	1	0	0	1	0	1	0
PS	Open	Natural	0	0	0	0	0	0	0

Appendix 2. Presence (1) and absence (0) of aquatic macroinvertebrate taxa in KSS project area wetlands (continued).

Wetland	Habitat	Nature	Synthemistidae	Tanypodinae	*Temnocephela comes*	Thaumaleidae	*Triplectides*	Veliidae	Zygoptera
CC5	Open	Natural	0	0	0	0	0	0	0
CC5P	Mixed	Natural	0	0	1	0	1	0	1
CCX	Open	Natural	0	0	1	0	0	0	0
EPP1	Mixed	Natural	1	0	0	1	1	1	0
EPP3	Mixed	Natural	0	1	0	0	1	0	0
EPP4	Mixed	Natural	0	1	0	1	1	0	0
EPP5	Mixed	Natural	1	1	0	0	1	1	1
EPP6	Mixed	Natural	0	0	0	0	1	1	0
EPP7	Mixed	Natural	0	0	0	0	1	0	1
EPP8	Mixed	Natural	0	1	0	0	1	0	0
EPP9	Mixed	Natural	0	1	0	0	1	0	0
N	Mixed	Natural	0	0	0	0	1	0	0
NO	Littoral	Artificial	0	0	0	0	0	0	0
NS	Littoral	Artificial	0	0	1	0	0	0	0
PD	Mixed	Natural	0	0	0	0	1	0	0
PN	Mixed	Natural	0	0	0	0	1	0	0
PS	Open	Natural	0	0	0	0	0	0	0

APPENDIX 12:
KEMERTON SILICA SAND COLLATION OF FAUNA REPORTS ON THE KSS PROPERTY
JUNE 2008
MBS ENVIRONMENTAL

Kemerton Silica Sand
Collation of Fauna Reports on the KSS Property

June 2008

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1. INTRODUCTION

Kemerton Silica Sand (KSS) has a silica sand mining operation located 35 kilometres north of the Port of Bunbury and approximately 150 kilometres south of Perth. The project is situated on a property, originally of approximately 1,600 hectares, of which 60 hectares is disturbed by the current operations. The current operation was approved by the Western Australian Environment Minister in 1994 and has been undertaken since 1995. Silica sand resources exist across the entire site; however the high environmental values over much of the site limit potential access to all of this resource. KSS have identified an area containing sufficient silica sand resources to allow mining for approximately 50 years. Access to this area will enable secure long term resource extraction to occur.

This report is a collation of fauna assessment work over approximately a ten year period by Bamford Consulting Ecologists on the KSS property and surrounding region. This report collates information principally from three separate reports by Bamford Consulting Ecologists.

1. Bamford, M.J. and Bamford, A.R. 2003. Assessment of Fauna values in the KSS Property. Unpublished report by Bamford Consulting Ecologists, prepared for Kemerton Silica Sand Pty Ltd.
2. Bamford, M.J. and Bamford, A.R. 2004. The status of the Chuditch (*Dasyurus geoffroyi*) in areas proposed for expansion by Kemerton Silica Sands. Unpublished report by Bamford Consulting Ecologists, prepared for Kemerton Silica Sand Pty Ltd.
3. Bamford, M.J. and Bamford, A.R. 2004. The utilisation by Short-billed Black Cockatoos (*Calyptorhynchus latirostris*) of the proposed dredge mining extension area of Kemerton Silica Sands. Unpublished report by Bamford Consulting Ecologists, prepared for Kemerton Silica Sand Pty Ltd.

Bamford Consulting Ecologists were commissioned to assess the fauna values of the property. Included in this assessment were the following:

- Review of fauna of the Kemerton area and the fauna likely to utilize the KSS property, including the determination of local and regional conservation significance.
- A fauna habitat map of the KSS property, identifying in particular significant habitats for fauna.
- A discussion of the function of the KSS property for fauna, particularly with respect to its role as a movement corridor.
- The provision of recommendations for impact minimization and rehabilitation.
- The identification of species likely to benefit from the presence of permanent wetlands after mining.
- The significance of the KSS property as a breeding and foraging area for the Short-billed Black-Cockatoo.
- To assess the availability of appropriate habitat for Chuditch, and to conduct trapping to gauge the numbers of Chuditch currently using the site.

1.1 BACKGROUND

KSS is currently preparing a Public Environmental Review for the proposed extension of sand dredging operations, to access silica sand resources suitable to export for glass manufacture. Approval is now being sought to mine an additional 283 hectares (23.6%) of the KSS property. This will allow long-term operations and consequently long-term environmental management and rehabilitation plans.

A number of surveys have been conducted on the KSS property as part of environmental assessment and monitoring in the period 1993 to 2004 (Ninox Wildlife Consulting, 1993 and 1994; Bamford and Ninox Wildlife Consulting, 1993; Bamford and Bamford, 1998, 1999, 2000, 2002, 2003 and 2004), and studies carried out for the Department of Resource Development over the whole Kemerton region in 1998 to determine the conservation value of the Buffer Zone (Bamford and Bamford, 1999b).

The studies carried out for the project provide specific information regarding fauna on the KSS property. The other studies were conducted over broader areas than the KSS property and provide fauna information on a more regional level. A considerable body of information on the fauna and their habitat associations of both the KSS property and the Kemerton region is therefore available.

The KSS property is located largely on Bassendean Sands with low relief. Much of the KSS property is subject to seasonal waterlogging or inundation and supports dampland complexes of dense shrublands and heaths, with some localised depressions that form long-lasting, but still seasonal, wetlands. A number of wetlands occur on the property. Nine of these wetlands are gazetted under the *Western Australian Environmental Protection (Swan Coastal Plain Lakes) Policy (EPP) 1992*. Most of these occur in the eastern portion of the property and six of these wetlands are located on land that has been transferred from Kemerton Silica Sand Pty Ltd to the Western Australian Department of Environment and Conservation (DEC).

Such extensive dampland complexes and the network of seasonal wetlands are not well developed elsewhere in the Kemerton region. Much of the remainder of the Kemerton region lies within the Karrakatta and Yoongarillup landforms where the associated relief is stronger and wetlands tend to be more discrete. Conversely, the extensive eucalypt and banksia woodlands of the wider region, identified by Bamford and Bamford (1999b) as being a very significant feature for fauna, are less extensive on the KSS property, being confined to low ridges particularly in the south western portion of the KSS property.

The KSS property has been subject to considerable disturbance in the past. Ninox Wildlife Consulting (1994) noted that parts of the woodland in the western part of the property appeared to have been cleared, perhaps shortly before or after World War Two, but had subsequently regenerated. A pine plantation, harvested in about 1995, was planted almost to the peak water level of two of the most significant wetlands (EPP 8 and 9).

From the regional perspective, the main vegetation and landform features are:

- Extensive eucalypt woodlands primarily in the west and centre of the Kemerton region, but extending into the KSS property. Some of these woodlands are reminiscent of the tall eucalypt forests of the nearby Darling Escarpment, and it is these woodlands that support a number of the species commonly associated with the Darling 'Scarp' forests. On the KSS property, these woodlands are scattered throughout but tend to be concentrated in the western part of the site. There are also some woodlands of Peppermint *Agonis flexuosa*, including some isolated stands in the east of the KSS land around EPP 6.

- Banksia woodlands found in the north of the Kemerton region are poorly developed on the KSS property. These woodlands are similar to those of the Perth region.
- Wetlands, ranging from deep, permanent systems in the south-west of the Kemerton region, to seasonal wetlands and extensive damplands of the KSS property. The damplands on the KSS property are mainly in the extreme east and are especially important because they support several significant species, including a relictual population of the Black-striped Jollytail *Galaxiella nigrostriata*.

The conservation status of fauna species is assessed under Federal and State Acts such as the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* and the Western Australian *Wildlife Conservation Act 1950 (WC Act)*. The significance levels for fauna used in the *EPBC Act* are those recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994). The *WC Act* uses a set of Schedules but also classifies species using some of the IUCN categories. These categories and Schedules are described in Appendix 1.

The *EPBC Act* also has lists of migratory species that are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA) and the Bonn Convention (The Convention on the Conservation of Migratory Species of Wild Animals). In addition, Environment Australia has supported the publication of reports on the conservation status of reptiles (Cogger, *et al.* 1993) and birds (Garnett and Crowley, 2000), while the Threatened Species and Communities Section of Environment Australia has produced a list of Threatened Australian Fauna (Environment Australia, 1999), although this list is effectively a precursor to list produced under the *EPBC Act*. These publications also use the IUCN categories, although those used by Cogger *et al.* (1993) differ in some respects as this report pre-dates Mace and Stuart's review.

In Western Australia, DEC has produced a supplementary list of Priority Fauna, being species that are not considered Threatened under the *WC Act* but for which the Department feels there is cause for concern. Some Priority species, however, are also assigned to the IUCN Conservation Dependent category. Levels of Priority are described in Appendix 1.

Fauna species included under conservation acts and/or agreements are formally recognised as of conservation significance under state or federal legislation. Species listed only as Priority by DEC, or that are included in publications such as Garnett and Crowley (2000) and Cogger *et al.* (1993) but not in State or Federal Acts, are also of recognised conservation significance. In addition, species that are at the limit of their distribution, those that have a very restricted range and those that occur in breeding colonies, such as some waterbirds, can be considered of conservation significance, although this level of significance has no legislative or published recognition and is based on interpretation of distribution information. The WA Department of Environmental Protection (DEP) (2000) used this sort of interpretation to identify significant bird species in the Perth metropolitan area as part of Perth Bushplan. On the basis of the above comments, three levels of conservation significance are recognised in this report:

- *Conservation Significance (CS) 1*: Species listed under State or Federal Acts.
- *Conservation Significance (CS) 2*: Species not listed under State or Federal Acts, but listed in publications on threatened fauna or as Priority species by DEC.
- *Conservation Significance (CS) 3*: Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

The Short-billed Black-Cockatoo is listed as Endangered under the *EPBC Act* and as Schedule 1 (Rare and likely to Become Extinct) of the *WC Act*. The area of investigation for the proposed extension covers wetland areas, Banksia woodland and jarrah forest and has the potential to impact upon a population of the Endangered Short-billed Black-Cockatoo.

The Chuditch is listed as Vulnerable under the *EPBC Act* and as Schedule 1 (Rare and likely to Become Extinct) of the *WC Act*. The status of the species in the Kemerton area is uncertain, however, as the only records in the area are of one seen crossing Treasure Road, less than five kilometres west of the KSS property, in the late 1990s, and one road-kill near Australind, about 20 kilometres south-west of the study area in November 1997 (M. Bamford, personal records). Because of the uncertainty of the status of the Chuditch at the KSS property and therefore the likely impact of the proposal upon it, Bamford Consulting Ecologists were commissioned to assess the availability of appropriate habitat for Chuditch, and to conduct trapping to gauge the numbers of Chuditch currently using the site.

2. METHODOLOGY

2.1 FAUNA SURVEY

The aim of this review is to assess the KSS property in the light of information on fauna presented in various reports. As part of this assessment, the KSS property was visited in January 2002. This visit focussed on areas of special interest in the western part of the KSS property, such as damplands and the woodland in the southern sector.

The various fauna studies carried out in the Kemerton region have included opportunistic observations, systematic searching, trapping for reptiles and mammals, netting for bats and spotlighting. Hence, the fauna of the region is well documented. It is very unlikely that all species present at Kemerton have been recorded, and therefore lists of vertebrate fauna likely to occur in the region have been developed on the basis of published and unpublished records. The main source of information was a printout from the WA Museum for specimen records of frogs, reptiles and mammals from the region bounded by 32^{o} 00'S to 33^{o} 00'S, and 115^{o} 30'E to 116^{o}00' E. Information on birds likely to occur in the area was obtained from Blakers *et al.* (1984) and records from Birds Australia for the Bunbury region.

Lists of the fauna species present or expected to occur in the Kemerton region and specifically on the KSS site are presented in this report. Where species have not been recorded but are expected to occur in the area, the species preferred habitat, where such preferences are known to be very specific, have also been recorded. Species that may have occurred in the area but are locally extinct are listed separately.

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 (common names for amphibians and reptiles from Bush *et al*. 1995), Strahan (1983) for mammals and Christidis and Boles (1994) for birds. Where recent taxonomic revisions have occurred, earlier names are given in parenthesis. This is particularly the case with reptiles, for which several recent revisions have been carried out but some new names have not been widely published or accepted. Complete common (where available) and scientific names are used.

2.2 COCKATOO SURVEY

2.2.1 Desktop Review

The desktop review was conducted by making a thorough search of the available literature including library searching and keyword searches using Biological Abstracts. In order to access unpublished information, discussions were also conducted with Mr. Tony Kirkby who, in association with Mr Ron Johnstone at the Western Australian Museum, is conducting research on cockatoos in the south-west Western Australia.

2.2.2 Field survey

To determine the number of birds using the KSS property, and to compare these numbers to nearby areas, three transects were set up. One transect ran around the south, west and northern perimeter of the KSS property and the other two transects were located in natural habitat within 10 kilometres of the KSS property. The southern control transect was located in an area of jarrah forest about 10 kilometres south-south-west of the KSS property and the northern control transect was located in an area of pine plantations, Banksia woodland and damplands about five kilometres north of the KSS property. As Short-billed Black-Cockatoos occur at relatively low densities overall but are grouped into dense, noisy flocks that are highly conspicuous and easy to detect, transects were carried out from a vehicle.

The transect around the south, west and northern perimeter of the KSS property was 11.1 kilometres long, the southern control transect was 8.7 kilometres long and the northern control transect was 10.4 kilometres long. Each transect was surveyed on five occasions between 17 and 20 November 2003, and on eight occasions between 9 and 12 May. Surveys were conducted in a random order to remove any bias associated with time of day or weather. All birds detected were recorded, as well as whether they were perched or flying. In addition, a record was kept of all other sightings of Short-billed Black-Cockatoos within the KSS property and notes were taken on their behaviour and plant species used for food.

In order to assess the potential value of the KSS property as breeding habitat for Short-billed Black-Cockatoos, all potential habitat trees within the proposed extension were examined from the ground. Upon examination trees were classified as either (i) containing no hollow potentially usable by avifauna, (ii) containing hollows potentially usable by avifauna excluding cockatoos, or (iii) containing hollows potentially suitable for Short-billed Black-Cockatoos. Assessments of hollow suitability were made entirely on the entrance diameter of the hollows and did not take into account entrance aspect, hollow location (trunk or spout), etc., which are also likely to influence hollow occupation by Short-billed Black-Cockatoos. A list of hollow-bearing trees located within the KSS property is given in Appendix 2.

2.3 CHUDITCH SURVEY

In order to see if Chuditch were present on the KSS property, forty cage traps were deployed around the perimeter of the property to the south, west and north of the current operation, with intervals of 100 metres between traps. Traps were not deployed in areas where the habitat was considered to be unsuitable, such as in the wetlands. Each trap was covered with a Hessian bag and placed alongside or under logs or shrubs. Traps were baited with a mixture of peanut paste, rolled oats and sardines. The traps were open for five nights, 8 – 13 May 2004, for a total of 200 trap-nights (Table 1). The traps were checked every morning, and all traps were re-baited on the 11 May.

Habitat assessment of the KSS property had previously been carried out but further observations were made during the 8 - 13 May trapping period. Habitat features such as fallen, hollow trees are particularly significant for Chuditch and were noted.

Table 1: Trap locations

Trap number	Location	Trap number	Location
1	33°09.0009'S, 115°46.9443'E	21	33°08.1850'S, 115°45.9210'E
2	33°09.0015'S, 115°46.8977'E	22	33°08.1110'S, 115°45.9136'E
3	33°08.9909'S, 115°46.8388'E	23	33°08.0449'S, 115°45.9116'E
4	33°08.9893'S, 115°46.7677'E	24	33°07.9370'S, 115°45.9094'E
5	33°08.9938'S, 115°46.5228'E	25	33°07.9016'S, 115°45.9069'E
6	33°08.9911'S, 115°46.4574'E	26	33°07.8225'S, 115°45.9193'E
7	33°08.9890'S, 115°46.3713'E	27	33°07.7615'S, 115°45.9162'E
8	33°08.9991'S, 115°46.3115'E	28	33°07.5943'S, 115°45.9079'E
9	33°08.9993'S, 115°46.2573'E	29	33°07.5675'S, 115°45.9093'E
10	33°09.0113'S, 115°46.2158'E	30	33°07.3636'S, 115°45.8997'E
11	33°09.0742'S, 115°46.2239'E	31	33°07.2953'S, 115°45.8977'E
12	33°09.1475'S, 115°46.2183'E	32	33°07.2242'S, 115°45.8967'E
13	33°09.3833'S, 115°46.2226'E	33	33°07.1797'S, 115°45.9514'E
14	33°09.5172'S, 115°46.2267'E	34	33°07.1833'S, 115°46.0266'E
15	33°08.6342'S, 115°45.9208'E	35	33°07.0182'S, 115°46.2967'E
16	33°08.5708'S, 115°45.9247'E	36	33°06.9512'S, 115°46.2982'E
17	33°08.5024'S, 115°45.9227'E	37	33°06.8304'S, 115°46.3004'E
18	33°08.4175'S, 115°45.9225'E	38	33°08.6407'S, 115°47.0442'E
19	33°08.3580'S, 115°45.9122'E	39	33°09.1057'S, 115°46.9931'E
20	33°08.2610'S, 115°45.9149'E	40	33°09.2164'S, 115°47.0238'E

3. RESULTS

3.1 FAUNA SURVEY

3.1.1 Overview

The purpose of this section is to provide an overview of the fauna of the Kemerton region, of which the KSS property is a subset. Table 2 shows the numbers of species in the major taxonomic groups of vertebrate fauna for the Kemerton region (modified from Bamford and Bamford, 1999b).

Table 2: Number of Species per Taxonomic Group in the Kemerton Region

	Expected	Observed	CS1	CS2	CS3	Locally extinct
Freshwater fish	6	5		1	1	unknown
Amphibians	11	8				unknown
Reptiles	34	21	1	1	4	0
Birds	131	105	6	7	9	4
Mammals	25	19	2	3	3	5

Note: The number at each level of conservation significance (CS) is indicated.

The Kemerton region supports a rich fauna, principally because it includes a large area of remnant and regrowth native vegetation, whereas much of the surrounding coastal plain has been developed for agriculture. Of particular note is the high number of CS3 species, being species that are not of formally recognised conservation significance but that are regionally important. In the Kemerton region, these are mainly species that have declined elsewhere on the coastal plain. Species of conservation significance recorded or expected in the Kemerton area are listed on Table 3 to Table 5. This also indicates those species recorded or expected on the KSS property. With the exception of the Perth Lined Lerista and two waterbird species that breed in colonies on wetlands in the far west of the Kemerton region, all species of conservation significance have been recorded or are expected on the KSS property. Details of the fauna of the KSS property are discussed below.

Many of the species of conservation significance are present in the Kemerton region because it is one of the largest contiguous areas of native vegetation on the Swan Coastal Plain between Bunbury and Perth. Kemerton is a region of considerable conservation importance and any proposed development in the area, such as an extension to the KSS Mine, has to consider potential environmental impacts upon the conservation values of the KSS property within the Kemerton region.

Table 3: Fauna Species Recorded or Expected in the Kemerton Region that are of Conservation Significance Level 1

Species	*EPBC Act*	*WC Act*	KSS property
Australasian Bittern		Schedule 1 (Vulnerable)	+
Chuditch	Vulnerable	Schedule 1 (Vulnerable)	+
Common Greenshank	Migratory		*
Common Sandpiper	Migratory		*
Long-billed (Baudin's) Black-Cockatoo	Vulnerable	Schedule 1 (Vulnerable)	+
Peregrine Falcon		Schedule 4	+
Quenda or Southern Brown Bandicoot		Conservation Dependent	*
Short-billed (Carnaby's) Black-Cockatoo	Endangered	Schedule 1 (Endangered)	*
South-West Carpet Python		Schedule 4	+
Undescribed skink *Glaphyromorphus sp.*			+

Note: The status of each species on the KSS property is indicated as recorded (*) or expected (+).

Table 4: Fauna Species Recorded or Expected in the Kemerton Region that are of Conservation Significance Level 2

Species	Garnett & Crowley, Cogger *et al.*	DEC	KSS property
Barking Owl	Near Threatened	Priority 2	+
Black Bittern	Near Threatened	Priority 2	+
Black-striped Jollytail (Minnow)		Priority 3[1]	*
Brush Wallaby		Priority 4	*
Freckled Duck	Least Concern	Priority 4	+
Little Bittern	Least Concern	Priority 4	+
Masked Owl	Near Threatened	Priority 4	+
Perth Lined Lerista	Rare/Insufficiently Known		
Rakali or Water-Rat		Priority 4	*
Red-tailed Black-Cockatoo	Near Threatened		*
Square-tailed Kite	Least Concern		+
Western False Pipistrelle		Priority 4	+

Note: The status of each species on the KSS property is indicated as recorded (*) or expected (+).
[1] Black-striped Jollytail (Minnow) has since been reclassified as Priority 1.

Table 5: Fauna species recorded or expected in the Kemerton region that are of Conservation Significance level 3

Species	KSS Property
Western Pygmy Perch	*
Red-legged Skink	+
Western Ctenotus	+
Mourning Skink	+
undescribed skink *Glaphyromorphus* sp.	?
Spotted Pardalote	*
Golden Whistler	*
Western Yellow Robin	+
Grey Currawong	+
Western Rosella	+
Darter (breeding colony)	
Nankeen Night Heron (breeding colony)	
Little Pied Cormorant (breeding colony)	*
Australian Owlet-nightjar	+
Honey Possum	*
Western Pygmy Possum	*
Brush-tailed Possum	+

Note: The status of each species on the KSS property is indicated as recorded (*) or expected (+).

3.1.2 Freshwater Fish

Freshwater fish recorded in the Kemerton region include four native species and one introduced species, with a fifth native species expected but not yet recorded (Table 6). Note that some other native and introduced species are probably present in local rivers.

Table 6: Fish Species Present or Likely to be Present

Species		Kemerton region	KSS Property	Status
Galaxiidae (jollytails or native minnows)				
Black-striped Jollytail	*Galaxiella nigrostriata*	*	*	CS2
Western Minnow	*Galaxias occidentalis*	*	*	
Percichthyidae (Australian perches)				
Nightfish	*Bostockia porosa*	*	*	
Nannopercidae (pygmy-perches)				
Westralian Pygmy-perch	*Edelia vittata*	*	*	CS3[1]
Poeciliidae (live-bearers)				
Mosquitofish	*Gambusia holbrooki*	*	*	Intro.
Gobiidae (gobies)				
Swan River Goby	*Pseudogobius olorum*	+	+	

Note: * Species recorded.
+ Species expected to occur.
Intro = Species that have been introduced.
[1] Species listed as CS3 in Table 5 but not listed by the author here.

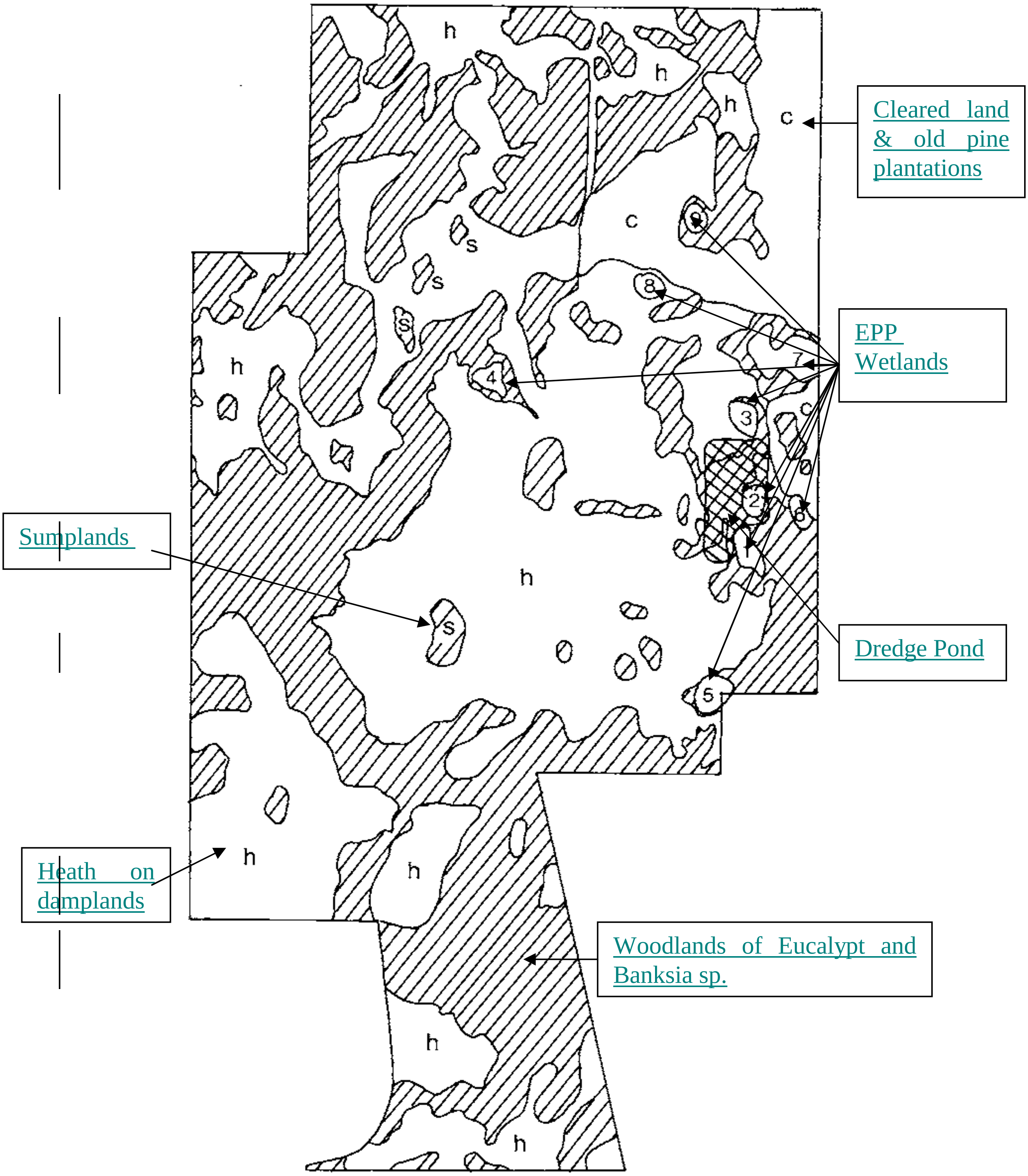
In the Kemerton region, all fish species have been recorded only from seasonal wetlands on the KSS property and the land recently vested in DEC. Most of the species are only able to temporarily colonise the wetlands in winter, but the Black-striped Jollytail is a resident. The Jollytail is able to survive periods when wetlands dry out, possibly by sheltering in the burrows of freshwater crayfish that intercept the watertable (Morgan *et al.* 1998). Bamford and Bamford (2000) have reported five summer refuge sites, all associated with seasonal wetlands in the eastern part of the KSS property. Two of these however, failed to support Jollytails in 2002 due to low water levels associated with below average rainfall.

The Jollytails disperse widely during the high water levels of winter and may spread into the western part of the KSS property at such times, but there are no known summer refuges for the species in this western area of the property. Despite this, within the western part of the property there are some patches of vegetation consistent with low-lying areas that may retain water for sufficiently long to serve as refuge areas, at least in successive years of average or above average rainfall. These are indicated as vegetation types F-1, F-2 and F-3 on the vegetation map provided by Mattiske Consulting. The four most likely sites have been indicated on Figure 1.

The Westralian Pygmy-perch, Western Minnow, Nightfish and introduced Mosquitofish require permanent water and only colonise some of the KSS wetlands during years of high water levels in winter and spring. This occurred in 1993 and again in 1999 (Bamford and Bamford, 2000). They are unlikely to disperse as far as the western part of the KSS property and could not survive there for more than one season. These species disperse from agricultural drains to the south-east, presumably the Mangosteen Drain. Bamford and Bamford (2000) have suggested that attempts should be made to exclude the Mosquitofish as it has the potential to colonise permanent wetlands created by mining. If that occurs, the presence of this voracious introduced species could compromise the conservation value of the seasonal wetlands for aquatic invertebrates, native fish and frogs, as it is a predator of such species (Blythe, 1994; Morgan *et al*. 1998).

The Black-striped Jollytail is listed as Priority 3 by DEC and the Kemerton population is a relict, with only one other population known on the Swan Coastal Plain, near Muchea north of Perth, and the main population occurring in wetlands along the south coast east of Margaret River. The species is of CS2 and the Kemerton population is of great conservation and scientific value. A proposal to modify one of the Kemerton wetlands so that it would support the Jollytail has been put forward to DEC and DEP. This wetland (EPP 7) was originally within the KSS property but has since been vested with DEC. It is currently unsuitable for the Jollytail because of lack of vegetation cover.

Figure 1: Fauna habitats of the KSS property at Kemerton, based upon vegetation maps provided by Mattiske Consulting.



3.1.3 Amphibians

Eight of 11 frog species expected in the Kemerton region have been recorded, and all are known from or expected on the KSS property (Table 7). Most are closely associated with wetlands and all have aquatic larvae, but the Moaning Frog, Marbled Frog and Pobblebonk range widely in woodland areas outside the breeding season. Several of the species rely on predictable changes in water levels in early winter as part of their breeding cycle therefore requiring natural or predictable fluctuations in water levels to survive.

None of the frog species is of conservation significance, but populations of the Marbled Frog are uncommon on the Swan Coastal Plain (Bush *et al*. 1995). The record of the Granite Froglet on the KSS Wetlands is unconfirmed. This species usually occurs in wetlands of the Darling Escarpment, where it is widespread and abundant, but an outlying population at Kemerton would be very unusual for the coastal plain and of CS3.

Table 7: Frog Species Present in the Kemerton Area

Species		Kemerton region	KSS Property	Status
Myobatrachidae (ground frogs)				
Quacking Froglet	*Crinia georgiana*	+	+	
Glauert's Froglet	*Crinia (Ranidella) glauerti*	*	*	
Sandplain Froglet	*Crinia (Ranidella) insignifera*	*	*	
Granite Froglet	*Crinia (Ranidella) pseudinsignifera*		?*	
Green-bellied Froglet	*Geocrinia leai*	*	*	
Moaning Frog	*Heleioporus eyrei*	*	*	
Marbled Frog	*Heleioporus psammophilus*	+	+	
Pobblebonk	*Limnodynastes dorsalis*	*	*	
Guenther's Toadlet	*Pseudophryne guentheri*	*	*	
Hylidae (tree frogs)				
Slender Tree Frog	*Litoria adelaidensis*	*	*	
Motorbike Frog	*Litoria moorei*	*	*	

Note: * Species recorded.
+ Species expected to occur.

3.1.4 Reptiles

Only 21 of the 34 species of reptiles expected in the Kemerton region have been recorded in the area (Table 8). Thirteen species have been recorded on the KSS property and, with the exception of the Perth Lined Lerista, all are expected. Most of the species which are expected but that have not been recorded are cryptic, such as burrowing snakes, and are therefore difficult to trap and record.

The majority of the reptile species are likely to be widespread on the KSS property, but will avoid areas that are inundated for long periods of time. Therefore, woodland will support the most species, although a few species are aquatic or closely associated with riparian vegetation around wetlands, including the Long-necked Tortoise, South-West Cool Skink, the skink *Glaphyromorphus australis*, Mourning Skink and Tiger Snake.

Table 8: Reptile Species Present in the Kemerton Area

Reptile Species		Kemerton Region	KSS Property	Status
Chelidae (side-neck tortoises)				
Long-necked Tortoise	*Chelodina oblonga*	*	*	
Gekkonidae (geckoes)				
Marbled Gecko	*Phyllodactylus marmoratus*	+	+	
Pygopodidae (legless lizards)				
Sandplain Worm Lizard	*Aprasia repens*	+	+	
Burton's Legless Lizard	*Lialis burtonis*	*	*	
Common Scaleyfoot	*Pygopus lepidopodus*	+	+	
Agamidae (dragon lizards)				
Western Bearded Dragon	*Pogona minor*	*	*	
Varanidae (monitors or goannas)				
Gould's Sand Goanna	*Varanus gouldii*	*	+	
Rosenberg's Goanna	*Varanus rosenbergi*	*	*	
Scincidae (skink lizards)				
South west Cool Skink	*Acritoscincus (Bassiana) trilineatum*	*	*	
Fence Skink	*Cryptoblepharus plagiocephalus*	*	*	
	Ctenotus impar	*	+	
Red-legged Skink	*Ctenotus labillardieri*	*	+	CS3
Western Ctenotus	*Ctenotus australis (lesueurii)*	*	+	CS3
King's Skink	*Egernia kingii*	+	*	
Mourning Skink	*Egernia luctuosa*	*	+	CS3
Salmon-bellied Skink	*Egernia napoleonis*	*	*	
	Glaphyromorphus australis	+	+	
	Glaphyromorphus sp.	?	?	CS3
	Hemiergis quadrilineata	*	*	
	Lerista distinguenda (?elegans)	*	*	
Perth Lined Lerista	*Lerista lineata*	?+		CS2
Dwarf Skink	*Menetia greyii*	*	*	
	Morethia lineoocellata	*	*	
Bobtail	*Tiliqua rugosa*	*	*	
Typhlopidae (blind snakes)				
	Ramphotyphlops australis	*	+	
Boidae (pythons)				
South west Carpet Python	*Morelia spilota imbricata*	+	+	CS1
Elapidae (front-fanged snakes)				
Crowned Snake	*Notechis coronatus*	+	+	
Bardick	*Notechis curtus*	+	+	
Tiger Snake	*Notechis scutatus*	*	*	
Dugite	*Pseudonaja affinis*	*	*	
Gould's Snake	*Parasuta (Rhinoplocephalus) gouldii*	+	+	
Black-backed Snake	*Parasuta (Rhinoplocephalus) nigriceps*	+	+	
Jan's Bandy-Bandy	*Simoselaps (Vermicella) bertholdi*	*	+	
Black-naped Snake	*Simoselaps (Vermicella) bimaculata*		+	

Note: * Species recorded.
+ Species expected to occur.

The only reptile species of CS1 that may be present, in both the Kemerton area in general and on the KSS property is the South-West Carpet Python (Other Specially Protected Fauna under the *WC Act*, Vulnerable according to Cogger *et al.* (1993)). It could be present in almost any habitat but requires dense vegetation and tree hollows for shelter. The one species of CS2 expected in the Kemerton area, the Perth Lined Lerista, is the only reptile species not also expected on the KSS property. The Perth Lined Lerista could be present in the deep sandy soils of banksia woodland in the north of Kemerton, and is included for the region on the basis of single records at Yalgorup to the north Youngson and Harold (1989) and Busselton to the south (Storr *et al.* 1999), and the presence of suitable habitat. Of the three species of CS3, the Red-legged and Mourning Skinks are uncommon on the Swan Coastal Plain while the Western Ctenotus is close to the southern limit of its range. The Red-legged Skink is one of the escarpment species with an outlying population at Kemerton and, like the Western Ctenotus, could be present in any eucalypt woodland in the Kemerton area, including those of the KSS property. In contrast, the Mourning Skink is closely associated with wetlands.

Glaphyromorphus sp. is an undescribed skink known only from a few specimens, several of which came from just north of Bunbury. It may be extinct and its taxonomic status is in question. Searches were carried out for this species in 1998 and it may, like its congener *G. australis*, be closely associated with dense vegetation around wetlands. It could therefore potentially be present on the KSS property, especially around the more vegetated wetland areas. Despite surveys for the species, however, it has not been recorded.

3.1.5 Birds

Of the 132 bird species expected in the Kemerton region, 105 have been recorded there (Table 9). On the KSS property, however, only 129 species are expected and only 72 have been recorded. The slightly lower number of expected species on the KSS property is due largely to the absence of natural, permanent wetlands, while the much lower numbers of recorded species reflects less time spent surveying birds and the absence or only small areas of some habitats. Habitats that are scarce or absent on the KSS property compared with the Kemerton region in general include permanent wetlands and woodlands of Jarrah, Tuart and Banksia. The dredge pond created by KSS has begun to attract waterbirds that would not normally occur on the property, but this wetland is still in an early stage of rehabilitation. It will become more attractive to a wide range of waterbirds as riparian vegetation becomes established.

Table 9: **Bird Species Present in the Kemerton Area**

Species		Kemerton Region	KSS Property	Status
Casuariidae (emus and cassowaries)				
Emu	*Dromaius novaehollandiae*	*	*	
Phasianidae (pheasants and quails)				
Brown Quail	*Coturnix ypsilophora*		+	
Stubble Quail	*Coturnix pectoralis*		+	
Anatidae (ducks, geese and swans)				
Black Swan	*Cygnus atratus*	*	*	
Freckled Duck	*Stictonetta naevosa*	+	+	CS2
Australian Shelduck	*Tadorna tadornoides*	*	*	
Pacific Black Duck	*Anas superciliosus*	*	*	
Grey Teal	*Anas gibberifrons*	*	*	
Chestnut Teal	*Anas castanea*	+	+	

Species		Kemerton Region	KSS Property	Status
Australasian Shoveler	*Anas rhynchotis*	+	+	
Pink-eared Duck	*Malacorhynchus membranaceus*	+	+	
Hardhead (White-eyed Duck)	*Aythya australis*	*	*	
Australian Wood Duck	*Chenonetta jubata*	*	*	
Musk Duck	*Biziura lobata*	*	+	
Blue-billed Duck	*Oxyura australis*	*	+	
Podicepididae (grebes)				
Great Crested Grebe	*Podiceps cristatus*	+	+	
Hoary-headed Grebe	*Poliocephalus poliocephalus*	*	*	
Australasian Grebe	*Tachybaptus novaehollandiae*	*	+	
Anhingidae (darters)				
Darter	*Anhinga melanogaster*	*	+	CS3
Phalacrocoracidae (cormorants)				
Great Cormorant	*Phalacrocorax carbo*	*		
Pied Cormorant	*Phalacrocorax varius*	*		
Little Black Cormorant	*Phalacrocorax sulcirostris*	*	+	CS3
Little Pied Cormorant	*Phalacrocorax melanoleucos*	*	*	CS3
Ardeidae (herons and egrets)				
White-faced Heron	*Egretta novaehollandiae*	*	*	
Little Egret	*Egretta garzetta*	+	+	
White-necked Heron	*Ardea pacifica*	*	*	
Great Egret	*Egretta alba*	*	+	
Cattle Egret	*Ardeola ibis*	+	+	
Nankeen Night Heron	*Nycticorax caledonicus*	*	+	CS3
Little Bittern	*Ixobrychus minutus*	+	+	CS2
Black Bittern	*Ixobrychus flavicollis*	+	+	CS2
Australasian Bittern	*Botaurus poiciloptilus*	+	+	CS1
Plataleidae (ibis and spoonbills)				
Glossy Ibis	*Plegadis falcinellus*	+	+	
Australian White Ibis	*Threskiornis molucca*	*	*	
Straw-necked Ibis	*Threskiornis spinicollis*	*	+	
Yellow-billed Spoonbill	*Platalea flavipes*	*	+	
Accipitridae (kites, hawks and eagles)				
Black-shouldered Kite	*Elanus notatus*	*	*	
Square-tailed Kite	*Lophoictinia isura*	+	+	CS3
Whistling Kite	*Haliastur sphenurus*	*	*	
Swamp Harrier	*Circus approximans*	*	*	
Brown Goshawk	*Accipiter fasciatus*	*	+	
Collared Sparrowhawk	*Accipiter cirrhocephalus*	*	*	
Wedge-tailed Eagle	*Aquila audax*	*	*	
Little Eagle	*Hieraaetus morphnoides*	*	+	
Falconidae (falcons)				
Peregrine Falcon	*Falco peregrinus*	+	+	CS1
Australian Hobby	*Falco longipennis*	*	*	
Brown Falcon	*Falco berigora*	*	+	
Nankeen Kestrel	*Falco cenchroides*	*	*	
Turnicidae (button-quails)				
Painted Button-quail	*Turnix varia*	*	*	

Species		Kemerton Region	KSS Property	Status
Rallidae (crakes and rails)				
Buff-banded Rail	*Rallus philippensis*	*	+	
Baillon's Crake	*Porzana pusilla*	*	+	
Spotless Crake	*Porzana tabuensis*	*	+	
Australian Crake	*Porzana fluminea*	+	+	
Black-tailed Native-hen	*Gallinula ventralis*	*	+	
Dusky Moorhen	*Gallinula tenebrosa*	*	+	
Purple Swamphen	*Porphyrio porphyrio*	*	*	
Eurasian Coot	*Fulica atra*	*	*	
Scolopacidae (sandpipers)				
Common Greenshank	*Tringa nebularia*	*	*	CS1
Common Sandpiper	*Tringa hypoleucos*	*	*	CS1
Recurvirostridae (stilts and avocets)				
Black-winged Stilt	*Himantopus himantopus*	+	+	
Charadriidae (lapwings and plovers)				
Red-capped Plover	*Charadrius ruficapillus*	*	+	
Black-fronted Dotterel	*Elseyornis melanops*	*	*	
Red-kneed Dotterel	*Erythrogonys cinctus*	*	+	
Columbidae (pigeons and doves)				
Laughing Turtle-Dove	*Streptopelia senegalensis*	+	+	Intro.
Common Bronzewing	*Phaps chalcoptera*	*	*	
Crested Pigeon	*Ocyphaps lophotes*	*	+	
Cacatuidae (cockatoos)				
Red-tailed Black Cockatoo	*Calyptorhynchus banksii naso*	*	*	CS2[1]
Short-billed Black-Cockatoo	*Calyptorhynchus latirostris*	*	*	CS1
Long-billed Black-Cockatoo	*Calyptorhynchus baudinii*	+	+	CS1
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*	*	+	CS3
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	*Ninox connivens*	+	+	CS2
Southern Boobook Owl	*Ninox novaeseelandiae*	*	+	
Tytonidae (barn owls)				
Masked Owl	*Tyto novaehollandiae*	+	+	CS2
Barn Owl	*Tyto alba*	+	+	
Podargidae (frogmouths)				
Tawny Frogmouth	*Podargus strigoides*	*	*	
Aegothelidae (owlet-nightjars)				

Species		Kemerton Region	KSS Property	Status
Australian Owlet-nightjar	*Aegotheles cristatus*	*	+	CS3
Halcyonidae (forest kingfishers)				
Laughing Kookaburra	*Dacelo novaeguineae*	*	*	Intro.
Sacred Kingfisher	*Todiramphus sanctus*	*	*	
Meropidae (bee-eaters)				
Rainbow Bee-eater	*Merops ornatus*	*	*	
Maluridae (fairy-wrens)				
Southern Emu-wren	*Stipiturus malachurus*	+	+	
Splendid Fairy-wren	*Malurus splendens*	*	*	
Pardalotidae (pardalotes)				
Spotted Pardalote	*Pardalotus punctatus*	*	*	CS3
Striated Pardalote	*Pardalotus striatus*	*	*	
White-browed Scrubwren	*Sericornis frontalis*	*	*	
Western Gerygone	*Gerygone fusca*	*	*	
Weebill	*Smicrornis brevirostris*	*	+	
Inland Thornbill	*Acanthiza apicalis*	*	*	
Western Thornbill	*Acanthiza inornata*	*	*	
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	*	*	
Meliphagidae (honeyeaters)				
Red Wattlebird	*Anthochaera carunculata*	*	*	
Western Wattlebird	*Anthochaera lunulata*	+	+	
Singing Honeyeater	*Lichenostomus virescens*	*	+	
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*	*	*	
White-fronted Chat	*Epthianura albifrons*	*	*	
Petroicidae (Australian robins)				
Scarlet Robin	*Petroica multicolor*	*	+	
Western Yellow Robin	*Eopsaltria griseogularis*	*	+	CS3
Neosittidae (sittellas)				
Varied Sittella	*Daphoenositta chrysoptera*	*	+	
Pachycephalidae (whistlers)				
Golden Whistler	*Pachycephala pectoralis*	*	*	CS3
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*	*	*	
Artamidae (woodswallows)				
Black-faced Woodswallow	*Artamus cinereus*	*	*	
Dusky Woodswallow	*Artamus cyanopterus*	*	*	
Grey Butcherbird	*Cracticus torquatus*	*	*	

Species		Kemerton Region	KSS Property	Status
Australian Magpie	*Gymnorhina tibicen*	*	*	
Corvidae (ravens and crows)				
Grey Currawong	*Strepera versicolor*	*	+	CS3
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)				
Clamorous Reed-Warbler	*Acrocephalus stentoreus*	*	*	
Little Grassbird	*Megalurus gramineus*	*	*	
Zosteropidae (white-eyes)				
Silvereye	*Zosterops lateralis*	*	*	

Note: * Species recorded.
+ Species expected to occur.
Intro – Species that has been introduced.
[1] Red-tailed Black Cockatoo has since been reclassified as Priority CS1.

Six bird species of CS1 are expected in the Kemerton region and three of these have been recorded (Table 3 and Table 9). The three that have been recorded have all been seen on the KSS property, and the two migratory species (Common Greenshank and Common Sandpiper) have been seen only on the KSS dredge pond in the entire Kemerton region. However, only single birds have been seen on any one occasion.

The third CS1 species that has been recorded is the Short-billed (or Carnaby's) Black-Cockatoo. This is a seasonal visitor to the coastal plain over summer but breeds in the Wheat-Belt. In the Kemerton region, including the KSS property, these cockatoos have been observed foraging in pine plantations and eucalypt and Banksia woodlands. They are probably regular visitors to the area and it would be important foraging habitat for them because of the extent of clearing on the coastal plain. They are discussed in more detail in Section 0 and 4.2. The very similar Long-billed (or Baudin's) Black-Cockatoo is more specialised in feeding on eucalypts and is largely restricted to the tall forests of the South-West, but has been reported in coastal eucalypt woodlands. It may also visit the Kemerton woodlands.

The remaining two CS1 species are the Australasian Bittern and the Peregrine Falcon. The Australasian Bittern is a waterbird that favours swamps with dense reed cover. There is little suitable habitat for it in the Kemerton region, but it is known from nearby Benger Swamp and therefore may be an occasional visitor. There may even be potential to create habitat for it in the dredge pond on the KSS property.

The Peregrine Falcon is not listed under the *EPBC Act* and is only Schedule 4 under the *WC Act*, which is a lower level of recognition that for the other CS1 species. It is not listed by Garnett and Crowley (2000). The Peregrine Falcon is widespread but in low numbers on the Swan Coastal Plain, including in agricultural areas. If it is present in the Kemerton region and the KSS property, the most significant feature of the habitat would be nest trees, as it nests in large, shallow hollows that are only found in very large trees.

Seven bird species that have been recorded or are expected in the Kemerton area are of CS2 (Table 4 and Table 9). Only one of these, however, the Red-tailed Black-Cockatoo (forest sub-species) has been recorded. It is seen regularly in eucalypt woodlands, including those of the KSS property, and is unusual on the coastal plain. Of the remaining CS2 species, three are waterbirds (Freckled Duck, Black Bittern and Little Bittern) and the Kemerton region provides only limited habitat for them. If rehabilitated with overhanging paperbark trees and extensive rushbeds, the dredge pond has the potential to provide habitat for these species.

The Masked Owl has been reported occasionally from Tuart forest south of Bunbury and therefore has been included on the general Kemerton list because there are Tuarts on the extreme western edge of the Kemerton region. The species is not confined to Tuarts, however, and could roost and nest in large hollows in trees anywhere in the region, including o the KSS property. The Barking Owl is infrequently reported from the South-West, but it is known from the Swan Coastal Plain, including a recent report from the southern suburbs of Perth (Maddeford, 2001). The Square-tailed Kite has recently been removed from DEC’s priority list and is included by Garnett and Crowley (2000) only as Least Concern, so should probably no longer be regarded as of CS2.

Nine bird species recorded or expected in the Kemerton region are of CS3 (Table 5 and Table 9). All have been recorded in the Kemerton region and three have been recorded on the KSS property. They include three waterbird species (Darter, Nankeen Night Heron ands Little Pied Cormorant) that are significant because they breed in colonies in the area. The Little Pied Cormorant colony is located in EPP 8 on the KSS property. This colony contains fewer than five pairs and was in use in 1993 when the site was first visited and was still in use from 1997 to 2000, but was not used when water levels were low due to poor rainfall in 2001 and 2002 (M. Bamford, unpub. data). The other two waterbird species breed in wetlands in the west of the Kemerton region. They are therefore not significant on the KSS property, although they may visit there occasionally.

The remaining CS3 species are of significance because they are species of the Jarrah forest of the Darling Escarpment that either occasionally visit the Kemerton eucalypt woodlands, or are resident in these woodlands. Species such as the Spotted Pardalote, Golden Whistler and Western Yellow Robin were once considered to be regular migrants to the Swan Coastal Plain (Serventy and Whittell, 1976), but are now considered to be rare vagrants except in a few localities such as Kemerton. The Golden Whistlers appear to be present all year at Kemerton.

Many of the bird species of conservation significance are visiting the Kemerton region as outlying populations or as regular visitors from the jarrah forests of the nearby Darling Escarpment. Whether residents or visitors, habitat linkage to this forest may be important. The woodlands of the KSS property, as the easternmost of the Kemerton woodlands, may be important in giving such species access to the whole Kemerton area.

At least three species of birds may be locally extinct in the Kemerton region (Table 11) and they would have been associated with the dense vegetation of wetlands and damplands. The Western Bristlebird is now confined to a few locations on the south coast east of Albany, but the White-breasted Robin and Red-eared Firetail still occur in riparian vegetation within the Jarrah forest of the Darling Escarpment, and could potentially colonise the Kemerton region if a corridor of suitable vegetation existed between the two areas.

3.1.6 Mammals

The mammal fauna of the Kemerton region and much of mainland Australia has declined catastrophically, which is why regionally extinct mammal species (Table 11) represent a high proportion of the mammal fauna in relation to extant native species (Table 10). This loss of species has been attributed to changes in fire regime, habitat loss and predation by foxes and cats over large areas (Burbidge and McKenzie, 1989; Paton, 1991). In the South-West, such extinctions occurred in the first half of the Twentieth Century and there are few records of the extinct species in the region, making it difficult to predict which may have been present. Therefore, the extinct list is probably conservative.

Table 10: Mammal Species Present or Expected in the Kemerton Area

Species		Kemerton Region	KSS Property	Status
Tachyglossidae (echidnas)				
Echidna	*Tachyglossus aculeatus*	+	+	
Dasyuridae				
Chuditch	*Dasyurus geoffroii*	*	+	CS1
Peramelidae (bandicoots)				
Quenda or Southern Brown Bandicoot	*Isoodon obesulus*	*	*	CS1
Tarsipedidae (honey possum)				
Honey Possum	*Tarsipes rostratus*	*	*	CS3
Phalangeridae (possums)				
Brush-tailed Possum	*Trichosurus vulpecula*	*	+	CS3
Burramyidae (pygmy possums)				
Western Pygmy Possum	*Cercartetus concinnus*	*	*	CS3
Macropodidae (kangaroos and wallabies)				
Western Grey Kangaroo	*Macropus fuliginosus*	*	*	
Brush or Black-gloved Wallaby	*Macropus irma*	*	*	CS2
Mollosidae (mastiff bats)				
White-striped Bat	*Tadarida australis*	*	+	
	Mormopterus planiceps	+	+	
Vespertilionidae (vesper bats)				
Gould's Wattled Bat	*Chalinolobus gouldii*	*	+	
Chocolate Wattled Bat	*Chalinolobus morio*	+	+	
Western False Pipistrelle	*Falsistrellus mackenziei*	*	+	CS2
Southern Forest Bat	*Vespadelus (Eptesicus) regulus*	*	+	
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	*	+	
Gould's Long-eared Bat	*Nyctophilus gouldii*	+	+	
Greater Long-eared Bat	*Nyctophilus major*	*	+	
Muridae (rats and mice)				
Rakali or water rat	*Hydromys chrysogaster*	*	*	CS2
Moodit or Southern Bush Rat	*Rattus fuscipes*	+	+	
House Mouse	*Mus musculus*	*	*	Intro
Black Rat	*Rattus rattus*	*	+	Intro
Leporidae (rabbits and hares)				
Rabbit	*Oryctolagus cuniculus*	*	*	Intro
Canidae (foxes and dogs)				
European Red Fox	*Vulpes vulpes*	*	*	Intro
Felidae (cats)				
Feral Cat	*Felis catus*	*	*	Intro
Suidae (pigs)				
Feral Pig	*Sus scrofa*	*	*	Intro

Note: * Species recorded.
+ Species expected to occur.
Intro – Species that has been introduced.

The KSS property has the potential to support all of the 24 mammal species recorded or expected in the general Kemerton region, and while the majority would range widely over the available habitats, some have specific preferences. For example, the Rakali or water-rat is an aquatic species that has been seen in EPP 7. It requires permanent or near-permanent water, so probably occurs in all the permanent wetlands of the Kemerton region, and may be a seasonal visitor to the wetlands of the KSS property. It will probably colonise the dredge pond as rehabilitation of this proceeds.

There are no other aquatic mammals present, but several other species may use and even depend upon vegetation associated with wetlands and damplands. The Quenda or southern brown bandicoot favours dense, low vegetation, and the shrublands and heathlands that occupy much of the KSS property appear to be ideal habitat, although it has only been recorded once in the KSS property (Bamford and Bamford, 1999a) and at one site elsewhere in the Kemerton region (Bamford and Bamford, 1999b).

The Honey Possum is also likely to utilise the dense shrublands and heathlands, especially when flowers are available, but it may range widely into other vegetation types as the seasonal availability of flowers changes. The diversity of vegetation types, especially in the KSS property but also throughout the Kemerton region, may be an important feature for the Honey Possum.

Other mammals may largely utilise the woodlands of the Kemerton region, including the eucalypt woodlands of the KSS property. The bat species, which may forage widely at night, probably roost in hollow branches and under loose bark of large trees in the woodland. The Grey Kangaroo is common throughout the region but may forage widely over adjacent farmland.

Introduced species are well-represented in the mammal fauna and most are likely to be widespread throughout native vegetation in the region. The rabbit, however, is usually only common where it has access to adjacent farmland, while the feral pig is known only from dense wetland vegetation in the east of the KSS property. The fox and the cat can place pressure on populations of native species and are favoured by habitat fragmentation and the construction of tracks.

Of the native species recorded or expected in the Kemerton region, two are of CS1, three are of CS2 and three are of CS3 (Table 3 to Table 5).

The two CS1 species, the Chuditch and the Quenda, have both been recorded in the Kemerton region but appear to occur at low population densities. The record of the Chuditch is based upon a road-killed specimen found in 1997 on the Old Coast Road to the south-west of the Kemerton region, and one seen crossing Treasure Road in 1998. It has therefore not been recorded on the KSS property but is very likely to be present, particularly in the woodlands. They are discussed in more detail in Section 4.3. The scarcity of the Quenda in what appears to be suitable habitat is perplexing and may reflect past disturbance and an absence of a nearby population able to colonise the area. All records are recent and the species was not found in the intensive 1983 survey, so it may be that the Quenda is only just beginning to re-colonise the area. Much of the KSS property supports the low, dense vegetation favoured by the Quenda.

Two of the CS2 species, the Rakali and the Brush Wallaby, have been recorded on the KSS property. As noted above, the Rakali is resident in permanent wetlands but will visit seasonal wetlands. The Brush Wallaby is widespread in heaths and woodlands. The third CS2 species, the Western False Pipistrelle, is known only from a 1982 record on the southern edge of

Mialla Lagoon in the west of the Kemerton region. Similar habitat of eucalypt woodland fringing a wetland is present on the KSS property, and the species is probably present throughout the Kemerton region.

The Honey Possum, Western Pygmy Possum and Brush-tailed Possum all considered being CS3 species because their populations have declined and are now fragmented on the Swan Coastal Plain. The persistence of the Honey Possum and Western Pygmy Possum is particularly unusual, and reflects the large area and diversity of the native vegetation. The Honey Possum is known from several sites in the region including the KSS property, especially in shrubland and heath. The Pygmy Possum is known from a single specimen recorded in 1993 in the western part of the KSS property (Ninox Wildlife Consulting, 1994). It is commonly associated with eucalypts so is presumably present in the woodlands of the KSS property and throughout the Kemerton region. The Brush-tailed Possum has also declined on the Swan Coastal Plain but has recently increased in abundance in some areas due to Fox control (M. Bamford, pers. obs.). It is primarily a woodland species and has been recorded only in the south of the Kemerton region.

Of the mammal species considered to be extinct in the Kemerton region, the Brush-tailed Phascogale and the dunnart were recently recorded at Gwindinup, about 40 kilomtetres south of Kemerton (Bamford and Bamford, 1999c). This raises the possibility that these two species may be present nearby or in very low numbers at Kemerton. Both are principally woodland species.

Table 11 lists the vertebrate species that are known or believed to have become extinct in the Kemerton region since European settlement, and indicates the main habitat types where they may have occurred. These are:

- Eucalypt/Banksia woodland of uplands.
- Banksia woodland of uplands.
- Wetland heath - dense, low vegetation fringing wetlands, including on seasonal damplands.

Note that this list is not complete, and that a number of other mammal and bird species known to have declined or disappeared in the South-West may have been present in the Kemerton region.

Table 11: Vertebrate Species Presumed Extinct in the Kemerton Region

Species		Eucalypt Banksia	Banksia Woodland	Wetland Heath
Pardalotidae (pardalotes and allies)				
Western Bristlebird	*Dasyornis longirostris*			+
Petroicidae (Australian robins)				
White-breasted Robin	*Eopsaltria georgiana*			+
Passeridae (finches)				
Red-eared Firetail	*Stagonopleura oculata*			+
Dasyuridae				
Brush-tailed Phascogale	*Phascogale tapoatafa*	+	+	+
dunnart	*Sminthopsis gilberti*	+	+	
Pseudocheiridae (ring-tailed possums)				
Western Ring-tailed Possum	*Pseudochierus occidentalis*	+		
Potoroidae (potoroos)				
Woylie	*Bettongia penicillata*	+	+	+
Boodie	*Bettongia lesueur*	+	+	+
Macropodidae (kangaroos and wallabies)				
Tammar	*Macropus eugenii*	+	+	+
Quokka	*Setonix brachyurus*			+
Muridae (rats and mice)				
Noodji	*Pseudomys albocinereus*		+	

Note: * Species recorded.
+ Species expected to occur.

3.2 COCKATOO SURVEY

3.2.1 Desktop review

A literature review revealed that there is very little published information on the breeding population of Short-billed Black-Cockatoos around Bunbury. The presence of breeding birds in the area was first revealed by Saunders (1979) but there were few additional records. There is no mention of a breeding population in the area by Johnstone and Storr (1999) but this undoubtedly reflects the lack of research done in the area by the Western Australian Museum to that time. Research conducted by the Western Australian Museum in the area subsequent to 1999 has revealed a breeding population that extends from Yalgorup National Park in the north to Ludlow in the south (T. Kirkby, personal communication; personal observation). Currently about half a dozen nests are known and they have all been located in Tuarts *Eucalyptus gomphocephala* (T. Kirkby, personal communication). Saunders (1979) states that the breeding population around Bunbury probably follows the Wandoo *Eucalyptus wandoo* down the coastal plain although he does not specifically state whether any nests he recorded were in Wandoo. There are no records of Jarrah *Eucalyptus marginata* being used as nest trees in the Bunbury area and the nearest nests so far recorded in Jarrah are found around Serpentine (T. Kirkby, personal communication).

There is no specific information published on the foraging behaviour of birds from the Bunbury breeding population but there is no reason to suppose that it differs from foraging behaviour elsewhere in the species range (T. Kirkby, personal communication). Recorded food plants for the species include 35 species of Proteaceae, four of Myrtaceae and one each of Causuarinaceae, Fabaceae, Geraniaceae, Pinaceae and Polygonaceae (Higgins, 1999; Johnstone and Kirkby, 1999). The primary food species appear to be introduced pine trees ***Pinus*** spp., Marri *Corymbia calophylla*, Jarrah, *Banksia* spp., *Dryandra* spp., *Grevillea* spp. and *Hakea* spp., with other species being used relatively infrequently (Higgins, 1999). Descriptions of foraging habitat during the breeding season include native vegetation, particularly proteaceous shrubs of kwongan heathlands and occasionally in Marri woodland (Higgins, 1999). In the non-breeding season, foraging habitat include pine plantations, fruiting Marri and heathland vegetation (Higgins, 1999). They have also been recorded foraging in coastal scrub, jarrah forest, wandoo woodland, Banksia woodland, coastal Tuart forest and on pastures (M. Craig and M. Bamford, personal observations). The species also occasionally feeds on wood-boring larvae in a range of tree and shrub species (Higgins, 1999).

3.2.2 Field survey

A minimum of 60 Short-billed Black-Cockatoos utilised the KSS property during the November 2003 survey period. This was the size of a flock observed feeding in *Banksia ilicifolia* and Jarrah in the western portion of the property on 17 November 2003 (Table 12). During the May 2004 survey period a minimum of 80 Short-billed Black-Cockatoos utilised the KSS property. This was the size of a flock observed feeding in *B. attenuata* on 9 May 2004 (Table 14). Short-billed Black-Cockatoos were also observed feeding on *B. grandis* during the survey and all these species, except *B. grandis*, are widespread on the KSS property. All are widespread in the Kemerton region, although *B. ilicifolia* are slightly concentrated around damplands on the KSS property.

Table 12: A list of all sightings of Short-billed Black-Cockatoos within the Kemerton Silica Sands property outside vehicle transects in November

Date	Time	Northing	Easting	No. of birds	Notes
17/11/03	0740	6331421	385480	c. 20	Feeding in *B. ilicifolia*
17/11/03	0810	6332521	384845	c. 60	Feeding in *B. ilicifolia* and *E. marginata*
18/11/03	1550	6331156	385327	c. 30	Feeding in *B. ilicifolia*
19/11/03	1103	6333641	385426	12	Feeding in *B. attenuata*
19/11/03	1104	6333872	385301	1	Feeding in *B. attenuata*
19/11/03	1520	6331450	385789	7	Feeding in *B. ilicifolia*

The number of Short-billed Black-Cockatoos utilising the control areas were comparable to the number using the KSS property. A minimum of 40 birds in November and 45 birds in May utilised the area of jarrah forest around the southern transect and a minimum of 9 birds in November and 155 birds in May utilised the pine plantation and Banksia woodland around the northern transect (Table 13 and Table 14).

The data show some seasonal variation in the numbers of birds using each of the three transect areas, with more birds in autumn (May) than in spring (November). This is particularly true for the northern transect.

In November, the number of birds recorded per kilometre was similar in all three transects. Including birds that were flying, or were heard only, a total of 0.72 birds per kilometre were recorded on the KSS transect compared with 1.53 birds per kilometre along the southern control transect and 0.41 birds per kilometre along the northern control transect (Table 13). When only birds that were perched were used to calculate the totals, the number of birds utilising the extension areas was only 0.05 birds per kilometre compared with 0.31 birds per kilometre along the southern control transect and 0.30 birds per kilometre along the northern control transect (Table 13).

In May, the number of birds recorded per kilometre was similar on the KSS transect and the northern transect, but considerably fewer on the southern transect. A total of 3.07 birds per kilometre were recorded along the KSS transect, compared with 0.79 birds per kilometre along the southern transect and 2.14 birds per kilometre along the northern transect (Table 14). The number of birds per kilometre increased between November and May for both the KSS transect and the northern transect, but decreased on the southern transects. When only birds that were perched were used to calculate totals, the number of birds using the KSS area was 2.39 birds per kilometre compared with 0.64 birds per kilometre along the southern transect and 2.03 birds per kilometre along the northern transect (Table 14).

A total of 60 eucalypt trees were recorded within the KSS property that had hollows of sufficient size to be potentially used by avifauna. Of these, nine contained hollows that were sufficiently large to be of potential use by Short-billed Black-Cockatoos. Despite this, none of the hollows showed signs of occupation by Short-billed Black-Cockatoos. In addition, no pairs of Short-billed Black-Cockatoos were observed flying together in the late afternoon, and all observations of single birds and pairs were of birds feeding during the morning. Breeding pairs are commonly observed together in the late afternoon as that is when the birds change over at the nest.

Table 13: A list of all Short-billed Black-Cockatoos seen during vehicle transects in November 2003

Transect	Date	Time	Northing	Easting	No. of birds	Notes
North Control	17/11/03	1400-1440			0	
	18/11/03	0550-0640			0	
	18/11/03	1015-1100	6336296	384796	9	2 birds feeding in *Pinus*, joined by 7 others
	19/11/03	0810-0855			0	
	19/11/03	1740-1830	6336722	382775	1	
	20/11/03	0735-0820	6336415	385863	6	Flying to south
			6337186	383077	9	Flying to west
						Feeding in *Pinus*
South Control	17/11/03	1500-1550			0	
	18/11/03	0655-0750	6329887	383222	6	Flying south-west
			6329413	382592	2	Perched
	18/11/03	0910-1000			0	
	18/11/03	1650-1745	6327113	382462	7	2 calling flying south, 5 calling to east
			6329239	382566	6	Feeding in *B. grandis*
			6329867	382600	7	Feeding in *B. attenuata*
			6328130	382706	1	Feeding in *B. attenuata*
	19/11/03	0540-0640	6326864	382644	40	Flying to south
			6329525	382596	6	Calling to west
	20/11/03	0630-0720	6326864	382706	4	Calling to south
			6329979	383227	1	Calling to east
KSS	17/11/03	0855-0955			0	
	17/11/03	1615-1705	6333052	384829	1	Calling while flying south
	18/11/03	0805-0900	6332668	384838	4	Calling while flying south
	18/11/03	1125-1210	6334156	384800	1	Perched in *E. marginata*
	19/11/03	0650-0750	6333188	384819	2	Pair feeding in *B. ilicifolia*
	20/11/03	0535-0625	6333763	384803	40	Flying to east-south-east
Total					**143**	

Table 14: A list of all Short-billed Black-Cockatoos seen during vehicle transects in May 2004.

Transect	Date	Time	Northing	Easting	No. of birds	Notes
North Control	9/05/04	1003-1037			0	
	9/05/04	1455-1414	6336000	383390		Flying to south-east, from pines to forest
			6336016	383390	3	Flying to east, from pines to farmland
	10/05/04	0924-1001			0	
	10/05/04	1326-1411	6336625	382805	3	Flying to north
	11/05/04	1022-1054			0	
	11/05/04	1428-1525			0	
	12/05/04	1009-1053	6338257	385114	2	Adult male feeding juvenile in *Pinus*
			6336128	382779	10	Perched and calling from large dead jarrah
	12/05/04	1317-1415	6337995	385759	155	Feeding in *B. attenuata*
			6338252	385098	2	Perched in *Pinus* (adult and juvenile)
South Control	9/05/04	0913-0950			0	
	9/05/04	1319-1400			0	
	10/05/04	1029-1114	6330072	382901	8	Flying to south-west
	10/05/04	1424-1513			0	
	11/05/04	0921-1010			0	
	11/05/04	1536-1626	6328795	383235	45	Perched and calling from Jarrahs.
	12/05/04	0900-0946	6329094	383242	2	Calling to north.
	12/05/04	1339-1625			0	
KSS	9/05/04	0752-0903	6331454	386590	5	Feeding in *B. ilicifolia*
	9/05/04	1415-1519	6331431	385814	80	Feeding in *B. attenuata*
			6332507	384845	10	Flying to east
	10/05/04	0740-0905	6333888	384794	3	Feeding in *B. attenuata*
			6333875	384932	59	53 feeding on *B. ilicifolia*, 6 feeding in *Pinus*.
	10/05/04	1518-1615	6331676	384861	5	Flying to north
			6335694	385385	8	Flying to west to perch in jarrah
			6336015	385771	5	Perched and calling from *B. attenuata*
			6333569	386702	40	Perched, and some of flock feeding on *B. attenuata* and *B. ilicifolia*
	11/05/04	0741-0914			0	
	11/05/04	1327-1428	6331404	385017	20	Calling to north-west
	12/05/04	0729-0856	6333975	384803	20	Feeding on *B. attenuata* and *B. ilicifolia*
	12/05/04	1436-1534	6336019	385962	18	Flying to north-west
Total					**513**	

3.3 CHUDITCH SURVEY

No Chuditch, or any other mammals, were trapped during the survey. Despite this, the habitat available on the KSS property is considered suitable for Chuditch. In particular, partial clearing carried out in the middle of the twentieth century has resulted in many fallen trees and piles of branches that would provide shelter for Chuditch.

4. DISCUSSION

4.1 FAUNA SURVEY

The vertebrate fauna of the Kemerton region is remarkably rich and includes species of conservation significance, principally because the area includes one of the largest remnants of native vegetation on the Swan Coastal Plain between Mandurah and Bunbury. The complexity of landforms and range of vegetation types also contribute to the fauna values of the region.

Within the Kemerton area, the KSS property contains many of the vegetation types that are significant for fauna, such as seasonal wetlands, shrublands and heath of seasonal damplands, and eucalypt woodlands. Therefore, the KSS property can be expected to support most of the species recorded or expected in the Kemerton region. With respect to fauna and the proposed mining in the remaining areas of the KSS property, the main points to note are:

4.1.1 Key Fauna Habitats

The key fauna habitats in the KSS property are mapped in Figure 1. Fauna habitats consist of sumplands (seasonal wetlands with *Melaleuca* spp. forming an overstorey), damplands (occasionally inundated, low-lying areas with dense heath) and Eucalypt/Banksia woodland on sandy ridges. Damplands occur throughout the KSS property but are poorly represented elsewhere in the Kemerton region. Woodlands are part of the woodlands that are widespread in the west of the Kemerton area generally. Therefore, the western part of the KSS property is in some respects transitional in the fauna habitats present between the undulating landscapes to the west of the property and the low relief terrain that characterises the eastern portion of the KSS property. The KSS property differs in fauna habitats from the rest of the Kemerton region in the presence of extensive damplands but the absence of extensive Banksia woodland, Tuart/Peppermint woodland and permanent wetlands. The KSS dredge pond is the only permanent wetland on the KSS property.

An important feature of the fauna habitats of the KSS property is the combination of woodland on low ridges and heath on damplands. This combination of habitats means the KSS property may support more species than a similar-sized area that contains only woodland or only heath. This is not only because some species occur in woodland and some in heath, but because ecotones between habitats are often particularly rich in species. Within the KSS property, woodland and margins of woodland with heath are likely to support more species than other habitats.

4.1.2 Significant Species

With the exception of one lizard species, the Perth Lined Lerista, all species of conservation significance recorded or expected in the Kemerton region may be present on the KSS property. Within the Kemerton region, the KSS property is unique in supporting a relictual population of the Black-striped Jollytail, and this is associated with the extensive network of seasonal wetlands and damplands mainly in the east of the property. For other significant species, the

KSS property may be less valuable then elsewhere in the Kemerton region. For example, the woodlands on the KSS property have been subject to historical logging activities and contain relatively few large trees. Other parts of the Kemerton region, like near Mialla Lagoon, contain much more large trees. Large trees are important for many of the significant species, such as the two owls and the Chuditch. They may be present in the KSS property, but at lower densities than elsewhere in the region.

4.1.3 Function of the KSS property for fauna:

The KSS property is species rich, although some species are represented in low densities. The property may be important even for such species because of its location. The woodlands of the KSS property are the largest, most easterly example of this sort of vegetation in the region. Therefore, they may be important in allowing movement of fauna, especially birds, between the forests of the Darling Escarpment and the coastal woodlands west of the property. For example, Red-tailed Black-Cockatoos have been seen at several locations in the Kemerton region, and have been seen in remnant trees in paddocks east of the KSS property. They may rely on these trees, and on woodlands in the KSS property, to act as stepping stones to allow them to access the extensive woodlands in the west of the Kemerton region.

4.1.4 Significance of the KSS property for fauna:

The significance of the KSS property for fauna can be summarised as follows:

- It contains the most extensive seasonal wetlands and damplands in the Kemerton region. These support a relictual population of the Black-striped Jollytail.
- It provides linkage between the coastal woodlands and the forests of the escarpment that lie to the east.

4.1.5 Recommendations for impact minimization within the KSS property

Further mining in the KSS property will inevitably result in habitat loss, only some of which will be reversible through rehabilitation. To minimise impacts, the following recommendations should be considered.

- Retain examples of all habitat types, including ecotones between woodland and heath.
- An important feature of the woodlands is old trees bearing hollows, whereas the important feature of the heaths is the density of low vegetation. Such dense, low vegetation can be rehabilitated relatively quickly compared with woodland containing mature and old trees. Therefore, the impact of mining in heath of the damplands should be shorter-lived than the impact of mining in woodland, so where choices are available, retention of woodland should be favoured. This would be consistent with favouring protection of woodland because it is richer in fauna species, including some that may be moving between Kemerton and the forests of the Darling Escarpment.
- In conjunction with mining and rehabilitation, protect and enhance the existing linkage function of woodlands in the KSS property. Enhancement could be achieved by creating woodland in rehabilitation areas where possible and even supporting the planting of native (i.e. local) tree species on private property east of the KSS property.

- Rehabilitation should incorporate procedures that are now becoming standard on minesites, including: harvesting and mulching of existing vegetation for immediate use on sites being rehabilitated; stripping of topsoil for immediate use on sites being rehabilitated; shaping of rehabilitation sites to natural contours where possible; and planting of native (local provenance) seedlings that do not readily volunteer from topsoil or mulch. Rehabilitation should commence as soon as possible after any disturbance and should aim to re-create pre-existing vegetation types where practical.
- Volume loss as a result of mining will inevitably occur, resulting in the creation of permanent lakes, as has already occurred on the property. Although not natural, such wetlands have the potential to be of conservation value, especially as a summer refuge for waterbirds. This is already happening with the existing dredge pond, where large counts of Pacific Black Ducks and Australian Shelducks were made in 2001 and 2002, and small numbers of sandpipers and plovers are also occasionally observed. The greatest value will be achieved if permanent wetlands that result from mining have features including: extensive shallows, gently sloping shorelines, sandbars and fringing vegetation in the form of rushes and paperbark trees. Dead trees placed overhanging or in the water will act as perches.
- Permanent wetlands created by mining have the disadvantage that they will support introduced fish such as the Mosquitofish. At Kemerton, this would be a particular concern if the Mosquitofish could annually colonise seasonal wetlands where Black-striped Jollytails occur. The Mosquitofish can be kept out of permanent wetlands by preventing linkage between the wetlands and drains that cross nearby agricultural land. The existing dredge pond has a concrete overflow weir and future such structures should be designed to have a drop that will act as a barrier to fish.
- KSS already has a policy of restricting site access to minimise disturbance of vegetation, creation of unnecessary tracks and spread of plant diseases. It is important to maintain this policy for the entire site.

4.2 COCKATOO SURVEY

4.2.1 Desktop review

It is difficult to assess the potential of the KSS property to be used by breeding pairs of Short-billed Black-Cockatoos due to a lack of information on the breeding population in the area. All known nests in the area are located in Tuarts, which would imply that the KSS property has little or no suitable breeding habitat for the species as Tuarts have not been recorded on the KSS property. Saunders (1979) implies that the species breeds in Wandoo in the region, although his statements are equivocal. Whether this statement is correct or not does not influence the suitability of the KSS property as breeding habitat, as Wandoo is not present on the site. The remaining possibility is that Short-billed Black-Cockatoos are using Jarrah and Marri as nest sites. These two species are used commonly as nest trees along the eastern edge of the Jarrah forest (T. Kirkby, personal communication) but have not been recorded as nest species around Bunbury. However, considering the very low number of nests that have been recorded around Bunbury (<10), the absence of breeding records from these two species is probably of little significance. On current evidence it is impossible to know whether the breeding population around Bunbury uses Jarrah and Marri for nesting but it seems probable that they do, at least occasionally. This would suggest that the KSS property, which supports mainly Jarrah in the dry areas of the property, is potentially suitable to be used by breeding pairs of Short-billed Black-Cockatoos.

It is also difficult to assess forage value of different habitats on the KSS property due to a dearth of published information on foraging habitat use. Therefore, it is probably more accurate to assess potential habitat value based on the presence of suitable food plant species. It is unlikely that the wetlands provide suitable foraging habitat as the species has never been recorded feeding on Cyperaceae. However the rest of the property would appear to have moderate to high value as foraging habitat. The overstorey is primarily Jarrah and Marri and there are *B. ilicifolia* and *B. attenuata* in the understorey. Several species of *Dryandra*, *Grevillea* and *Hakea* are also present. This indicates that there are, at least potentially, abundant food resources in this habitat and it is likely that Short-billed Black-Cockatoos would regularly use this habitat for foraging.

Based on published information, it is also difficult to assess the breeding and foraging value of surrounding habitats relative to the KSS property for Short-billed Black-Cockatoos. If it is assumed that the breeding population in the Bunbury area breeds only in Tuarts, then the value of the surrounding habitat for breeding would be considerably higher than the KSS property.

Tuarts are more abundant closer to the coast, which would indicate that the most suitable breeding habitat would lie around or to the west of the Old Coast Road between Mandurah and Bunbury. Tuarts are scarce as far east as the KSS property. However, if birds also nest in Jarrah and Marri, the preference for Tuart simply being a reflection of where people have searched, the potential value of the KSS property as breeding habitat increases. However, only nine trees containing potentially suitable hollows were found in the western portion of the KSS property, an area of *ca.* 1000 hectares, whereas large Tuarts, many containing hollows, occur at a density of one tree every one to two hectares along the Old Coast Road. The KSS property would appear to be of low value as breeding habitat in the regional context.

Again, it is almost impossible to accurately determine the value of the KSS property as foraging habitat compared with surrounding areas. The KSS property was mostly cleared during the 1930s and 1940s and as a consequence it has a high density of *B. ilicifolia*, which is favoured by disturbance, compared with some of the surrounding habitat. The cockatoos were feeding heavily on this Banksia during the field surveys, particularly in November, but it produces few fruit and few, albeit large, seeds, so is probably only a short-term seasonal food source.

B. ilicifolia (Holly-leafed Banksia) was not included in the study by Cooper *et al.* (2002) on the energetic value of plant species for cockatoos, but they did examine *B. attenuata*, Marri, Jarrah and *Pinus radiata*. It was found that 11 *B. attenuata* fruit, 99 Marri fruit, 585 Jarrah fruit and 18 *Pinus radiata* cones would provide the energy requirements for one Short-billed Black-Cockatoo for one day. The number of fruit per tree varies annually and with the size and age of the tree, but on this basis it is probable that the pine plantation represented the greatest food source per unit area for cockatoos within the Kemerton region. *B. attenuata* are probably next in importance as they are widespread. Marri, Jarrah and *B. ilicifolia* occur in much lower numbers but may be seasonally important.

On the basis of available information on foraging and food value of different species, and observations on vegetation types within the KSS property and elsewhere in the Kemerton region, the value of the KSS property as foraging habitat for the Short-billed Black-Cockatoo is probably less than the proportion of the area represented. About half the KSS property supports habitat that is not suitable for foraging by cockatoos. While areas that do provide foraging habitat are unremarkable in the regional context except for the concentration of *B. ilicifolia*. There may be potential for use of *B. ilicifolia* in rehabilitation to create this seasonal foraging habitat for the cockatoos.

Counts of fruit per tree and density estimates for the trees could be used to determine the cockatoo carrying capacity of different vegetation types, but in almost all cases the availability of seed varies seasonally. The birds therefore need access to a range of vegetation types across the year. It is possible that a relatively uncommon plant, like *B. ilicifolia*, is important for just a few days across the year.

4.2.2 Field survey

4.2.2.1 Population size

During the November survey, a minimum of 60 Short-billed Black-Cockatoos utilised the KSS property. There appeared to be one flock of about 60 birds that occurred regularly along the western boundary of the property and a flock of about 30 birds that occurred in the southern part of the study areas. Given that these flocks were separately observed only 30 minutes apart on the morning of 17 November 2003, it is likely that the observations relate to separate flocks although this cannot be determined for certain. If they are separate flocks, then it is likely that the number of birds foraging in the KSS property at the time of the survey was about 100.

In the May survey, a minimum of 80 Short-billed Black-Cockatoos utilised the KSS property. On the same afternoon that the flock of 80 birds was observed, another 10 birds were observed in a different part of the transect only 15 minutes later. This suggests that there were probably at least 90 birds using the KSS property on the afternoon of the 9 May 2004, although again, this cannot be determined for certain.

During November, a minimum of 40 birds was estimated for the southern control area but considering that groups were seen several kilometres apart, it is likely that the number of birds involved was around 60 or 70. In May, a similar minimum of 45 birds was estimated for the southern control area, and as few other birds were observed during any of the other May surveys, 45 birds is considered to be a reasonable minimum.

The minimum number of birds estimated for the northern control area was nine in November, although this is likely to be an underestimate. In May, the minimum was estimated at 155 birds. Unlike the other two areas, this transect sampled primarily pine plantations. As birds are only likely to visit this habitat to feed, they were unlikely to be recorded unless they were on the edge of the pine plantation as feeding birds are generally quiet and less conspicuous than at other times.

In contrast to the low November count in the northern control area, a minimum of 155 birds was present in May. This variation in bird density between the November and May surveys may be partially due to birds congregating in larger flocks during autumn (May). Another factor is that the *B. attenuata*, which flowers in summer, may have more seeds available in autumn. The large flocks of Short-billed Black-Cockatoos in the northern transect and on the KSS property were feeding in *B. attenuata* trees.

Given that the southern control area is smaller than the KSS transect area, the density of birds there is likely to be similar to the density in the KSS property. The density of birds in the northern control area could also be similar to the density in the other two areas but this is difficult to ascertain from our transect data. The results from the transects are difficult to evaluate as Short-billed Black-Cockatoos are generally found in flocks so the number of individuals recorded on any one transect is highly variable. Some of the transect counts were inflated by the sighting of a single large flock in each area, therefore, it is difficult to be confident that any observed differences in abundance between the sites were real. Based on the data collected, it is probably best to conclude that the number of birds utilising the KSS property during the survey period was not significantly greater than the number of birds utilising adjacent control areas that will be unaffected by the proposed extension.

Short-billed Black-Cockatoos have been recorded moving up to 154 kilometres and individuals have moved 45 kilometres in two days (Higgins, 1999), so the close proximity of the transects means that the same birds could have been counted in each area. While this is unlikely, it emphasises the point that the proposed extension will affect only a small proportion of the habitat available to birds in the area, which is continuous to the north, south and west of the KSS property.

It is not possible to accurately determine the number of birds that can be supported by the KSS property over an extended period of time. The species is migratory, regionally mobile even when not migrating and occasionally forms large aggregations; all features that make it very hard to assess the value of a small area. As noted above, the theoretical carrying capacity of different vegetation types could be determined by calculating the seed density of each potential food species, while the distribution of broad vegetation types already indicates that the KSS property supports a small proportion of regional foraging habitat. Recent studies on numbers of fruit per *B. attenuata* tree carried out near Perth (J. Wilcox and M. Bamford, unpubl. data) found that one hectare of Banksia woodland provide enough food to support less than one black-cockatoo for a year.

It is probably more realistic to estimate the number of Short-billed Black-Cockatoos utilising the KSS property based on what we know of the population in the region. Little is known about the breeding population in the area as it was only recently discovered, but it is considered to be small. It is unlikely that the number of birds using the property is much greater than the 100 birds estimated above, unless most of the birds utilising the property are non-breeding individuals, in which case the birds seen on any one occasion might not be the same individuals are seen previously or subsequently. During regular visits to the KSS property since 1993, flocks of Short-billed Black-Cockatoos observed have consistently been small (10 - 100), unlike the aggregations of many hundreds or thousands of birds seen north of Perth (M. Bamford, unpubl. data).

4.2.2.2 Breeding on the KSS Property

There was no evidence the Short-billed Black-Cockatoos use the KSS property for breeding, despite the November survey being conducted at a time when birds should have been breeding. They typically lay eggs in the region around the middle of November (T. Kirkby, personal communication). However, considering the short duration of the survey (four days), this does not mean that some pairs do not breed within the KSS property, while small numbers of potentially suitable nesting hollows were found. What the result of the survey indicates is that, if any pairs do breed in the KSS property, the numbers involved are likely to be small.

4.2.3 Conclusion

The lack of published information and the biology of the Short-billed Black-Cockatoo make it difficult to answer the questions posed by Environment Australia, but a number of conclusions can be made.

- The value of the KSS property for breeding is low in the regional context, with no evidence of breeding and few potentially suitable nest hollows.
- Parts of the KSS property support suitable foraging habitat that was being utilised by the species at the time of the field surveys. However, the abundance and density of birds were similar at control sites.
- The value of foraging habitat on the KSS property was similar to or less than the value of foraging habitat at control sites. However, the value of foraging habitat is very difficult to assess as usage of different plant species varies seasonally and information is not available on seed density in different vegetation types.

Seasonal variations, combined with the short duration of the surveys, make it impossible to determine unequivocally the value of the KSS property as foraging and breeding habitat compared with surrounding areas. However, there is no evidence that the KSS property has greater value as foraging and breeding habitat than surrounding areas. What is clear is that the wetlands provide unsuitable foraging and breeding habitat for Short-billed Black-Cockatoos and this habitat should be preferentially cleared in any future extension.

4.3 CHUDITCH SURVEY

The Chuditch was once widespread across Australia, but is now confined to the south-west of Western Australia where it occurs in eucalypt forests and woodlands. Its decline appears to be related to the spread of the introduced fox *Vulpes vulpes,* and based on ongoing studies being carried out by DEC, the Chuditch increases in abundance where foxes are controlled.

Although no Chuditch were trapped during this survey, small numbers are clearly present in the region based on observations made in the late 1990’s (M. Bamford, pers. records). They have also been recorded in the Leschenault Peninsula Conservation Park, *ca.* 10 kilometres to the west. These Chuditch made their way to the Conservation Park by themselves, not as part of a release effort (Johnson, 1999). This suggests that Chuditch are slowly re-colonising the area, particularly since fox control has been undertaken in nearby state forest. In a trapping study carried out across the Kemerton Industrial area in 1998, however, no Chuditch were caught (M. Bamford pers. records). This suggests that at least at that time, the Chuditch was scarce in the region. The KSS property was included in a 1992/1993 fauna survey and Chuditch were not recorded on that occasion (Ninox Wildlife Consulting, 1994).

In contrast, Chuditch were found to be common in eucalypt forest in the Gwindinup area, *ca.* 40 kilometres south of Kemerton (M. Bamford, pers. records). The records at Gwindinup were based on trapping carried out in August and December 1999. The total trapping effort was 225 trap-nights in each survey period, which is similar to the 200 trap-nights used on the KSS property. At Gwindinup, however, three and six Chuditch were captured in August and December respectively. Although at a different time of the year, May was chosen for the KSS trapping program following discussions with the Department of Conservation and Land Management (now DEC). May coincides with the period when juveniles are dispersing and was therefore determined to be the period when captures were likely to be highest and impacts on females with pouch young could be avoided.

The results of the trapping on the KSS property and the comparison with Gwindinup data suggest that if Chuditch were common at the former site, they would have been caught. The results indicate that the KSS property does not support a resident population and that even dispersing specimens were scarce or absent at the time the survey was conducted. This suggests that there is no resident population nearby.

While the conclusion from the May 2004 study and from all previous studies at Kemerton is that the Chuditch is, at best, a vagrant in the region, the existence of occasional records and of suitable habitat makes it likely that Chuditch do occasionally occur in the KSS property. The KSS property could even support resident Chuditch if factors that affect them, such as foxes, were controlled. Chuditch hold overlapping territories of 55 to 120 hectares (females), or at least 400 hectares (males) (Strahan, 1995), so the site could support a few individuals. Note that during rehabilitation, the potential exists to create Chuditch shelters such as log-piles.

The lack of any other mammals on the KSS property trapping program was unexpected, as the 1998 study across the Kemerton Industrial area resulted in the capture of two Brush-tailed Possums *Trichosurus vulpecula* and 14 Black Rats *Rattus rattus.* Neither of these species was recorded in the KSS area in 1992/1993. Notable for its absence from all Kemerton studies is the Quenda or Southern Brown Bandicoot *Isoodon obesulus*.

5. REFERENCES

Bamford, M.J. and Watkins, D. 1983. Kemerton Wetlands; the Vertebrate Fauna and its Regional Significance. Unpublished report to Alcoa of Australia, Perth.

Bamford, M.J. and Bamford, A.R. 1998. Kemerton Silica Sands Mine. Annual report on fauna monitoring programme; 1997. Unpublished report by Bamford Consulting Ecologists for Arbotech, Perth.

Bamford, M.J. and Bamford, A.R. 1999a. Kemerton Silica Sands Mine. Annual report on fauna monitoring programme; 1998. Unpublished report by Bamford Consulting Ecologists for Ecos Consulting, Perth.

Bamford, M.J. and Bamford, A.R. 1999b. Kemerton Fauna Study and Review, 1998. Unpublished report by Bamford Consulting Ecologists for Muir Environmental.

Bamford, M.J. and Bamford, A.R. 1999c. Fauna survey of the Gwindinup area. Unpublished report to Cable Sands WA, Bunbury.

Bamford, M.J. and Bamford, A.R. 2003. Assessment of Fauna values in the KSS Property. Unpublished report by Bamford Consulting Ecologists, prepared for Kemerton Silica Sand Pty Ltd.

Bamford, M.J. and Bamford, A.R. 2004. The status of the Chuditch (*Dasyurus geoffroyi*) in areas proposed for expansion by Kemerton Silica Sands. Unpublished report by Bamford Consulting Ecologists, prepared for Kemerton Silica Sand Pty Ltd.

Bamford, M.J. and Bamford, A.R. 2004. The utilisation by Short-Billed Black Cockatoos (*Calyptorhynchus latirostris*) of the proposed dredge mining extension area of Kemerton Silica Sands. Unpublished report by Bamford Consulting Ecologists, prepared for Kemerton Silica Sand Pty Ltd.

Blakers, M., Davies, S.J.J.F. and Reilly, P.N. 1984. The Atlas of Australian Birds. Royal Australasian Ornithologists Union. Melbourne University Press, Melbourne.

Blyth, B. 1994. Predation by ***Gambusia holbrooki*** on anuran larvae at the RGC Wetlands Centre, Capel, Western Australia. RGC Wetlands Centre Technical Report No. 22. RGC Mineral Sands Ltd, Capel.

Burbidge, A.A. and McKenzie, N.L. 1989. Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. Biol. Cons. 50: 143-198.

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.

Christidis, L. and Boles, W.E. 1994. The Taxonomy and Species of Birds of Australia and its Territories. Royal Australasian Ornithologists Union, Monograph 2.

Cogger, H.G., Cameron, E.E., Sadlier, R.A. and Eggler, P. 1993. The Action Plan for Australian Reptiles. Endangered Species Programme Project Number 124, Australian Nature Conservation Agency, Canberra.

Cooper, C.E., Withers, P.C., Mawson, P.R., Bradshaw, S.D., Prince, J. and Robertson, H. 2002. Metabolic ecology of cockatoos in the south-west of Western Australia. *Aust. J. Ecol.* **50**: 67-76.

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

How, R.A. 1998. Long-term sampling of a herpetofaunal assemblage on an isolated urban bushland remnant, Bold Park, Perth. J. Roy. Soc. WA. **81**: 143-148.

Jaensch, R.P., Vervest, R.M. and Hewish, M.J. 1988. Waterbirds in Nature Reserves of South-Western Australia 1981-1985: Reserve Accounts. Royal Australasian Ornithologists Union Report No. 30. RAOU, Melbourne.

Higgins, P.J. 1999. *Handbook of Australian, New Zealand & Antarctic Birds Volume 4: Parrots to Dollarbirds*. Oxford University Press, South Melbourne.

Johnson, B. 1999. Those spotted things: the Chuditch continues its comeback. *Landscope*, **15**(1) 22-27.

Johnstone, R.E. and Kirkby, T. 1999. Food of the Forest Red-tailed Black-Cockatoo *Calyptorhynchus banksii naso* in south-west Western Australia. *Western Australian Naturalist* **22**: 167-178.

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

Kennedy, M. (ed). 1992. Australasian Marsupials and Monotremes. An Action Plan for their Conservation. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

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.

Maddeford, W. 2001. Barking Owl at Blue Gum Lake. Western Australian Bird Notes 99: 16.

Maxwell, S., Burbidge, A.A. and Morris, K. 1996. Action Plan for Australian Marsupials and Monotremes. Environment Australia, Canberra.

Morgan, D.L., Gill, H.S. and Potter, I.C. 1998. Distribution, identification and biology of freshwater fish in south-western Australia. Records of the Western Australian Museum Supplement No. 56.

Ninox Wildlife Consulting. 1994. The Kemerton Silica Sands Project Area. Vertebrate Fauna Assessments December 1992 – December 1993. Unpublished report prepared for Kemerton Silica Sand Pty Ltd.

Paton, D.C. 1991. Loss of Wildlife to Domestic Cats. Pp. 64-69 in: The Impact of Cats on Native Wildlife, C. Potter (ed). Australian National Parks and Wildlife Service.

Pen, L.J., Gill, H.S., Humphries, P. and Potter, I.C. 1993. Biology of the black-stripe minnow *Galaxiella nigrostriata*, including comparisons with the other two Galaxiella species. Journal of Fish Biology **43**: 847-863.

Saunders, D.A. 1979. Distribution and taxonomy of the White-tailed and Yellow-tailed Black-Cockatoos *Calytorhynchus spp*. Emu **79**: 215-227.

Strahan, R. (Ed.) 1995. The Mammals of Australia. Australian Museum/Reed Books, Sydney.

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

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

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

Storr, G.M., Smith, L.A. and Johnstone, R.E. 1999. Lizards of Western Australia. I. Skinks. 2nd Edition. WA Museum, Perth.

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

APPENDICES

APPENDIX 1:
CATEGORIES USED IN THE ASSESSMENT OF CONSERVATION STATUS

Environmental Protection and Biodiversity Conservation Act and the WA Wildlife Conservation Act 1999 (categories mainly from IUCN, based on 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.

Other Specially Protected Fauna (WA Act only).

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

Least Concern. Taxa that are not Threatened.

WA DEC Priority species (species not listed under the *Wildlife Conservation Act 1950*, 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.

APPENDIX 2:
TREE HOLLOWS POTENTIALLY SUITABLE FOR COCKATOOS OR OTHER VERTEBRATE FAUNA

Type of hollows	Northing	Easting
Potentially suitable for cockatoos	6332565	385074
	6330616	386469
	6330988	386401
	6331183	386207
	6331254	385580
	6331250	385581
	6333467	385549
	6333278	385374
	6331374	385580
Potentially suitable for other vertebrate fauna	6332613	384987
	6333096	384850
	6333116	384859
	6333105	384895
	6333108	384904
	6333202	384827
	6333126	385092
	6333043	385092
	6332949	385200
	6332967	385080
	6330526	386082
	6330586	386100
	6330764	386506
	6330997	386381
	6331034	386293
	6331207	386309
	6331179	386038
	6331218	386026
	6331250	385571
	6331249	385552
	6331222	385331
	6331234	385603
	6330313	385855
	6330504	385993
	6333482	385613
	6333536	385451
	6333345	385375
	6334021	385896

Type of hollows	Northing	Easting
	6333974	385880
	6333953	385971
	6333974	385949
	6333303	385284
	6333384	385264
	6334712	385426
	6334484	386352
	6334519	386343
	6331938	386486
	6331913	386398
	6331777	386482
	6331721	386478
	6331693	386371
	6331385	386130
	6331363	385617
	6335290	385572
	6335296	385580
	6335475	385615
	6336025	386183
	6335526	386604
	6335347	386583
	6335455	386661
	6335475	386615

APPENDIX 13:
TARGETED FAUNA SURVEY (WESTERN RINGTAIL POSSUM AND BRUSH-TAILED PHASCOGALE) MINE EXPANSION AREA FEBRUARY 2009 GREG HAREWOOD

Fauna Assessment

(Level 1)

&

Targeted Fauna Survey

(Western Ringtail Possum & Southern Brush-tailed Phascogale)

Mine Extension Area

Kemerton Silica Sand Pty Ltd

Kemerton

February 2009

Report: SF006756

Version 2

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APPENDIX E: Significant Species Profiles

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The conclusions are based upon field data and the environmental monitoring and/or testing carried out over a limited period of time and are therefore merely indicative of the environmental condition of the site at the time of preparing the report. Also it should be recognised that site conditions, can change with time.

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EXECUTIVE SUMMARY

This report details the results of a Level 1 fauna assessment as per the EPA's Guidance Statement 56 (EPA 2004) and a targeted fauna survey of the proposed mine extension area (MEA) at Kemerton Silica Sand Pty Ltd (KSS) operations. The site is located about 25 km north east of the Bunbury townsite and has a total area of about 283 ha, most of which is covered with some form of native vegetation (Figures 1& 2).

The information obtained as part of the fauna assessment reported here will be used, in conjunction with other studies, to obtain approvals and then facilitate the subsequent controlled and guided development of the subject site with the principal aim of minimising environmental impacts.

Several fauna assessments of KSS's land holdings have been carried out previously. It is understood that a more current review of the sites potential to host fauna of conservation significance is required and in particular the Western Ringtail Possum (WRP) and the Southern Brush-tailed Phascogale. An assessment of fauna species in general that use or may use the MEA was also required.

The assessment reported on here has included a desktop analysis, a daytime site reconnaissance survey that included opportunistic fauna observations, a night time survey of the site and a four night trapping program using Elliot's and cage traps.

Field survey work was carried out by Greg Harewood (B.Sc. Zoology) on a number of days and nights between the 28th January 2009 and the 6th February 2009 under a license issued by the Department of Environment and Conservation (DEC)(# SF006756).

The broadly defined fauna habitats within the study area, based on vegetation structure are described below:

1. **Open Woodland of Jarrah (*Eucalyptus marginata*) and Banksia species over shrubland (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities A1, A2 and A3):** Characteristic vegetation type found on most of the raised mosaic of subtle Bassendean dunes in the study area. Density of trees and understory/ground cover varies considerably across the site. *Kunzea ericifolia* represents a common understory plant, in some places forming a dense tall shrubland, with only scattered emergent trees. Ground cover is variable with significant areas covered only with sparse low shrubland, grasses or bare sand. The density of hollow trees is variable (see Figure 4). Significant portions appear to be regrowth from an historical clearing event as evidenced by old piles of significant size trees scattered throughout the area. Apart from these, fallen hollow logs are rare (Plate 1).

2. **Woodland to Forest of Peppermint (*Agonis flexuosa*) (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities C1 and C2):** Very limited extent with the study area. Unit C1 represents sparse Peppermint **(*Agonis flexuosa*)** in association with Jarrah **(*Eucalyptus marginata*)** over grassland. Unit C2 is denser and Peppermint grows in association with occasional *Banksia attenuata*, *Banksia ilicifolia* and *Nuytsia floribunda* over mixed shrubs. Hollow trees and fallen logs are rare (Plate 2).

3. **Woodland of Flooded Gum (*Eucalyptus rudis) - Melaleuca preissiana* and occasional *Banksia littoralis* over Myrtaceae spp. over mixed sedges (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Community D2):** Confined to a small area near the far western boundary of the MEA. Some hollows found both in *E. rudis* and older Melaleuca specimens. An understory of medium to low shrubs when present is dense. Some seasonal waterlogging is evident (Plate 3).

4. **Low Woodland of *Melaleuca preissiana* and occasional *Nutsia floribunda* over *Hypocalymma angustifolium, Pelicalymma ellipticum* and mixed shrubs over mixed sedges (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Community E2):** Limited extent in study area. Represents low lying areas subject to seasonal waterlogging and possibly inundation in wetter years (Plate 4). Provides potential habitat for fish and breeding amphibian species for limited period of the year.

5. **Low Woodland to Forest of *Melaleuca rhaphiophylla over mixed sedges or Baumea articulata (mapped* by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities F1 or F3):** Found in low lying areas that are seasonally inundated or waterlogged: Limited extent. Represents sumpland wetland type (Plate 5). Represents the lowest lying areas within the MEA and therefore has the potential to provide longer term refuge for species that require flooded or waterlogged environments to breed or persist.

6. **Tall Shrublands and Shrubland dominated by *Kunzea ericifolia* or *Hakea varia* (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities G1 and G3):** Limited extent. Found in or bordering lower lying areas (Plate 6).

7. **Low Closed Heath to Closed Heath of Myrtaceae spp. (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities H1, H2 and H3):** Dominant vegetation type over the low lying Dampland areas. The majority is a closed heath of *Melaleuca lateritia* and *Astartea fascicularis* over *Lepidosperma longitudinale* and *Leptocarpus tenax* (Plate 7).

8. **Disturbed Areas:** Including seasonally inundated drain that runs though the low-lying areas to the residue dam and the residue dam itself. The residue dam consists of elevated piles of bare sand and low lying flats covered in silt and sand. Some scattered low shrubs and sedges. Sections appear to be seasonally inundated and may form a shallow lake during the wetter months of the year (see Figure 2)

The location of "habitat" trees indentified on site during this survey and others reported by Bamford (2003) are shown in Figure 4.

Potentially, 20 native mammal (includes 9 bat species), 127 bird, 10 frog, 34 reptile and six fish species could be expected to occur in or utilise at times, the study area. Of the 197 native animals that are listed as potentially occurring at the site, eight are considered to be Endangered/Vulnerable or in need of special protection. In addition 7 migratory species may frequent the site at times. Ten DEC Priority species may also use the site. Eight introduced species may also be present.

The results of a targeted inspection of the site for evidence of WRP failed to find any sign of this species and it is concluded that they are not present on site or are only present rarely as transient individuals. The Southern Brush-tailed Phascogale was captured several times during the trapping program and its use of the site is now confirmed.

In summary, the vertebrate fauna species of conservation significance (listed on State or federal Threatened/Migratory species lists or DEC Priority species) that have been positively identified as utilising the MEA areas for some purpose during the various surveys of the site are:

- *Calyptorhynchus latirostris* Carnaby`s Cockatoo – S1/EN
  Known to utilise the area as foraging habitat. Unlikely to breed on site despite presence of a small number (2) of potential nest hollows identified.

- *Calyptorhynchus baudinii* Baudin`s Cockatoo - S1/VU
  Small amount of definitive foraging evidence observed during survey (number of chewed Marri nuts – see Plate 8). Unlikely to breed on site despite presence of a small number (2) of potential nest hollows identified.

- *Calyptorhynchus banksii naso* Forest Red-tailed Black Cockatoo – S1
  Known to utilise the area as foraging habitat. Unlikely to breed on site despite presence of a small number (2) of potential nest hollows identified.

- *Isoodon obesulus fusciventer* Quenda – P5
  Appears to be present in low numbers where dense groundcover present.

- *Phascogale tapoatafa ssp.* Southern Brush-tailed Phascogale - S1
  Captured during trapping program.

- *Macropus irma* Western Brush Wallaby - P4

Sighted during most recent survey. Present in low numbers.

Species of conservation significance that have been recorded in the KSS property (Banford 2003) but not in the MEA area, but can be considered to possibly utilise the MEA area for some purpose at times due to presence of at least marginal habitat:

- *Galaxiella nigrostriata* Black-striped Minnow – P3
  May frequent the low lying areas when seasonally inundated. Populations could however not persist on site.

- *Tringa hypoleucos* Common Sandpiper - Migratory
  Seasonal visitor to general area. May frequent the open (manmade) low lying areas when seasonally inundated.

- *Tringa nebularia* Common Greenshank - Migratory
  Seasonal visitor to general area. May frequent the open (manmade) low lying areas when seasonally inundated.

- *Merops ornatus* Rainbow Bee-eater – Migratory
  Common seasonal visitor to south west. May forage/roost in the study area.

- *Hydromys chrysogaster* Water Rat – P4
  May frequent the low lying areas when seasonally inundated. Populations could however not persist on site.

Species of conservation significance that have been recorded in the general area or have the potential to be present but to date have not been recorded within the KSS property or the MEA area are listed below. These species can be considered to possibly utilise the MEA area for some purpose at times due to presence of at least marginal habitat. The actual status of some species on site is uncertain:

- *Lerisita lineata* Perth Lined Lerista – P3
  Populations present in coastal areas nearby. Status onsite unknown.

- *Morelia spilota imbricata* Southern Carpet Python – S4/P4
  Potential for this species to be present in low densities.

- *Ardea alba* Great Egret – Migratory
  May frequent the open (manmade) low lying areas when seasonally inundated.

- *Ardea ibis* Cattle Egret - Migratory
  May frequent the open (manmade) low lying areas when seasonally inundated.

- *Falco peregrinus* Peregrine Falcon - S4
  Uncommon so unlikely to be resident in area but study site may form part of larger home range. No potential nest sites observed.

- *Botaurus poiciloptilus* Australasian Bittern – S1/VU
  Small amount of marginal habitat. Transient individuals may visit the site on occasions when seasonally inundated.

- *Ixobrychus flavicollis* Black Bittern - P2
  Small amount of marginal habitat. Transient individuals may visit the site on occasions when seasonally inundated.

- *Ixobrychus minutus* Little Bittern – P4
  Small amount of marginal habitat. Transient individuals may visit the site on occasions when seasonally inundated.

- *Plegadis falcinellus* Glossy Ibis - Migratory
  May rarely frequent the open (manmade) low lying areas when seasonally inundated.

- *Ninox connivens connivens* Barking Owl – P2
  May occasionally forage in general area though status onsite uncertain.

- *Tyto n. novaehollandiae* Masked Owl – P3
  May occasionally forage in general area though status onsite uncertain.

- *Apus pacificus* Fork-tailed Swift – Migratory
  Rare seasonal visitor. May forage in area but very unlikely to roost.

- *Dasyurus geoffroii* Chuditch - S1
  Targeted surveys have not identified this species on site, but its presence at times cannot be discounted.

- *Falsistrellus mackenziei* Western False Pipistrelle - P4
  May occasionally forage in general area. Status onsite uncertain.

Species of conservation significance that appeared in database searches, and while possibly present in the wider area in suitable habitat are not listed as potential species due to known localised extinction (and no subsequent recruitment from adjoining areas) and/or lack of suitable habitat and/or the presence of feral predators. Some may occur as rare vagrants:

- *Haliaeetus leucogaster* White-bellied Sea Eagle – Migratory
  May very occasionally fly over site but very unlikely to forage or nest onsite.

- *Pseudocheirus occidentalis* Western Ringtail Possum - S1/VU
  Majority of habitat is unsuitable or marginal quality for this species. Targeted surveys found no evidence of this species onsite. Transient individuals may very occasionally visit the site.

- *Setonix brachyurus* Quokka – S1/VU
  Locally extinct.

The survey work reported on here has confirmed the presence of the Southern Brush-tailed Phascogale and this should be taken into consideration during fauna management planning. While the results suggest that WRPs are not currently using the site, transient individuals may occasionally be present. It is also possible that the species status on site may change over time. It is therefore recommended that a precautionary approach be taken with respect to WRP management. Observations made during this most recent survey work also suggest Quenda are utilising select areas of the MEA in relatively low numbers and this fact will need to be incorporated into site planning.

1. INTRODUCTION

This report details the results of a Level 1 (EPA 2004) fauna assessment and a targeted fauna survey of the proposed mine extension area (MEA) at Kemerton Silica Sand Pty Ltd (KSS) operations. The site is located about 25 km north east of the Bunbury townsite and is centred at approximately 33.125093 °S and 115.772038 °E (Figure 1). The MEA has a total area of about 283 ha and is mostly covered with some form of native vegetation (Figure 2).

The MEA has been identified as containing a substantial silica sand resource required for the mine to continue operating in the long term. It is understood that mining of the MEA area will be occur in 5 ha stages with mined areas being progressively rehabilitated. The information obtained as part of the fauna assessment reported on here will be used, in conjunction with other studies, to obtain approvals and then facilitate the subsequent controlled and guided development of the subject site with the principal aim of minimising environmental impacts.

Several fauna assessments of KSS's land holdings have been carried out previously, the most recent being in 2004 where targeted surveys for the Chuditch and Carnaby's Black Cockatoo were undertaken by Bamford Consulting Ecologists (Bamford 2004a, Bamford 2004b).

It is understood that a more current review of the sites potential to host fauna of conservation significance is required and in particular the WRP and the Southern Brush-tailed Phascogale. An assessment of fauna species in general that use or may use the MEA was also required.

2. PREVIOUS VERTEBRATE FAUNA SURVEYS

Fauna surveys have been undertaken at KSS and the surrounding area over a number of years. Table 1 lists the 13 fauna studies which have been conducted within the KSS property.

Table 1: Previous Fauna Studies carried out on the KSS Property

No.	Author	Date	Title
1	M.J. Bamford and Ninox Wildlife Consulting	1993	Interim report: Vertebrate fauna of the Kemerton Silica Sand project.
2	Ninox Wildlife Consulting	Jan-93	Report: Vertebrate fauna assessment of the Kemerton Silica Sand project.
3	M.J. Bamford and Ninox Wildlife Consulting	Oct-93	Vertebrate fauna assessment of the Kemerton Silica Sand project.
4	Ninox Wildlife Consulting	Feb-94	The Kemerton Silica Sand project area: Vertebrate fauna assessments December 1992 - December 1993.
5	M.J. & A.R. Bamford, Consulting Ecologists	Jan-98	Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Programme; 1997.
6	M.J. & A.R. Bamford, Consulting Ecologists	Feb-99	Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Programme; 1998.
7	M.J. & A.R. Bamford, Consulting Ecologists	May-00	Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Programme; 1999.
8	M.J. & A.R. Bamford, Consulting Ecologists	Jul-01	Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Programme; 2000 - 2001.
9	M.J. & A.R. Bamford, Consulting Ecologists	Sep-02	Kemerton Silica Sand Pty Ltd: Summary report on Fauna Surveys; 2001 - 2002.
10	M.J. & A.R. Bamford, Consulting Ecologists	Feb-03a	Assessment of Fauna values in the KSS property.
11	M.J. & A.R. Bamford, Consulting Ecologists	Feb-03b	Kemerton Silica Sand Pty Ltd: Fauna Monitoring 18th December 2002.
12	M.J. & A.R. Bamford, Consulting Ecologists	May-04	The status of the Chuditch (*Dasyurus geoffroii*) in areas proposed for expansion by KSS.
13	M.J. & A.R. Bamford, Consulting Ecologists	Jun-04	The utilisation by short-billed black cockatoos (*Calyptorhynchus latirostris*) of the proposed dredge mining extension area of KSS.

MBS Environmental (2008) has reviewed all of the abovementioned reports and provide the following summary:

Fauna studies carried out in the Kemerton region include opportunistic observations, systematic searching, trapping for reptiles and mammals (approximately 1,000 trap nights in total at all sites at Kemerton) netting for bats and spotlighting. Fauna of the region is considered to be well documented.

Waterbird surveys involved a total count of all waterbird species present at each site. In addition, notes were made of their activity, such as roosting or foraging, and the habitat in which the birds are present. Breeding attempts (nests, eggs and/or dependent young) were also recorded (Bamford, 1997).

Sampling of fish involved the use of fish-traps and sweep-nets (Bamford, 1997). Four survey trips occurred every year at similar times to surveys undertaken in previous years, focusing on late summer/early autumn when most or all wetlands are dry, early winter when wetlands begin to fill, late winter/early spring when water levels are high and both waterbirds and Jollytails are breeding, and late spring/early summer when water levels are low. Trapping and netting were carried out for set time-periods so that sampling was standardised, but subsequent discussions with Dr Howard Gill (Murdoch University) suggested that such standardisation is of little value when sampling small freshwater fish in complex habitats (Bamford, 1997). This is because fish are unevenly distributed in different vegetation types, sampling efficiency varies with vegetation type and the density of the fish varies with the water level. In each wetland containing adequate water, two traps (baited with a mixture of Rabbit pellets and Dog biscuits) were set for 25 - 30 minutes and sweep-netting was carried out for two periods of 10 minutes (Bamford, 1997). Fish caught were measured as an indication of population structure and growth rates, with large numbers of captures being sub-sampled to avoid holding fish for too long (Bamford, 1997).

Bamford (2003) reviewed results of earlier studies focusing on areas of special interest in the western part of the KSS property. Bamford (2003) produced lists of fauna species present or expected to occur in the Kemerton region and specifically on the KSS property. Where species have not been recorded, but are expected to occur in the area, the preferred species habitat, where such preferences are known to be very specific, were also recorded. Bamford (2003) concluded that:

- The Kemerton region supports a rich fauna, because it includes a large area of remnant and regrowth native vegetation, while much of the surrounding coastal plain has been developed for agriculture.
- The area supports a high number of CS3 species, not formally recognised for conservation significance but are regionally important. In the Kemerton region, these species have declined elsewhere on the Swan Coastal Plain.
- Many species of conservation significance are present in the Kemerton region because it is one of the largest contiguous areas of native vegetation on the Swan Coastal Plain between Bunbury and Perth.

3. SCOPE OF WORKS

The general fauna assessment of the KSS property was carried out to comply with requirements of a Level 1 terrestrial fauna survey as defined in EPA Guidance Statement 56 (EPA 2004). This included a background research or 'desktop' study and reconnaissance survey. The reconnaissance survey included low intensity sampling of the fauna and faunal assemblages to provide habitat descriptions and habitat maps of the project area.

A significant amount of previous work in this area has already been carried out. The main aim of this level 1 assessment will be to highlight species that are most likely occur within the MEA at a more specific level while providing a more recent review of the status of species of conservation significance in the area if possible.

A targeted WRP survey was conducted to map potential WRP habitat (extent and quality) within the proposal area. The existing vegetation mapping (Mattiske Consulting Pty Ltd 2003) will be used as a base for the WRP habitat mapping. Other factors that affect the quality of WRP habitat (besides species composition) such as canopy connectivity/linkage and tree condition were recorded during a daytime field reconnaissance survey of the site though it should be noted that not all factors that influence the value of WRP habitat are readily observed e.g. nutritional value of leaves.

The targeted WRP survey also aimed to determine as accurately as possible the number and distribution of WRPs utilising the area. This part of the assessment included a daytime survey to locate and record dreys, tree hollows, scats and individual WRPs. This was followed by a single nocturnal count of potential WRP habitat within the proposal area. Because of the size of the site the nocturnal survey work was carried out over two nights (i.e. one half one night, the other half the next night).

This assessment is equivalent to a "preliminary WRP assessment" as defined by the Department of Environment and Conservation (DEC).

A targeted Southern Brush-tailed Phascogale survey was also conducted to map Potential Phascogale habitat (extent and quality). The existing vegetation mapping (Mattiske Consulting Pty Ltd 2003) was used as a base for the Phascogale habitat mapping. Other factors that affect the quality of habitat (besides species composition), based on documented descriptions, will be recorded during a daytime field reconnaissance survey of the site though it should be noted that not all factors that influence the value of habitat are readily observed.

Evidence of occurrence within the MEA will be carried out concurrent with other daytime and night time surveys and will aim to locate any evidence of the species presence i.e. scats, individuals. It should however be noted that it can be very difficult to find evidence of this species during day surveys and to a certain extent during night surveys especially if only present in low densities.

A Phascogale Trapping Program was conducted over four nights utilising baited Elliot and cage traps positioned in potential habitat.

4. METHODOLOGY

4.1 FAUNA INVENTORY

4.1.1 Potential Fauna

A list of all terrestrial vertebrate fauna potentially occurring within the study area was compiled from searches done on the WA Museum (WAM) database, the DEC's Threatened Fauna and 'NatureMap" database, the Department of the Environment, Water, Heritage and the Arts (DEWHA) Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* database, Birds Australia's 'Birdata" database, published and unpublished reports and specialist books detailing fauna of the general area.

Taxonomy and nomenclature for fauna species used in this report generally follow Aplin and Smith (2001) for amphibians and reptiles, How *et al*. (2001) for mammals and Johnstone (2001) for birds. Some names, including common names recommended for national and international use by Christidis and Boles (1994) for birds, are also used. Common names for reptiles and amphibians come from a variety of sources and are not necessarily generally accepted. Sources include Van Dyk & Strahan (2008), Bush *et al.* (2007), Wilson and Swan (2008), Bush *et al.* (2002), Tyler *et al.* (2000) and Glauret (1961)

4.1.2 Fauna of Conservation Significance

The conservation significance of fauna species has been assessed using data from the following sources:

- *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*). Administered by the Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA);

- *Western Australian Wildlife Conservation Act 1950 (WAWC Act).* Administered by the Western Australian Department of Environment and Conservation (DEC);

- Red List produced by the Species Survival Commission (SSC) of the World Conservation Union (also known as the IUCN Red List - the acronym derived from its former name of the International Union for Conservation of Nature and Natural Resources). The Red List has no legislative power in Australia but is used as a framework for State and Commonwealth categories and criteria; and the

- DEC Priority Fauna list. A non-legislative list maintained by the DEC for management purposes.

The *EPBC Act* also requires the compilation of a list of migratory species that are recognised under international treaties including the:

- Japan Australia Migratory Bird Agreement 1981 (JAMBA);
- the China Australia Migratory Bird Agreement 1998 (CAMBA);
- the Republic of Korea-Australia Migratory Bird Agreement 2007 (ROKAMBA); and
- the Bonn Convention 1979 (The Convention on the Conservation of Migratory Species of Wild Animals).

(Note - Species listed under JAMBA are also protected under Schedule 3 of the *WAWC Act*.)

All migratory bird species listed in the annexes to these bilateral agreements are protected in Australia as Matters of National Environmental Significance under the *EPBC Act*.

The conservation status of all the vertebrate fauna species listed as occurring or possibly occurring in the vicinity of the study area has been assessed using the most recent lists published in accordance with the above-mentioned Acts, International Agreements and DEC's priority fauna list. The status of each species as defined in the above mentioned acts is indicated in the fauna listings of this report. A full listing of conservation codes are held in Appendix A.

4.2 FAUNA RECONNAISSANCE SURVEY

4.2.1 Fauna Habitat Assessment

A habitat assessment was carried out specifically targeting the likely habitats of listed (under the relevant Federal and State Acts) Threatened vertebrate species potentially occurring in the study area. The aim of the habitat assessment was to determine if it was likely that any of the Threatened species would be utilising the areas that will be impacted on as a consequence of the sites development.

The initial phase of the assessment involved the review of available information on the habitats of the Threatened species listed as possibly occurring in the area. During the field survey the habitat within the study area was assessed and specific elements searched for to determine the potential that any of the listed Threatened species maybe utilising the area and its significance to them. In addition the habitat information obtained was used to aid in the compilation of a potential fauna list.

The vegetation communities (Mattiske Consulting Pty Ltd, 2003) present have been used as the basis for a classification into broad fauna habitats. In addition details on specific habitat components such as significant trees with hollows, loose bark, fallen hollow logs, and the amount of leaf litter were noted if present.

The location of habitat trees, in addition to those previously identified were recorded. For the purposes of this study a "habitat" tree was defined as generally any tree which is live or dead that contains one or more visible hollows (cavities within the trunk or branches) suitable for the occupation of hollow-dependent fauna as a nesting, roosting and/or denning site.

The assessment of hollows was conducted from ground level. Because it is impossible to determine all the characteristics of hollows that are favoured by fauna species, the assessment of suitability was based entirely on the size of each hollow's entrance. The trees identified should only be taken as representing a guide to the distribution and abundance of habitat trees on site. It was beyond the scope of this report (and those previously undertaken) to examine every tree onsite from every angle, for hollows.

4.2.2 Opportunistic Fauna Observations

Opportunistic observations of fauna species were made during daytime surveys of the site. The surveys included a series of transects across the site while searching for fauna or signs of fauna and observations of bird species with binoculars. The diurnal searches were carried out on foot using a GPS equipped PDA for guidance and as a data recorder.

4.3 TARGETED FAUNA SURVEYS

4.3.1 Western Ringtail Possum and Phascogale Daytime Survey

Diurnal inspections of the site were conducted on foot over the study area on January 28th and 29th, 2009 for a total period of about 10 hours.

During the course of the opportunistic fauna survey the presence of dreys, obvious tree hollows (in addition to those already recorded and other potential refuge sites), scats and individuals of these species was specifically searched for and if found their location recorded. The diurnal searches were carried out on foot using a GPS equipped PDA for guidance and as a data recorder.

4.3.2 Western Ringtail Possum and Phascogale Nocturnal Survey

Nocturnal surveys of potential WRP and Phascogale habitat were carried out on the 28th January and the 2nd February 2009. Nocturnal counts involved systematic searching of potential WRP/Phascogale habitats within the proposal area along close spaced traverses, on foot using a head torch (with 6V incandescent bulb). The nocturnal counts were carried out using a GPS equipped PDA for guidance and as a data recorder. Suitable habitat within the proposal area was searched once over a two night period. The survey work involved about 17km of transects on foot over a period of approximately 8 hours.

4.3.3 Phascogale Trapping Program

The trapping program for Phascogales was carried out between the 2nd and 6th of February 2009. The trapping program utilised 60 Elliot traps and four cage traps placed within woodland habitats across the site. Traps were preferentially placed at the base of habitat trees. Traps were be baited with standard universal bait and left open for four nights.

5. SURVEY CONSTRAINTS

The assessment reported on here has included a desktop analysis, a daytime site reconnaissance survey that included opportunistic fauna observations, a night time survey of the site and a four night trapping program using Elliot's and cage traps. A significant number of previous surveys have also been carried out on site or in the vicinity.

Fauna species are indicated as potentially present within this report based on there being suitable (quality and extent) habitat within the study area. With respect to opportunistic observations, the possibility exists that certain species may not have been detected during field investigations due to:

- seasonal inactivity during field survey;
- species present within micro habitats not surveyed;
- cryptic species able to avoid detection;
- transient wide-ranging species not present during survey period.

The lack of observational data on some species should therefore not be taken as necessarily indicating that a species is absent from the site.

In recognition of the survey limitations a precautionary approach has been adopted for this assessment. Any fauna species that would possibly occur within the study area as identified through ecological databases, publications, discussions with local experts/residents and the habitat knowledge of the Author has been assumed to potentially occur in the study area.

Field survey work was carried out by Greg Harewood (B.Sc. Zoology) on a number of days and nights between the 28th January 2009 and the 6th February 2009.

The fauna survey was carried out under a license issued by the DEC (# SF006756).

6. RESULTS

6.1 REGIONAL BIOLOGICAL CONTEXT

The project area is situated near the western margin of the southern Swan Coastal Plain. The Swan Coastal Plain Bioregion (SWA) is classified as part of the Interim Biogeographical Regionalisation for Australia. The SWA bioregion is described as being a low lying coastal plain mainly covered with Woodlands, dominated by Banksia or Tuart on sandy soils, *Casuarina obesa* on outwash plains, and paperbark in swampy areas. In the east, the plain rises to duricrusted Mesozoic sediments dominated by Jarrah Woodland. The climate is warm Mediterranean. Three phases of marine sand dune development characterise the surface geology. As a consequence of significant clearing, the outwash plains, once dominated by *Casuarina obesa* – Marri Woodlands and Melaleuca shrublands, are extensive only in the south. (Thackway and Cresswell, 1996; IBRA, 2000).

The site falls within the Bassendean Vegetation Complex (central and south) as defined by Heddle *et al*. (1980). This complex is defined in general terms as consisting of vegetation that ranges between woodlands of Jarrah (*Eucalyptus marginata*), Sheoak (*Allocasuarina fraseriana*) and *Banksia* species to low woodland of *Melaleuca* species and sedgelands on the moister sites.

6.2 FAUNA HABITAT ASSESSMENT

6.2.1 Fauna Habitats

The extent of vegetation communities within the KSS property including the MEA are shown in Figure 3. The broadly defined fauna habitats within the study area, based on vegetation structure are described below:

1. **Open Woodland of Jarrah (*Eucalyptus marginata*) and Banksia species over shrubland (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities A1, A2 and A3):** Characteristic vegetation type found on most of the raised mosaic of subtle Bassendean dunes in the study area. Density of trees and understory/ground cover varies considerably across the site. *Kunzea ericifolia* represents a common understory plant, in some places forming a dense tall shrubland, with only scattered emergent trees. Ground cover is variable with significant areas covered only with sparse low shrubland, grasses or bare sand. The density of hollow trees is variable (see Figure 4). Significant portions appear to be regrowth from an historical clearing event as evidenced by old piles of significant size trees scattered throughout the area. Apart from these, fallen hollow logs are rare (Plate 1).

2. **Woodland to Forest of Peppermint (*Agonis flexuosa*) (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities C1 and C2):** Very limited extent with the study area. Unit C1 represents sparse Peppermint **(*Agonis flexuosa*)** in association with Jarrah **(*Eucalyptus marginata*)** over grassland. Unit C2 is denser and Peppermint grows in association with occasional *Banksia attenuata*, *Banksia ilicifolia* and *Nuytsia floribunda* over mixed shrubs. Hollow trees and fallen logs are rare (Plate 2).

3. **Woodland of Flooded Gum (*Eucalyptus rudis)* - *Melaleuca preissiana* and occasional *Banksia littoralis* over Myrtaceae spp. over mixed sedges (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Community D2):** Confined to a small area near the far western boundary of the MEA. Some hollows found both in *E. rudis* and older Melaleuca specimens. An understory of medium to low shrubs when present is dense. Some seasonal waterlogging is evident (Plate 3).

4. **Low Woodland of *Melaleuca preissiana* and occasional *Nutsia floribunda* over *Hypocalymma angustifolium, Pelicalymma ellipticum* and mixed shrubs over mixed sedges (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Community E2):** Limited extent in study area. Represents low lying areas subject to seasonal waterlogging and possibly inundation in wetter years (Plate 4). Provides potential habitat for fish and breeding amphibian species for limited period of the year.

5. **Low Woodland to Forest of *Melaleuca rhaphiophylla over mixed sedges or Baumea articulata (mapped* by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities F1 or F3):** Found in low lying areas that are seasonally inundated or waterlogged: Limited extent. Represents sumpland wetland type (Plate 5). Represents the lowest lying areas within the MEA and therefore has the potential to provide longer term refuge for species that require flooded or waterlogged environments to breed or persist.

6. **Tall Shrublands and Shrubland dominated by *Kunzea ericifolia* or *Hakea varia* (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities G1 and G3):** Limited extent. Found in or bordering lower lying areas (Plate 6).

7. **Low Closed Heath to Closed Heath of Myrtaceae spp. (mapped by Mattiske Consulting Pty Ltd (2003) as Vegetation Communities H1, H2 and H3):** Dominant vegetation type over the low lying Dampland areas. The majority is a closed heath of *Melaleuca lateritia* and *Astartea fascicularis* over *Lepidosperma longitudinale* and *Leptocarpus tenax* (Plate 7).

8. **Disturbed Areas:** Including seasonally inundated drain that runs though the low-lying areas to the residue dam and the residue dam itself. The residue dam consists of elevated piles of bare sand and low lying flats covered in silt and sand. Some scattered low shrubs and sedges. Sections appear to be seasonally inundated and may form a shallow lake during the wetter months of the year (see Figure 2)

Plates 1 to 7 illustrate the nature of major vegetation units/habitats existing within the study area.

The location of "habitat" trees indentified on site during this survey and others reported by Bamford (Bamford 2003) are shown in Figure 4. Hollows with entrances considered large enough to allow the entry of a cockatoo (as identified by Bamford 2003) are also shown. Habitat tree coordinates are listed in Appendix B.

Hollows are an import resource as many fauna species utilise them for day to day refuge and as breeding sites. In this area of the south west, hollows have the potential to be used by a range of fauna including, but not limited to, the three Black Cockatoo species, Common Brushtail Possums, Brush-tailed Phascogales, Galahs, Regent Parrots, Australian Ringneck Parrots, Red-capped Parrots, Western Rosellas, Elegant Parrots, Boobook Owls, Australian Owlet-nightjars, Sacred Kingfishers, Striated Pardalotes and Tree Martins.

6.3 FAUNA INVENTORY

6.3.1 Opportunistic Fauna Surveys

The results of the opportunistic fauna survey are summarised in Table 1 and listed in Appendix C. A total of 47 fauna species were observed (or positively identified from foraging evidence, scats, tracks, skeletons or calls) within the study area during the reconnaissance and trapping surveys carried out on the site between the 28th January and the 6th of February 2009. Evidence of four listed Threatened species was observed (Carnaby's Cockatoo – sighted and foraging evidence, Baudin's Cockatoo – foraging evidence, Forest Red-tailed Black Cockatoo - sighted and foraging evidence, Southern Brush-tailed Phascogale – captured). No migratory species were observed. A single DEC Priority species was observed (Western Brush Wallaby) and evidence of another species found (Southern Brown Bandicoot – tracks and diggings).

6.3.2 Potential Fauna

Table 2 summarises the numbers of potential species based on vertebrate class. A complete list of terrestrial vertebrate fauna possibly inhabiting or utilising the site at times is provided in Appendix C. The results of a DEC Threatened fauna database search are provided in Appendix D.

Details on specially protected, migratory and priority species expected and/or listed as potentially occurring in the general area is given in Table 3 and Appendix E.

Not all species listed in existing databases and publications as potentially occurring within the study area (i.e. *EPBC Act's* Threatened Fauna and Migratory species lists, DEC's Threatened Fauna Database and various publications) are shown in the expected listing in Appendix C. Some species have been excluded from this potential species list based largely on the lack of suitable habitat at the study site and in the general area or known local extinction.

Despite the omission of some species It should be noted that the list provided is very likely still an over estimation of the fauna species utilising the site (either on a regular of infrequent basis) as a result of the precautionary approach adopted for the assessment.

Table 2: Summary of Potential Fauna Species (As listed in Appendix C)

Group	Total number of potential species	Potential number of specially protected species	Potential number of migratory species	Potential number of priority species	Number of species observed Jan/Feb 09	Number of species previously recorded at KSS
Fish	7^{1}	0	0	1	0	5^{1}
Amphibians	10	0	0	0	0	8
Reptiles	34	1	0	1	4	13
Birds	128^{1}	5	7	4	35^{1}	76^{1}
Non-Volant Mammals	17^{6}	2	0	3	8^{3}	11^{5}
Volant Mammals (Bats)	9	0	0	1	0	0
Total	205^{8}	8	7	10	47^{4}	113^{7}

Superscript = number of introduced species included in total.

6.3.3 Fauna of Conservation Significance

A search of *EPBC Act's* Threatened Fauna list, DEC's Threatened Fauna Database and Priority List and scientific publications listed twenty eight specially protected, priority or migratory fauna species as possibly occurring in the general study area. Species that have no potential whatsoever, under normal circumstances, to utilise the site for any purpose or would only occur as rare vagrants are not listed as expected or discussed. Other species have been omitted from the potential list (Appendix C) for the site principally due to lack of suitable habitat or known local extinction (e.g. Quokka). A brief account of those significant species most likely to occur in the area or those that have previously been recorded in the vicinity along with details on their distribution and habitat preference are shown in Table 3. Additional details on these same species are given in Appendix E.

In summary, the vertebrate fauna species of conservation significance (listed on state or federal Threatened/Migratory species lists or DEC priority species) that have been positively identified as utilising the MEA areas for some purpose during the various surveys of the site are:

- *Calyptorhynchus latirostris* Carnaby`s Cockatoo – S1/EN
  Known to utilise the area as foraging habitat. Unlikely to breed on site despite presence of a small number (2) of potential nest hollows identified.

- *Calyptorhynchus baudinii* Baudin`s Cockatoo - S1/VU
  Small amount of definitive foraging evidence observed during survey (number of chewed Marri nuts – see Plate 8). Unlikely to breed on site despite presence of a small number (2) of potential nest hollows identified.

- *Calyptorhynchus banksii naso* Forest Red-tailed Black Cockatoo – S1
  Known to utilise the area as foraging habitat. Unlikely to breed on site despite presence of a small number (2) of potential nest hollows identified.

- *Isoodon obesulus fusciventer* Quenda – P5
  Appears to be present in low numbers where dense groundcover present.

- *Phascogale tapoatafa ssp.* Southern Brush-tailed Phascogale - S1
  Captured during trapping program.

- *Macropus irma* Western Brush Wallaby - P4
  Sighted during most recent survey. Present in low numbers.

Species of conservation significance that have been recorded in the KSS property but not in the MEA area, but can be considered to possibly utilise the MEA area for some purpose at times due to presence of at least marginal habitat:

- *Galaxiella nigrostriata* Black-striped Minnow – P3
  May frequent the low lying areas when seasonally inundated. Populations could however not persist on site.

- *Tringa hypoleucos* Common Sandpiper - Migratory

Seasonal visitor to general area. May frequent the open (manmade) low lying areas when seasonally inundated.

- *Tringa nebularia* Common Greenshank - Migratory
  Seasonal visitor to general area. May frequent the open (manmade) low lying areas when seasonally inundated.

- *Merops ornatus* Rainbow Bee-eater – Migratory
  Common seasonal visitor to south west. May forage/roost in the study area.

- *Hydromys chrysogaster* Water Rat – P4
  May frequent the low lying areas when seasonally inundated. Populations could however not persist on site.

Species of conservation significance that have been recorded in the general area or have the potential to be present but to date have not been recorded within the KSS property or the MEA area are listed below. These species can be considered to possibly utilise the MEA area for some purpose at times due to presence of at least marginal habitat. The actual status of some species on site is uncertain:

- *Lerisita lineata* Perth Lined Lerista – P3
  Populations present in coastal areas nearby. Status onsite unknown.

- *Morelia spilota imbricata* Southern Carpet Python – S4/P4
  Potential for this species to be present in low densities.

- *Ardea alba* Great Egret – Migratory
  May frequent the open (manmade) low lying areas when seasonally inundated.

- *Ardea ibis* Cattle Egret - Migratory
  May frequent the open (manmade) low lying areas when seasonally inundated.

- *Falco peregrinus* Peregrine Falcon - S4
  Uncommon so unlikely to be resident in area but study site may form part of larger home range. No potential nest sites observed.

- *Botaurus poiciloptilus* Australasian Bittern – S1/VU
  Small amount of marginal habitat. Transient individuals may visit the site on occasions when seasonally inundated.

- *Ixobrychus flavicollis* Black Bittern - P2
  Small amount of marginal habitat. Transient individuals may visit the site on occasions when seasonally inundated.

- *Ixobrychus minutus* Little Bittern – P4

Small amount of marginal habitat. Transient individuals may visit the site on occasions when seasonally inundated.

- *Plegadis falcinellus* Glossy Ibis - Migratory
  May rarely frequent the open (manmade) low lying areas when seasonally inundated.

- *Ninox connivens connivens* Barking Owl – P2
  May occasionally forage in general area though status onsite uncertain.

- *Tyto n. novaehollandiae* Masked Owl – P3
  May occasionally forage in general area though status onsite uncertain.

- *Apus pacificus* Fork-tailed Swift – Migratory
  Rare seasonal visitor. May forage in area but very unlikely to roost.

- *Dasyurus geoffroii* Chuditch - S1
  Targeted surveys have not identified this species on site, but its presence at times cannot be discounted.

- *Falsistrellus mackenziei* Western False Pipistrelle - P4
  May occasionally forage in general area. Status onsite uncertain.

Species of conservation significance that appeared in database searches, and while possibly present in the wider area in suitable habitat are not listed as potential species due to known localised extinction (and no subsequent recruitment from adjoining areas) and/or lack of suitable habitat and/or the presence of feral predators. Some may occur as rare vagrants:

- *Haliaeetus leucogaster* White-bellied Sea Eagle – Migratory
  May very occasionally fly over site but very unlikely to forage or nest onsite.

- *Pseudocheirus occidentalis* Western Ringtail Possum - S1/VU
  Majority of habitat is unsuitable or marginal quality for this species. Targeted surveys found no evidence of this species onsite. Transient individuals may very occasionally visit the site.

- *Setonix brachyurus* Quokka – S1/VU
  Locally extinct.

6.4 TARGETED FAUNA SURVEYS

6.4.1 Western Ringtail Possum and Phascogale Daytime Survey

No direct or indirect evidence of either targeted species was found during the survey period. A number of habitat trees additional to that previously identified were recorded (Figure 4). Evidence of the Common Brushtail Possum was found at several locations in the form of scats.

The vegetation units present on the site are shown in Figure 3. The vegetation unit that has the highest potential WRP habitat quality is Vegetation Community C2 which consists of and Open Woodland of *Agonis flexuosa*, with occasional *Banksia attenuata*, *Banksia ilicifolia* and *Nuytsia floribunda* over mixed shrubs. This unit has a limited extent in the study area (~4 ha). The other vegetation unit containing Peppermint (C1) was found to only contain a small number of wide spaced Peppermints and its value as WRP habitat is considered to be relatively low in comparison.

The Jarrah/Banksia Woodland to Open Woodland Vegetation Communities present within the study area (A1 and A2 – Figure 3) is variable in its structure and composition. Some areas consist of very few significant sized trees and are dominated by tall shrubland. Canopy connectivity between trees is generally discontinuous and WRPs moving through the area would need to come to ground frequently. Overall the quality of the Jarrah/Banksia Woodland areas as WRP habitat is low to marginal. While some sections could possibly support WRPs, the carry capacity would be very low (<0.25 WRP/ha). The long term persistence of a population of WRPs within the MEA would need a reliable supply of individuals from adjoining, better quality habitat, which may or may not be present, possibly to the west.

Other vegetation units with the study area have little or no value as WRP habitat except possibly for dispersal habitat, depending on the vegetation structure present. Low shrubland and heaths which make up a significant proportion of the vegetation on site have no WRP habitat value.

The documented preferred habitats of the Southern Brush-tail Phascogale are forests and open woodlands that contain hollow-bearing trees generally with a sparse ground cover. The site inspections suggest that almost all of the Jarrah/Banksia Woodland to Open Woodland Vegetation Communities present within the study area (A1 and A2 – Figure 3) represent potential Phascogale habitat. Areas containing the highest densities of habitat trees may represent the best quality habitat though other less obvious factors may also be important. The study area was also found to contain many log piles made up of large trees previously cleared. These may also be used by Phascogales as daytime refuge sites, in addition to the mapped habitat trees.

6.4.2 Western Ringtail Possum and Phascogale Nocturnal Survey

No sightings of either species were made during the course of the nocturnal surveys. The only species of interest sighted were Common Brushtail Possums (3), Southern Boobook Owls (2) and a Tawny Frogmouth (1).

6.4.3 Phascogale Trapping Program

The locations of each of the 60 small Elliot traps (Elliot A's) and three cage traps are shown in Figure 5 (total - 252 trap nights). In total two Phascogales were captured. Evidence of a Phascogale was also found in a closed trap (scats, fur), though this was likely left by the same individual captured on the subsequent night, at the same location.

7. CONCLUSION

Potentially, 20 native mammal (includes 9 bat species), 127 bird, 10 frog, 34 reptile and six fish species could be expected to occur in or utilise at times, the study area. Of the 197 native animals that are listed as potentially occurring at the site, eight are considered to be Endangered/Vulnerable or in need of special protection. In addition 7 migratory species may frequent the site at times. Ten DEC priority species may also use the site. Eight introduced species may also be present.

The survey work reported on here has confirmed the presence of the Southern Brush-tailed Phascogale and this should be taken into consideration during fauna management planning. While the results suggest that WRPs are not currently using the site, transient individuals may occasionally be present. It is also possible that the species status on site may change over time. It is therefore recommended that a precautionary approach be taken with respect to WRP management. Observations made during this most recent survey work also suggest Quenda are utilising select areas of the MEA in relatively low numbers and this fact will need to be incorporated into site planning.

8. REFERENCES

(not necessarily cited)

360 Environmental Pty Ltd (2008). Southern Seawater Desalination Project 2007, Terrestrial Flora and Fauna Survey Report. Unpublished report for the Water Corporation.

ATA Environmental (2006). Kemerton Power Station Reserve Vegetation, Flora and Fauna Assessment. Unpublished report for Transfield Services Kemerton Pty Ltd. May 2006.

Allen, G.R., Midgley, S.H., Allen, M. (2003). Freshwater Fishes of Australia. Western Australian Museum, Perth, Western Australia.

Aplin, K.P. and Smith, L.A. (2001). Checklist of the frogs and reptiles of Western Australia, Records of the Western Australian Museum Supplement No. 63, 51-74.

Bamford Consulting Ecologists (2008). Fauna Assessment of the Proposes South Binningup Development. Unpublished report for RPS Consulting/Mirvac.

Bamford, M.J. and Watkins, D. (1983). Kemerton Wetlands; the Vertebrate Fauna and its Regional Significance. Unpublished report to Alcoa of Australia, Perth.

Bamford, M.J. and Bamford, A.R. (1998). Kemerton Silica Sands Mine. Annual report on fauna monitoring programme; 1997. Unpublished report by Bamford Consulting Ecologists for Arbotech, Perth.

Bamford, M.J. and Bamford, A.R. (1999a). Kemerton Silica Sands Mine. Annual report on fauna monitoring programme; 1998. Unpublished report by Bamford Consulting Ecologists for Ecos Consulting, Perth.

Bamford, M.J. and Bamford, A.R. (1999b). Kemerton Fauna Study and Review, 1998. Unpublished report by Bamford Consulting Ecologists for Muir Environmental.

Bamford, M.J. and Bamford, A.R. (1999c). Fauna survey of the Gwindinup area. Unpublished report to Cable Sands WA, Bunbury.

Bamford, M.J. and Bamford, A.R. (2003). Assessment of Fauna values in the KSS Property. Unpublished report by Bamford Consulting Ecologists, prepared for Kemerton Silica Sand Pty Ltd.

Bamford, M.J. and Bamford, A.R. (2004a). The status of the Chuditch (*Dasyurus geoffroyi*) in areas proposed for expansion by Kemerton Silica

Sands. Unpublished report by Bamford Consulting Ecologists, prepared for Kemerton Silica Sand Pty Ltd.

Bamford, M.J. and Bamford, A.R. (2004b). The utilisation by Short-Billed Black Cockatoos (*Calyptorhynchus latirostris*) of the proposed dredge mining extension area of Kemerton Silica Sands. Unpublished report by Bamford Consulting Ecologists, prepared for Kemerton Silica Sand Pty Ltd.

Barrett, G. *et al* (2003). The New Atlas of Australian Birds. Royal Australian Ornithologists Union, Hawthorn East.

Bush, B., Maryan, B., Browne-Cooper, R. & Robinson, D. (2002). Reptiles and Frogs of the Perth Region. UWA Press, Nedlands.

Bush, B., Maryan, B., Browne-Cooper, R. & Robinson, D. (2007). Reptiles and Frogs in the Bush: Southwestern Australia. UWA Press, Nedlands.

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

Coffey Environments (2007). Kemerton Industrial Park, Environmental Overview for the KIP Strategy Plan. November 2007 Report 2006/117

Cogger, H.G., (1975). Reptiles and Amphibians of Australia. Reed, Sydney.

Dell, J. (2000). A draft summary assessment of the fauna values of the Kemerton Bushland. Unpublished report for the Conservation Branch, Policy Division, Department of Environmental Protection.

Department of Environmental Protection (2000). Bush Forever Volume 1. Policies, Principles and Processes. Government of Western Australia.

Environmental Protection Authority (2002). Terrestrial Biological Surveys As An Element of Biodiversity Protection. Position Statement No. 3. EPA, Perth.

Environmental Protection Authority (2003). Greater Bunbury Region Scheme – EPA Bulletin 1108. EPA, Perth.

Environmental Protection Authority (2004). Guidance for the Assessment of Environmental Factors - Terrestrial fauna surveys for environmental impact assessment in Western Australia. Guidance Statement No 56 EPA, Perth.

Glauret, L. (1961). A Handbook of the Lizards of Western Australia. Handbook 6, Western Australian Naturalists Club, Perth.

Government of Western Australia (1998). Perth Bushplan

Government of Western Australia (2000a). Bush Forever Volume 1. Policies, Principles and Processes. Department of Environmental Protection Perth, Western Australia.

Government of Western Australia (2000b). Bush Forever Volume 2. Directory of Bush Forever Sites. Department of Environmental Protection Perth, Western Australia.

How, R., Cooper, N.K. and Bannister, J.L. (2001). Checklist of the mammals of Western Australia, Records of the Western Australian Museum Supplement No. 63, 91-98.

Johnstone, R.E. (2001). Checklist of the birds of Western Australia, Records of the Western Australian Museum Supplement No. 63, 75-90.

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

Johnstone, R.E. and Storr, G.M. (2004). Handbook of Western Australian Birds: Volume 2 – Passerines (Blue-winged Pitta to Goldfinch). Western Australian Museum, Perth Western Australia.

Johnstone, R. E. (2008). Assessment of Potential Impact to Carnaby's Cockatoo and Baudin's Cockatoo for Southern Seawater Desalination Plant Binningup to Harvey. Prepared for URS Australia Pty Ltd.

Morcombe, M. (2004). Field Guide to Australian Birds. Steve Parish Publishing, Archerfiled, Queensland.

Morgan, D.L., Gill, H.S. and Potter, I.C. 1998. Distribution, identification and biology of freshwater fish in south-western Australia. Records of the Western Australian Museum Supplement No. 56.

Menkhorst, P.and Knight, F. (2001). A Field Guide to the Mammals of Australia. Oxford University Press, Melbourne.

Nevill, S (ed) (2005). Guide to the Wildlife of the Perth Region. Simon Nevill Publications, Perth.

Ninox Wildlife Consulting. (1994). The Kemerton Silica Sands Project Area. Vertebrate Fauna Assessments December 1992 – December 1993. Unpublished report prepared for Kemerton Silica Sand Pty Ltd.

Nowicki, A. (2007) Analysis of Capture Data: a case study using Program MARK for analysis of brushtail possum trapping data and its relevance to conservation management of the western ringtail possum. Thesis for Honours degree, Murdoch University.

Simpson, K. and Day, N. (2004). Field Guide to the Birds of Australia. Penguin Books, Ringwood.

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

Storr, G.M., Smith, L.A. and Johnstone R.E. (1990). Lizards of Western Australia III: Geckos and Pygopods. WA Museum, Perth.

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

Storr, G.M., Smith, L.A. and Johnstone R.E. (2002). Snakes of Western Australia. Revised Edition, WA Museum, Perth.

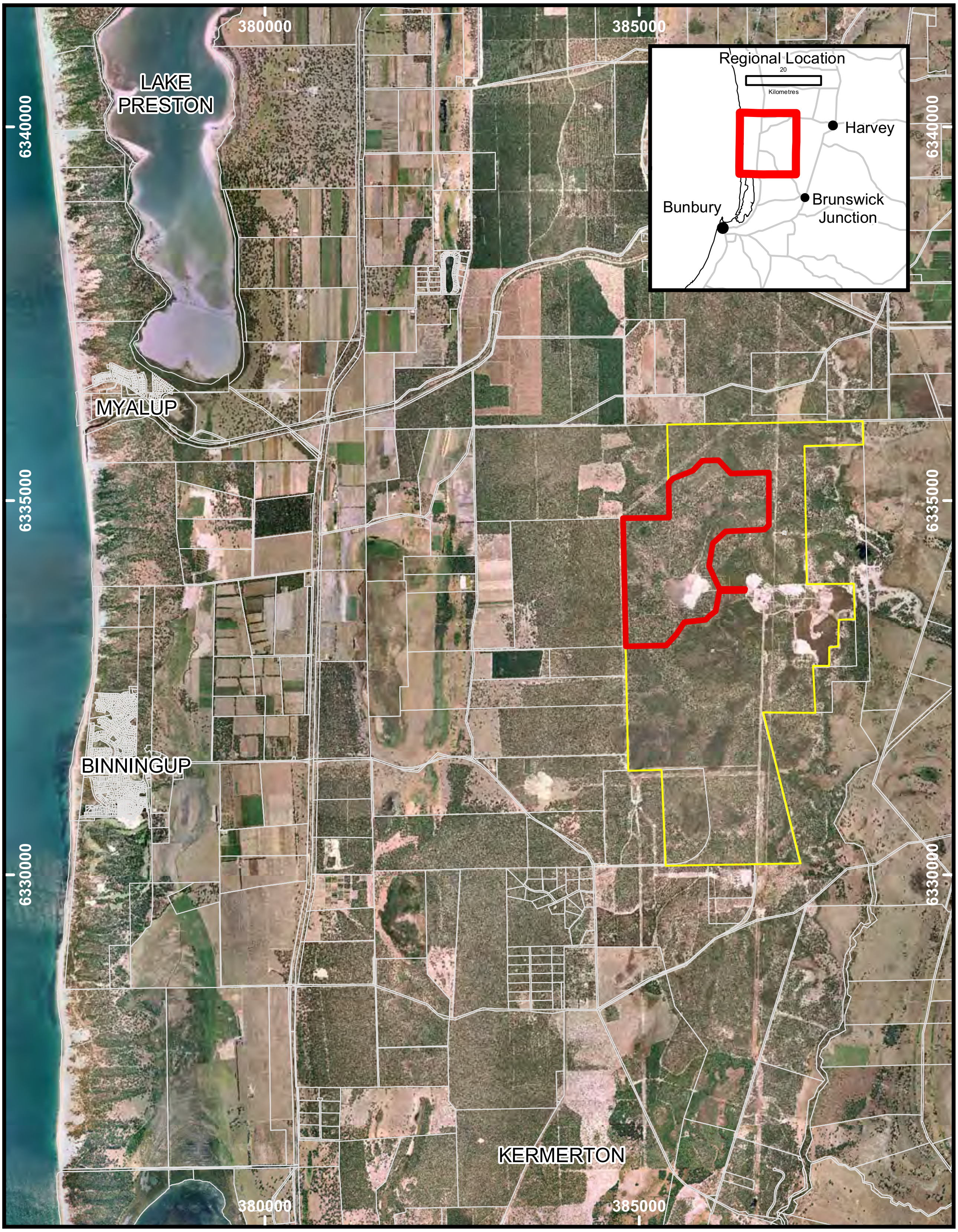
Tyler M.J., Smith L.A. and Johnstone R.E. (2000). Frogs of Western Australia, Revised Edition, WA Museum, Perth.

Thackway, R. and Cresswell, I.D. (1995). An Interim Biogeographic Regionalisation for Australia. Australian Nature Conservation Agency, Canberra.

Van Dyk, S. & Strahan, R. Eds (2008) The Mammals of Australia. Third edition Queensland Museum.

Wilson, S. and Swan, G. (2008) A Complete Guide to Reptiles of Australia. Reed, New Holland, Sydney.

FIGURES



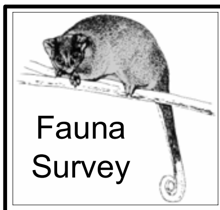
Legend

KSS Property Boundary

Mine Extension Area

0 1 2 3 4 5

Kilometres



DRAWN: G Harewood

DATE : Feb 2009

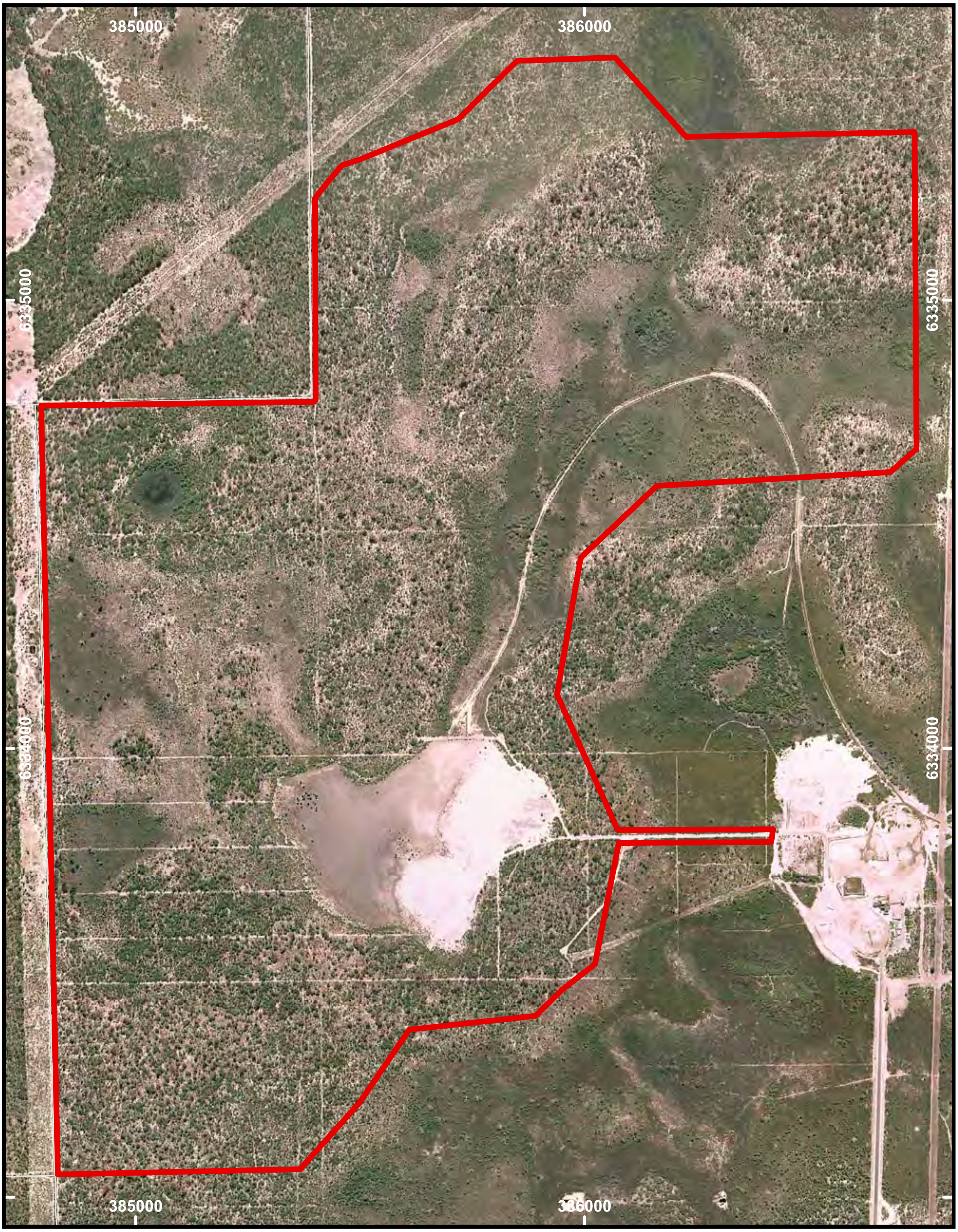
SCALE: 1: 75,000

MGA Zone 50

Kemerton Silica Sand Pty Ltd
Mine Extension Area

Study Area and Surrounds

Figure: 1



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Mine Extension Area

0 100 200 300 400 500
Metres

Fauna Survey

DRAWN: G Harewood

DATE : Feb 2009

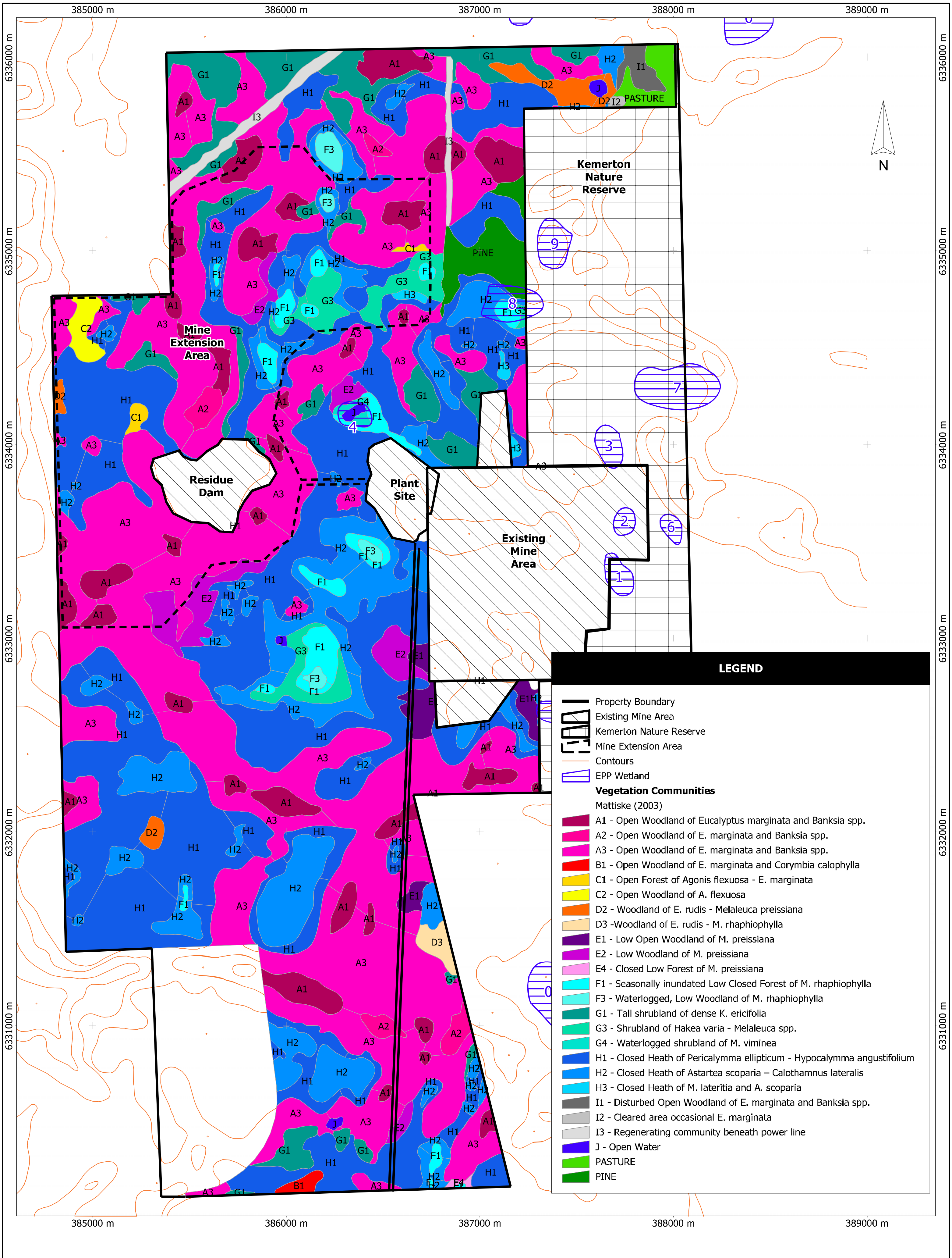
SCALE: 1: 12,500

MGA Zone 50

Kemerton Silica Sand Pty Ltd
Mine Extension Area

Study Area
Air Photo

Figure: 2



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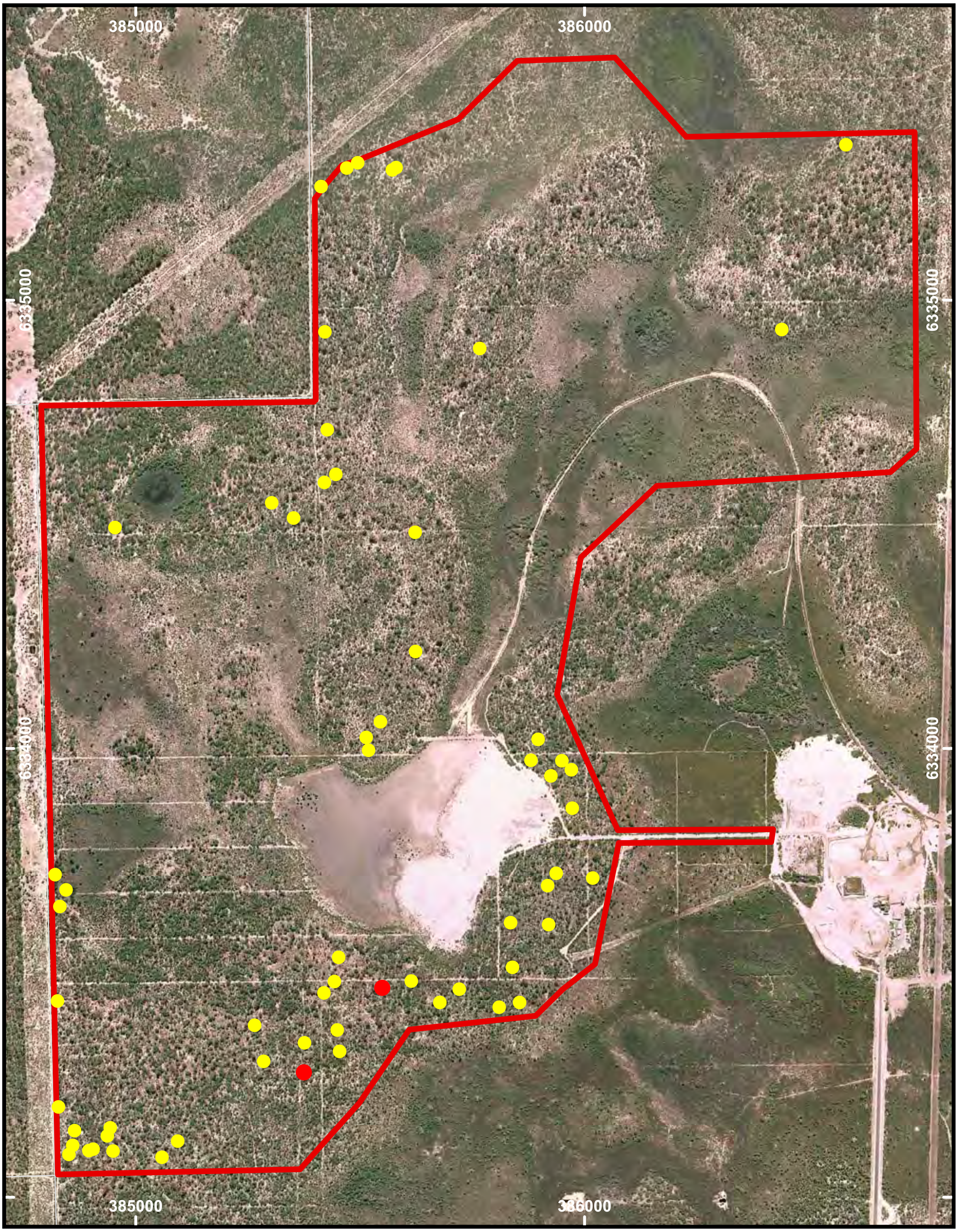
Scale: 1:30,000
Original Size: A3
Grid: Australia GDA94 (50)

0 500 m

Kemerton Silica Sand Pty Ltd

Vegetation Communities within the KSS Property

Figure 3



Legend

Mine Extension Area

Potential Cockatoo Nest Hollows

Habitat Trees

N

0 100 200 300 400 500

Metres

Fauna Survey

DRAWN: G Harewood

DATE : Feb 2009

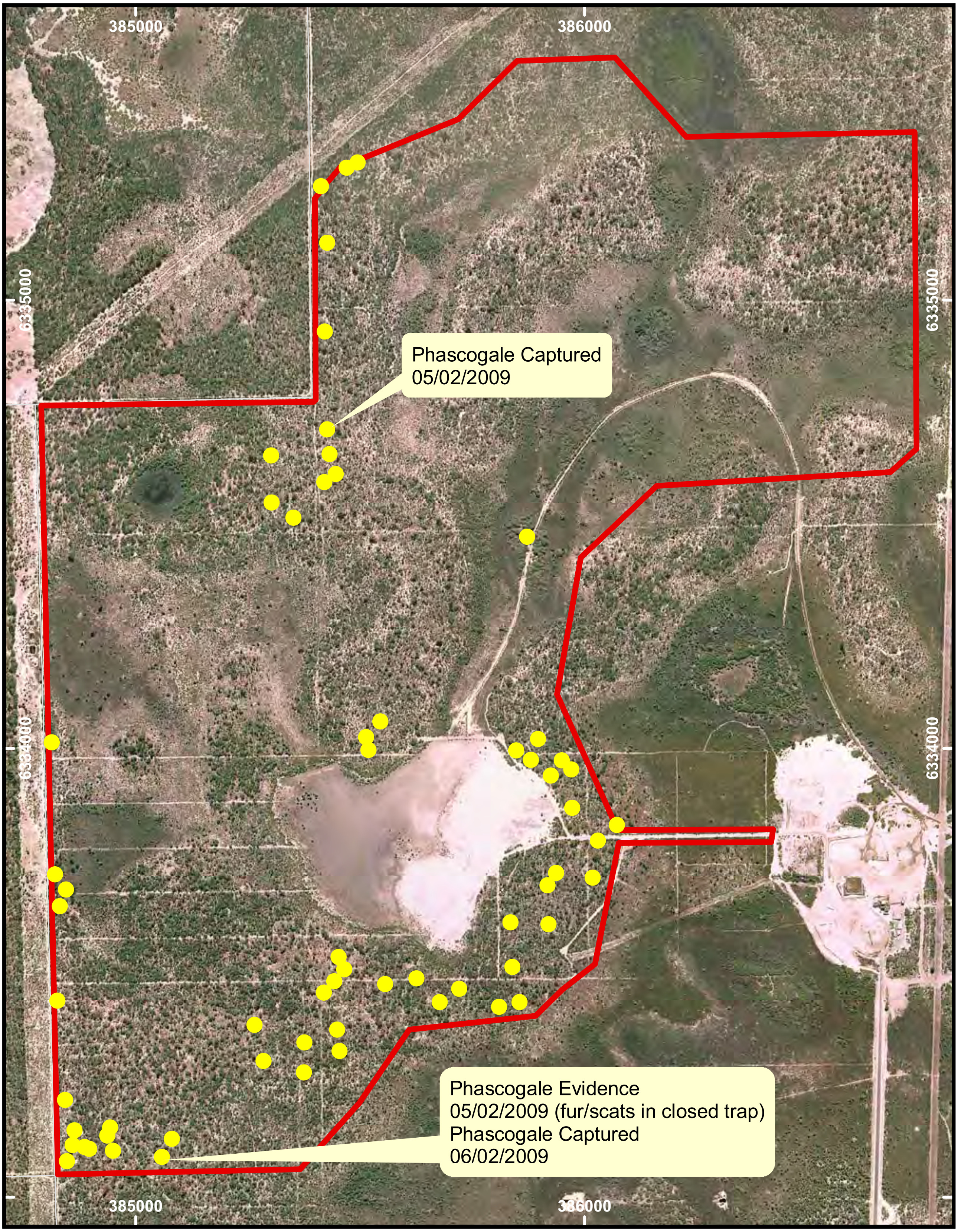
SCALE: 1: 12,500

MGA Zone 50

Kemerton Silica Sand Pty Ltd
Mine Extension Area

Habitat Trees
Indentified to Date

Figure: 4



Legend

Mine Extension Area

Trap Sites

0 100 200 300 400 500

Metres

Fauna Survey

DRAWN: G Harewood

DATE : Feb 2009

SCALE: 1: 12,500

MGA Zone 50

Kemerton Silica Sand Pty Ltd
Mine Extension Area

Phascogale Survey Trap Locations & Captures

Figure: 5

PLATES

Plate 1: Open Woodland of Jarrah (*E. marginata*) and Banksia species over shrubland (mapped as Vegetation Community A1)

Plate 2: Woodland to Forest of Peppermint (A*. flexuosa*) (mapped as Vegetation Community C2)

Plate 3: Woodland of *Eucalyptus rudis)* and *Melaleuca preissiana* over mixed shrubs (mapped as Vegetation Community D2)

Plate 4: Low Woodland of *Melaleuca preissiana* and mixed shrubs over mixed sedges (mapped as Vegetation Community E2)

Plate 5: Low Woodland of *Melaleuca rhaphiophylla over Baumea articulata* (mapped as Vegetation Community F3)

Plate 6: Tall Shrubland of *Kunzea ericifolia* (mapped as Vegetation Community G1)

Plate 7: Low Closed Heath of *Pericalymma ellipticum* and mixed shrubs over mixed sedges, with occasional emergent trees (mapped as Vegetation Community H1)

Plate 8: Marri nuts showing characteristic marks of foraging Baudin's Black Cockatoos

APPENDIX A

CONSERVATION CATEGORIES

EPBC Act (1999) Threatened Fauna Categories

Category	Code	Description
Extinct	E	There is no reasonable doubt that the last member of the species has died.
*Extinct in the wild	EW	A species (a) is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
*Critically endangered	CE	A species is facing an extremely high risk of extinction in the wild in the immediate future.
*Endangered	EN	A species: (a) is not critically endangered; and (b) is facing a very high risk of extinction in the wild in the near future.
*Vulnerable	VU	A species (a) is not critically endangered or endangered; and (b) is facing a high risk of extinction in the wild in the medium-term future.
Conservation dependent	CD	A species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered
*Migratory	Migratory	(a) all migratory species that are: (i) native species; and (ii) from time to time included in the appendices to the Bonn Convention; and (b) all migratory species from time to time included in annexes established under JAMBA, CAMBA and ROKAMBA; and (c) all native species from time to time identified in a list established under, or an instrument made under, an international agreement approved by the Minister.
Marine	Ma	Species in the list established under s248 of the EPBC Act

Note: Only species in those categories marked with an asterix are matters of national environmental significance under the EPBC Act.

Western Australian Wildlife Conservation Act (1950) Threatened Fauna Categories

Category	Code	Description
Schedule 1	S1	Fauna which is rare or likely to become extinct
Schedule 2	S2	Fauna which is presumed extinct
Schedule 3	S3	Birds which are subject to an agreement between the governments of Australia and Japan (JAMBA) relating to the protection of migratory birds and birds in danger of extinction
Schedule 4	S4	Fauna that is otherwise in need of special protection

Note: The *WAWC Act* also uses the categories defined by the *EPBC Act* to further define the status of species in the S1 category.

Western Australian DEC Priority Fauna Categories

Category	Code	Description
Priority 1	P1	Taxa with few, poorly known populations on threatened lands.
Priority 2	P2	Taxa with few, poorly known populations on conservation lands.
Priority 3	P3	Taxa with several, poorly known populations, some on conservation lands.
Priority 4	P4	Taxa in need of monitoring (Not currently threatened or in need of special protection, but could be if present circumstances change)
Priority 5	P5	Taxa in need of monitoring (Not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years)

IUCN Red List Threatened Species Categories

Category	Code	Description
Extinct	EX	Taxa for which there is no reasonable doubt that the last individual has died.
Extinct in the Wild	EW	Taxa which is known only to survive in cultivation, in captivity or and as a naturalised population well outside its past range and it has not been recorded in known or expected habitat despite exhaustive survey over a time frame appropriate to its life cycle and form.
Critically Endangered	CR	Taxa facing an extremely high risk of extinction in the wild.
Endangered	EN	Taxa facing a very high risk of extinction in the wild.
Vulnerable	VU	Taxa facing a high risk of extinction in the wild.
Near Threatened	NT	Taxa which has been evaluated but does not qualify for CR, EN or VU now but is close to qualifying or likely to qualify in the near future.
Least Concern	LC	Taxa which has been evaluated but does not qualify for CR, EN, VU, or NT but is likely to qualify for NT in the near future.
Data Deficient	DD	Taxa for which there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.

A full list of categories and their meanings are available at:

http://www.iucnredlist.org/info/categories_criteria2001#categories

APPENDIX B

HABITAT TREE COORDINATES

MEA - Habitat Tree Coordinates

	MGA		
ID	Zone	mE	mN
1	50H	385411	6335254
2	50H	385470	6335294
3	50H	385494	6335307
4	50H	385444	6334612
5	50H	385419	6334594
6	50H	385676	6333434
7	50H	385441	6333481
8	50H	385418	6333456
9	50H	385302	6334548
10	50H	385351	6334514
11	50H	385420	6334929
12	50H	384953	6334493
13	50H	385765	6334893
14	50H	386439	6334934
15	50H	385622	6334482
16	50H	385549	6333467
17	50H	385374	6333277
18	50H	384850	6333096
19	50H	384859	6333116
20	50H	384894	6333104
21	50H	384904	6333108
22	50H	384827	6333202
23	50H	385092	6333125
24	50H	385613	6333482
25	50H	385451	6333535
26	50H	385375	6333345
27	50H	385896	6334021
28	50H	385880	6333974
29	50H	385970	6333953
30	50H	385949	6333974
31	50H	385284	6333303

	MGA		
ID	Zone	mE	mN
32	50H	385263	6333383
33	50H	385426	6334712
34	50H	385571	6335290
35	50H	385580	6335296
36	50H	386582	6335346
37	50H	386017	6333712
38	50H	385916	6333695
39	50H	385936	6333723
40	50H	385918	6333607
41	50H	385834	6333613
42	50H	385838	6333513
43	50H	385854	6333435
44	50H	385809	6333424
45	50H	385720	6333464
46	50H	385448	6333373
47	50H	385453	6333326
48	50H	385058	6333089
49	50H	384948	6333104
50	50H	384936	6333137
51	50H	384942	6333155
52	50H	384862	6333148
53	50H	384825	6333437
54	50H	384830	6333649
55	50H	384843	6333685
56	50H	384819	6333719
57	50H	385518	6333996
58	50H	385512	6334025
59	50H	385545	6334060
60	50H	385623	6334217
61	50H	385924	6333939
62	50H	385971	6333867

APPENDIX C

FAUNA OBSERVED OR POTENTIALLY IN STUDY AREA

Fauna Observed or Potentially in Study Area

Compiled by Greg Harewood - February 2009

Observed (Sighted/Heard/Signs) = +

Kemerton Silica Sands - Mine Extension Area

Approx. Centroid 33.123854°S 115.773545°E GDA94

Habitats Present: Dominant - Open Woodlands of Jarrah and Banksia, Low Closed Heath over mixed shrubs and sedges. Others - Woodlands of Peppermint, Woodlands of Flooded Gum, Low Woodlands of Melaleuca, Tall shrublands of Kunzea and Shrubalnds of Hakea, Low lying areas subject to seasonal inundatior waterlogging, Manmade drain and shallow residue dam also subject to some seasonal inundation.

Class / **Family** / *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Fish				
Gobidae Gobies				
Pseudogobius olurum	Swan River Gobie			
Percichthyidae Basses and Cods				
Bostockia porosa	Nightfish		+	
Galaxiidae Galaxiids				
Galaxias occidentalis	Western Minnow		+	
Galaxiella nigrostriata	Black-striped Minnow	P3 LR/NT	+	
Nannopercidae Pygmy Perches				
Edelia vittata	Western Pygmy Perch		+	

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Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Poeciliidae Livebearers				
Gambusia holbrooki	Mosquito Fish	Introduced	+	
Amphibians				
Myobatrachidae Ground or Burrowing Frogs				
Crinia georgiana	Quacking Frog	LC		
Crinia glauerti	Glauert`s Froglet	LC	+	
Crinia insignifera	Squelching Froglet	LC	+	
Geocrinia leai	Lea`s Frog	LC	+	
Heleioporus eyrei	Moaning Frog	LC	+	
Heleioporus psammophilus	Sand Frog	LC		
Limnodynastes dorsalis	Banjo Frog	LC	+	
Pseudophryne guentheri	Güenther`s Toadlet	LC	+	
Hylidae Tree or Water-Holding Frogs				
Litoria adelaidensis	Slender Tree Frog	LC	+	
Litoria moorei	Motorbike Frog	LC	+	

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Class / Family / Species	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Reptiles				
Chelidae Side-necked Tortoises				
Chelodina oblonga	Long-necked Tortoise	LR/LC	+	
Gekkonidae Geckoes				
Christinus marmoratus	Marbled Gecko			
Pygopodidae Legless Lizards				
Aprasia repens	Sand-plain Worm Lizard			
Lialis burtonis	Common Snake Lizard		+	
Pygopus lepidopodus	Southern Scaleyfoot			
Agamidae Dragon Lizards				
Pogona minor	Western Bearded Dragon		+	
Varanidae Monitor's or Goanna's				
Varanus gouldii	Gould's Sand Monitor			
Varanus rosenbergi	Heath Monitor		+	

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Class Family Species	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Scincidae Skinks				
Acritoscincus trilineatum	South-western Cool Skink		+	+
Cryptoblepharus buchananii	Fence Skink		+	+
Ctenotus australis	Western Limestone Ctenotus			
Ctenotus impar	South-western Odd-striped Ctenotus			
Ctenotus labillardieri	Red-legged Skink			
Egernia kingii	King's Skink		+	
Egernia luctuosa	Mourning Skink			
Egernia napoleonis	Salmon-bellied Skink		+	
Hemiergis gracilipes	Southwestern Mulch Skink		+	
Hemiergis quadrilineata	Two-toed Earless Skink		+	
Lerista elegans	West Coast Four-toed Lerista			
Lerista lineata	Perth Lined Lerista	P3		
Menetia greyii	Dwarf Skink		+	
Morethia lineoocellata	Western Pale-flecked Morethia		+	
Morethia obscura	Dusky Morethia			
Tiliqua rugosa rugosa	Western Bobtail		+	+

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Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Typhlopidae Blind Snakes				
Ramphotyphlops australis	Southern Blind Snake			
Boidae Pythons, Boas				
Morelia spilota imbricata	Southern Carpet Python	S4 P4 LR/NT		
Elapidae Elapid Snakes				
Echiopsis curta	Bardick			
Elapognathus coronatus	Crowned Snake			
Neelaps bimaculatus	Black-naped Snake			
Notechis scutatus	Tiger Snake		+	+
Parasuta gouldii	Gould's Hooded Snake			
Parasuta nigriceps	Black-backed Snake			
Pseudonaja affinis	Dugite		+	
Simoselaps bertholdi	Jan`s Banded Snake			
Birds				
Casuariidae Emus, Cassowarries				
Dromaius novaehollandiae	Emu	Bp LC	+	+

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Class Family Species	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Phasianidae Quails, Pheasants				
Coturnix pectoralis	Stubble Quail	LC		
Coturnix ypsilophora	Brown Quail	LC		
Anatidae Geese, Swans, Ducks				
Anas gracilis	Grey Teal	LC	+	
Anas superciliosa	Pacific Black Duck	LC	+	
Aythya australis	Hardhead	Bh LC	+	
Chenonetta jubata	Australian Wood Duck	LC	+	
Cygnus atratus	Black Swan	LC	+	
Stictonetta naevosa	Freckled Duck	Bp LC		
Tadorna tadornoides	Australian Shelduck	LC	+	
Podicipedidae Grebes				
Poliocephalus poliocephalus	Hoary-headed Grebe	LC	+	
Tachybaptus novaehollandiae	Australasian Grebe	LC		
Anhingidae Darters				
Anhinga melanogaster	Darter	NT		

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Class Family *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Phalacrocoracidae Cormorants				
Phalacrocorax melanoleucos	Little Pied Cormorant	LC	+	
Phalacrocorax sulcirostris	Little Black Cormorant	LC		
Ardeidae Herons, Egrets, Bitterns				
Ardea alba	Great Egret	Mg CA JA		
Ardea ibis	Cattle Egret	Mg CA JA		
Ardea pacifica	White-necked Heron	LC	+	
Botaurus poiciloptilus	Australasian Bittern	S1 VU Bp EN B2ab(iii,iv,v)		
Egretta garzetta	Little Egret	LC		
Egretta novaehollandiae	White-faced Heron	LC	+	
Ixobrychus flavicollis	Black Bittern (SW population)	P3 Bp LC		
Ixobrychus minutus	Little Bittern	P4 Bp LC		
Nycticorax caledonicus	Rufous Night Heron	Bp LC		

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Class Family *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Threskiornithidae Iibises, Spoonbills				
Platalea flavipes	Yellow-billed Spoonbill	LC		
Plegadis falcinellus	Glossy Ibis	Mg CA LC		
Threskiornis molucca	Australian White Ibis	LC	+	
Threskiornis spinicollis	Straw-necked Ibis	LC		
Accipitridae Kites, Goshawks, Eagles, Harriers				
Accipiter cirrocephalus	Collared Sparrowhawk	Bp LC	+	
Accipiter fasciatus	Brown Goshawk	Bp LC		
Aquila audax	Wedge-tailed Eagle	Bp LC	+	+
Aquila morphnoides	Little Eagle	Bp		
Circus approximans	Swamp Harrier	LC	+	
Elanus caeruleus	Black-shouldered Kite	LC	+	
Haliastur sphenurus	Whistling Kite	Bp LC	+	
Hamirostra isura	Square-tailed Kite	Bp		

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Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Falconidae Falcons				
Falco berigora	Brown Falcon	Bp LC	+	
Falco cenchroides	Australian Kestrel	LC	+	
Falco longipennis	Australian Hobby	LC	+	
Falco peregrinus	Peregrine Falcon	S4 Bp LC		
Rallidae Rails, Crakes, Swamphens, Coots				
Fulica atra	Eurasian Coot	LC	+	
Gallinula tenebrosa	Dusky Moorhen	Bh LC		
Gallinula ventralis	Black-tailed Native-hen	LC		
Gallirallus philippensis	Buff-banded Rail	LC		
Porphyrio porphyrio	Purple Swamphen	LC	+	
Porzana fluminea	Australian Spotted Crake	LC		
Porzana pusilla	Baillon`s Crake	LC		
Porzana tabuensis	Spotless Crake	LC		
Turnicidae Button-quails				
Turnix varia	Painted Button-quail	Bp	+	+

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Class Family *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Scolopacidae Curlews, Sandpipers, Snipes, Godwits				
Tringa hypoleucos	Common Sandpiper	Mg CA RK JA	+	
Tringa nebularia	Common Greenshank	Mg CA JA RK LC	+	
Recurvirostridae Stilts, Avocets				
Himantopus himantopus	Black-winged Stilt	LC		
Charadriidae Lapwings, Plovers, Dotterels				
Charadrius melanops	Black-fronted Dotterel	LC	+	
Charadrius ruficapillus	Red-capped Plover	LC		
Erythrogonys cinctus	Red-kneed Dotterel	LC		
Columbidae Pigeons, Doves				
Ocyphaps lophotes	Crested Pigeon	LC		
Phaps chalcoptera	Common Bronzewing	Bh LC	+	+

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Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Cacatuidae Cockatoos, Corellas				
Calyptorhynchus banksii naso	Forest Red-tailed Black Cockatoo	S1 VU Be	+	+
Calyptorhynchus baudinii	Baudin`s Cockatoo	S1 EN Bp EN C2a(ii)		+
Calyptorhynchus latirostris	Carnaby`s Cockatoo	S1 EN Bp EN A2bcd+3bcd	+	+
Eolophus roseicapilla	Galah	LC		
Psittacidae Parrots				
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	LC		
Neophema elegans	Elegant Parrot	LC	+	
Platycercus icterotis icterotis	Western Rosella (Western ssp)	Bp LC		
Platycercus spurius	Red-capped Parrot	LC	+	+
Platycercus zonarius	Australian Ringneck Parrot	LC	+	+
Polytelis anthopeplus	Regent Parrot	LC	+	

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Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Cuculidae Parasitic Cuckoos				
Cacomantis flabelliformis	Fan-tailed Cuckoo	LC	+	
Chrysococcyx basalis	Horsfield`s Bronze Cuckoo	LC	+	
Chrysococcyx lucidus	Shining Bronze Cuckoo	LC	+	
Cuculus pallidus	Pallid Cuckoo	LC	+	
Strigidae Hawk Owls				
Ninox connivens connivens	Barking Owl (southwest population)	P2 Be LC		
Ninox novaeseelandiae	Boobook Owl	LC		+
Tytonidae Barn Owls				
Tyto alba	Barn Owl	LC		
Tyto n. novaehollandiae	Masked Owl (southwest population)	P3 Bp		
Podargidae Frogmouths				
Podargus strigoides	Tawny Frogmouth	LC	+	+
Aegothelidae Owlet-nightjars				
Aegotheles cristatus	Australian Owlet-nightjar	LC		

Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Apodidae Swifts, Swiftlets				
Apus pacificus	Fork-tailed Swift	Mg CA JA RK LC		
Halcyonidae Tree Kingfishers				
Dacelo novaeguineae	Laughing Kookaburra	Introduced	+	+
Todiramphus sanctus	Sacred Kingfisher	LC	+	
Meropidae Bee-eaters				
Merops ornatus	Rainbow Bee-eater	Mg JA LC	+	
Maluridae Fairy Wrens, GrassWrens				
Malurus splendens	Splendid Fairy-wren	Bh LC	+	+
Stipiturus malachurus	Southern Emu-wren	Bh LC		

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Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Pardalotidae Pardalotes, Bristlebirds, Scrubwrens, Gerygones, Thornbills				
Acanthiza apicalis	Broad-tailed Thornbill	Bh LC	+	+
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	Bh LC	+	
Acanthiza inornata	Western Thornbill	Bh LC	+	+
Gerygone fusca	Western Gerygone	LC	+	+
Pardalotus punctatus	Spotted Pardalote	LC	+	
Pardalotus striatus	Striated Pardalote	LC	+	
Sericornis frontalis	White-browed Scrubwren	Bh LC	+	+
Smicrornis brevirostris	Weebill	Bh LC	+	+

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Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Meliphagidae Honeyeaters, Chats				
Acanthorhynchus superciliosus	Western Spinebill	LC	+	+
Anthochaera carunculata	Red Wattlebird	LC	+	+
Anthochaera lunulata	Western Little Wattlebird	Bp		
Epthianura albifrons	White-fronted Chat	LC	+	
Lichenostomus virescens	Singing Honeyeater	LC		
Lichmera indistincta	Brown Honeyeater	LC	+	
Melithreptus lunatus	White-naped Honeyeater	Bp LC		
Phylidonyris melanops	Tawny-crowned Honeyeater	Bp LC		+
Phylidonyris nigra	White-cheeked Honeyeater	Bp	+	
Phylidonyris novaehollandiae	New Holland Honeyeater	Bp LC	+	+
Petroicidae Australian Robins				
Eopsaltria australis	Western Yellow Robin	Bh LC		
Petroica goodenovii	Red-capped Robin	LC		
Petroica multicolor	Scarlet Robin	Bh LC	+	

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Neosittidae Sitellas				
Daphoenositta chrysoptera	Varied Sittella	Bh LC		
Pachycephalidae Crested Shrike-tit, Crested Bellbird, Shrike Thrushes, Whistlers				
Colluricincla harmonica	Grey Shrike-thrush	Bh LC	+	+
Pachycephala pectoralis	Golden Whistler	Bh LC	+	+
Pachycephala rufiventris	Rufous Whistler	LC	+	
Dicruridae Monarchs, Magpie Lark, Flycatchers, Fantails, Drongo				
Grallina cyanoleuca	Magpie-lark	LC	+	
Rhipidura fuliginosa	Grey Fantail	LC	+	+
Rhipidura leucophrys	Willie Wagtail	LC	+	+
Campephagidae Cuckoo-shrikes, Trillers				
Coracina novaehollandiae	Black-faced Cuckoo-shrike	LC	+	+
Lalage sueurii	White-winged Triller	LC		

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Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Artamidae Woodswallows, Butcherbirds, Currawongs				
Artamus cinereus	Black-faced Woodswallow	Bp LC	+	+
Artamus cyanopterus	Dusky Woodswallow	Bp LC	+	
Cracticus tibicen	Australian Magpie	LC	+	+
Cracticus torquatus	Grey Butcherbird	LC	+	+
Strepera versicolor	Grey Currawong	Bp LC	+	+
Corvidae Ravens, Crows				
Corvus coronoides	Australian Raven	LC	+	+
Motacillidae Old World Pipits, Wagtails				
Anthus novaeseelandiae	Australian Pipit	LC	+	+
Dicaeidae Flowerpeckers				
Dicaeum hirundinaceum	Mistletoebird	LC		
Hirundinidae Swallows, Martins				
Hirundo neoxena	Welcome Swallow	LC	+	
Hirundo nigricans	Tree Martin	LC	+	+

WAWC Act Status - S1 to S4, EPBC Act Status - EN = Endangered, VU = Vulnerable, EX = Extinct, Mg = Migratory, DEC Priority Status - P1 to P5, Int. Agmts - CA = CAMBA, JA = JAMBA, RK = ROKAMBA, Bush Forever Decreaser Species - Bh = habitat specialists, Bp = wide ranging species, Be = extinct in Perth Coastal Plain Region. IUCN Red List Category Definitions = LC, LR, NT, DD ect - see Appendix and www.iucnredlist.org/info/categories_criteria2001#categories.

Class Family Species	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Sylviidae Old World Warblers				
Acrocephalus stentoreus	Clamorous Reed Warbler	LC	+	
Cincloramphus cruralis	Brown Songlark	LC		
Cincloramphus mathewsi	Rufous Songlark	LC		
Megalurus gramineus	Little Grassbird	LC	+	
Zosteropidae White-eyes				
Zosterops lateralis	Grey-breasted White-eye	LC	+	+
Mammals				
Tachyglossidae Echidnas				
Tachyglossus aculeatus	Echidna	LR/LC		
Dasyuridae Carnivorous Marsupials				
Dasyurus geoffroii	Chuditch	S1 VU VU C1		
Phascogale tapoatafa tapoatafa	Southern Brush-tailed Phascogale	S1 LR/NT		+
Peramelidae Bandicoots				
Isoodon obesulus fusciventer	Southern Brown Bandicoot	P5	+	+

WAWC Act Status - S1 to S4, EPBC Act Status - EN = Endangered, VU = Vulnerable, EX = Extinct, Mg = Migratory, DEC Priority Status - P1 to P5, Int. Agmts - CA = CAMBA, JA = JAMBA, RK = ROKAMBA, Bush Forever Decreaser Species - Bh = habitat specialists, Bp = wide ranging species, Be = extinct in Perth Coastal Plain Region. IUCN Red List Category Definitions = LC, LR, NT, DD ect - see Appendix and www.iucnredlist.org/info/categories_criteria2001#categories.

Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Phalangeridae Brushtail Possums, Cuscuses				
Trichosurus vulpecula	Common Brushtail Possum	LR/LC		+
Burramyidae Pygmy Possums				
Cercartetus concinnus	Western Pygmy-possum	LR/LC	+	
Tarsipedidae Honey Possum				
Tarsipes rostratus	Honey Possum	LR/LC	+	
Macropodidae Kangaroos, Wallabies				
Macropus fuliginosus	Western Grey Kangaroo	LR/LC	+	+
Macropus irma	Western Brush Wallaby	P4 LR/NT	+	+
Molossidae Freetail Bats				
Mormopterus planiceps	Western Freetail Bat	LR/LC		
Tadarida australis	White-striped Freetail-bat	LR/LC		

WAWC Act Status - S1 to S4, EPBC Act Status - EN = Endangered, VU = Vulnerable, EX = Extinct, Mg = Migratory, DEC Priority Status - P1 to P5, Int. Agmts - CA = CAMBA, JA = JAMBA, RK = ROKAMBA, Bush Forever Decreaser Species - Bh = habitat specialists, Bp = wide ranging species, Be = extinct in Perth Coastal Plain Region. IUCN Red List Category Definitions = LC, LR, NT, DD ect - see Appendix and www.iucnredlist.org/info/categories_criteria2001#categories.

Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Vespertilionidae Ordinary Bats				
Chalinolobus gouldii	Gould`s Wattled Bat	LR/LC		
Chalinolobus morio	Chocolate Wattled Bat	LR/LC		
Falsistrellus mackenziei	Western False Pipistrelle	P4 VU A2c		
Nyctophilus geoffroyi	Lesser Long-eared Bat	LR/LC		
Nyctophilus gouldi	Gould`s Long-eared Bat	LR/LC		
Nyctophilus timoriensis	Greater Long-eared Bat	DD		
Vespadelus regulus	Southern Forest Bat	LR/LC		
Muridae Rats, Mice				
Hydromys chrysogaster	Water Rat	P4 LR/LC	+	
Mus musculus	House Mouse	Introduced	+	
Rattus fuscipes	Western Bush Rat	LR/LC		
Rattus rattus	Black Rat	Introduced		
Canidae Dogs, Foxes				
Vulpes vulpes	Red Fox	Introduced	+	+

WAWC Act Status - S1 to S4, EPBC Act Status - EN = Endangered, VU = Vulnerable, EX = Extinct, Mg = Migratory, DEC Priority Status - P1 to P5, Int. Agmts - CA = CAMBA, JA = JAMBA, RK = ROKAMBA, Bush Forever Decreaser Species - Bh = habitat specialists, Bp = wide ranging species, Be = extinct in Perth Coastal Plain Region. IUCN Red List Category Definitions = LC, LR, NT, DD ect - see Appendix and www.iucnredlist.org/info/categories_criteria2001#categories.

Class **Family** *Species*	Common Name	Conservation Status	KSS Property (Records - Bamford/Ninox)	Mine Extension Area Jan/Feb 2009
Felidae Cats				
Felis catus	Cat	Introduced	+	
Suidae Pigs				
Sus scrofa	Pig	Introduced	+	+
Leporidae Rabbits, Hares				
Oryctolagus cuniculus	Rabbit	Introduced	+	+

WAWC Act Status - S1 to S4, EPBC Act Status - EN = Endangered, VU = Vulnerable, EX = Extinct, Mg = Migratory, DEC Priority Status - P1 to P5, Int. Agmts - CA = CAMBA, JA = JAMBA, RK = ROKAMBA, Bush Forever Decreaser Species - Bh = habitat specialists, Bp = wide ranging species, Be = extinct in Perth Coastal Plain Region. IUCN Red List Category Definitions = LC, LR, NT, DD ect - see Appendix and www.iucnredlist.org/info/categories_criteria2001#categories.

APPENDIX D

DEC & EPBC DATABASE SEARCH RESULTS

33.083 °S 115.717 °E / 33.191 °S 115.84 °E Kemerton Silica Sand Project area

* Date	Certainty	Seen	Location Name	Method

Schedule 1 - Fauna that is rare or is likely to become extinct

Phascogale tapoatafa ssp. (WAM M434) **Brush-tailed Phascogale, Wambenger** *1 records*

This arboreal marsupial occurs in forest and woodland where suitable tree hollows are available. Populations fluctuate dramatically in response to invertebrate prey abundance.

Date	Certainty	Seen	Location Name	Method
2008	1	1	Wellesley	Dead

Pseudocheirus occidentalis **Western Ringtail Possum** *4 records*

This species occurs in areas of forest and dense woodlands and requires tree hollows and/or dense canopy for refuge and nesting.

Date	Certainty	Seen	Location Name	Method
2007	1	1	Binningup/Myalup	Night sighting
2007	1	1	Binningup/Myalup	Night sighting
2008	1	2	Binningup	Night sighting
2008	1	2	Myalup	Night sighting

Botaurus poiciloptilus **Australasian Bittern** *2 records*

This species inhabits beds of tall dense reeds and sedges in freshwater swamps.

Date	Certainty	Seen	Location Name	Method
1986	1	8	Benger Swamp Nature Reserve	Day sighting
1992	1	2	Benger Swamp Nature Reserve	Day sighting

Calyptorhynchus banksii naso **Forest Red-tailed Black-Cockatoo** *1 records*

This subspecies of the Red-tailed Black Cockatoo is restricted to the forests of the south-west. It requires tree hollows to nest and breed and is totally dependent on jarrah-marri forest.

Date	Certainty	Seen	Location Name	Method
2008	1	7	Myalup	Day sighting

Calyptorhynchus latirostris **Carnaby's Black-Cockatoo** *3 records*

This species moves around seasonally in flocks to feeding areas in proteaceous scrubs and heaths and eucalypt woodlands as well as pine plantations. Breeding occurs in winter/spring, mainly in the eastern forests and wheatbelt where they can find mature hollow-bearing trees to nest in.

Date	Certainty	Seen	Location Name	Method
2007	1	1	Myalup	Day sighting
2007	1	50	Myalup	Day sighting
2007	1	10	Binningup/Myalup	Day sighting

Priority Three: Taxa with several, poorly known populations, some on conservation lands

Galaxiella nigrostriata **Black-stripe Minnow** *3 records*

This species typically occurs in shallow isolated pools in peat flats surrounding forested areas. 76 records from 1993-2001

Date	Certainty	Seen	Location Name	Method
1993	1		Wokalup	Caught or trapped
2001	1	10	Wokalup	Caught or trapped
2001	1	3	Wokalup	Caught or trapped

Priority Four: Taxa in need of monitoring

Hydromys chrysogaster **Water-rat, Rakali** *1 records*

This species occurs in waterways and wetlands that support its main prey items such as molluscs and crustaceans.

Date	Certainty	Seen	Location Name	Method
1975	1	1	Benger Swamp Nature Reserve	Dead

Ixobrychus minutus **Little Bittern** *1 records*

This cryptic species inhabits dense reeds and rushes bordering swamps, lakes and watercourses.

33.083 °S 115.717 °E / 33.191 °S 115.84 °E Kemerton Silica Sand Project area

*	*Date*	*Certainty*	*Seen*	*Location Name*	*Method*
	1972	1	1	Benger Swamp Nature Reserve	Day sighting

* Information relating to any records provided for listed species:-
Date: date of recorded observation
Certainty (of correct species identification): 1=Very certain; 2=Moderately certain; and 3=Not sure.
Seen: Number of individuals observed.
Location Name: Name of reserve or nearest locality where observation was made
Method: Method or type of observation

Protected Matters Search Tool

You are here: Environment Home > EPBC Act > Search

11 February 2009 18:07

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

You may wish to print this report for reference before moving to other pages or websites.

The Australian Natural Resources Atlas at http://www.environment.gov.au/atlas may provide further environmental information relevant to your selected area. Information about the EPBC Act including significance guidelines, forms and application process details can be found at http://www.environment.gov.au/epbc/assessmentsapprovals/index.html

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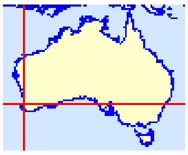
Search Type: Point

Buffer: 6 km

Coordinates: -33.126336,115.770732



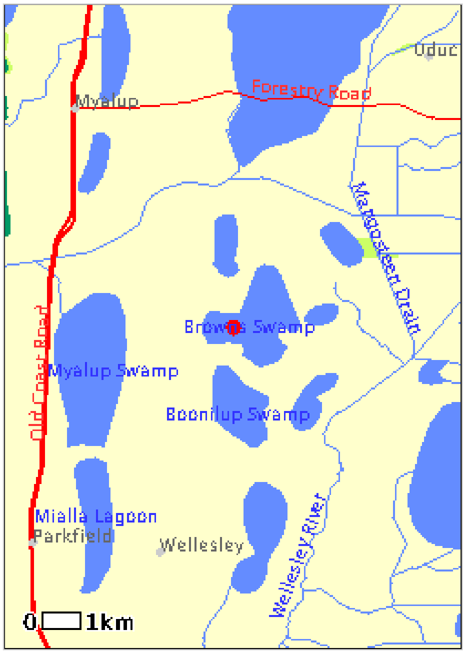
Report Contents: Summary

Details

- Matters of NES
- Other matters protected by the EPBC Act
- Extra Information

Caveat

Acknowledgments



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance - see http://www.environment.gov.au/epbc/assessmentsapprovals/guidelines/index.html.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Significance: (Ramsar Sites)	1

Commonwealth Marine Areas:	None
Threatened Ecological Communities:	None
Threatened Species:	7
Migratory Species:	7

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html.

Please note that the current dataset on Commonwealth land is not complete. Further information on Commonwealth land would need to be obtained from relevant sources including Commonwealth agencies, local agencies, and land tenure maps.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species. Information on EPBC Act permit requirements and application forms can be found at http://www.environment.gov.au/epbc/permits/index.html.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Places on the RNE:	None
Listed Marine Species:	5
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	1
Other Commonwealth Reserves:	None
Regional Forest Agreements:	None

Details

Matters of National Environmental Significance

Wetlands of International Significance [Dataset Information]
(Ramsar Sites)

PEEL-YALGORUP SYSTEM		Within 10 km of Ramsar site
Threatened Species [Dataset Information]	Status	Type of Presence

Birds		
Calyptorhynchus baudinii Baudin's Black-Cockatoo, Long-billed Black-Cockatoo	Vulnerable	Species or species habitat likely to occur within area
Calyptorhynchus latirostris Carnaby's Black-Cockatoo, Short-billed Black-Cockatoo	Endangered	Species or species habitat likely to occur within area
Mammals		
Dasyurus geoffroii Chuditch, Western Quoll	Vulnerable	Species or species habitat likely to occur within area
Pseudocheirus occidentalis Western Ringtail Possum	Vulnerable	Species or species habitat likely to occur within area
Setonix brachyurus Quokka	Vulnerable	Species or species habitat may occur within area
Plants		
Caladenia procera Carbunup King Spider Orchid	Critically Endangered	Species or species habitat known to occur within area
Drakaea micrantha Hopper & A.P.Brown nom. inval. Dwarf Hammer-orchid	Vulnerable	Species or species habitat likely to occur within area

Migratory Species [Dataset Information]	Status	Type of Presence
Migratory Terrestrial Species		
Birds		
Haliaeetus leucogaster White-bellied Sea-Eagle	Migratory	Species or species habitat likely to occur within area
Merops ornatus Rainbow Bee-eater	Migratory	Species or species habitat may occur within area
Migratory Wetland Species		
Birds		
Ardea alba Great Egret, White Egret	Migratory	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift	Migratory	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Migratory	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Migratory	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Dataset Information]	Status	Type of Presence
Birds		
Apus pacificus Fork-tailed Swift	Listed - overfly marine area	Species or species habitat may occur within area
Ardea alba Great Egret, White Egret	Listed - overfly marine area	Species or species habitat may occur within area
Ardea ibis Cattle Egret	Listed - overfly	Species or species habitat may occur within area

	marine area	
Haliaeetus leucogaster White-bellied Sea-Eagle	Listed	Species or species habitat likely to occur within area
Merops ornatus Rainbow Bee-eater	Listed - overfly marine area	Species or species habitat may occur within area

Extra Information

State and Territory Reserves [Dataset Information]

Byrd Swamp Nature Reserve, WA

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the *Environment Protection and Biodiversity Conservation Act 1999*. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under "type of presence". For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the migratory and marine provisions of the Act have been mapped.

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites;
- seals which have only been mapped for breeding sites near the Australian continent.

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Acknowledgments

This database has been compiled from a range of data sources. The Department acknowledges the following custodians who have contributed valuable data and advice:

- New South Wales National Parks and Wildlife Service
- Department of Sustainability and Environment, Victoria
- Department of Primary Industries, Water and Environment, Tasmania
- Department of Environment and Heritage, South Australia Planning SA
- Parks and Wildlife Commission of the Northern Territory
- Environmental Protection Agency, Queensland
- Birds Australia
- Australian Bird and Bat Banding Scheme
- Australian National Wildlife Collection
- Natural history museums of Australia
- Queensland Herbarium
- National Herbarium of NSW
- Royal Botanic Gardens and National Herbarium of Victoria
- Tasmanian Herbarium
- State Herbarium of South Australia
- Northern Territory Herbarium
- Western Australian Herbarium
- Australian National Herbarium, Atherton and Canberra
- University of New England
- Other groups and individuals

ANUCliM Version 1.8, Centre for Resource and Environmental Studies, Australian National University was used extensively for the production of draft maps of species distribution. Environment Australia is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

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Last updated: Thursday, 20-Nov-2008 14:17:56 EST

APPENDIX E

SIGNIFICANT SPECIES PROFILES

Black-striped Minnow *Galaxiella nigrostriata*

Status and Distribution: This species is classified as Priority 3 by the DEC. Allen *et al* (2003) states that this species is common but restricted to wetlands within 100km of the coast in south western Australia between Albany and Augusta with isolated populations known at Kemerton and Ellenbrook.

Habitat: Permanent or ephemeral pools, roadside ditches and small creeks in sandy, thickly vegetated wetland areas. Water is usually darkly tannin stained and acidic (pH 4.6 – 6.5) (Allen *et al* 2003).

Likely presence in study area: Recorded in the KSS property east of the MEA where it occupies both seasonal and permanent wetlands. The Black-striped Jollytail is widespread when water levels are high, but relies on a few summer refuge sites, where it survives in deep, cool pools and, when these dry out, retreats to water contained in the burrows of freshwater crayfish (Bamford, 2002).

The Jollytails disperse widely during high water levels in winter and have the potential to spread into the western part of the KSS property (including the MEA). There are no known summer refuges for the species in this area of the property (Morgan *et al.* 1998), but there are patches of vegetation consistent with low lying areas in the western part of the property. These areas may retain water for long enough to serve as refuge areas in successive years of average or above average rainfall. They are indicated as vegetation types F-1, F-2 and F-3 on the vegetation map (Figure 3).

Potential impact of development: The MEA is not known to support permanent populations of the Black-striped Minnow but it has the potential to spread into this area on a temporary basis in wetter months/years. There is therefore potential for this habitat to be changed or access to it restricted by changes in surface hydrology. There is also the potential, with proper management, for habitats to be enhanced for this species e.g. creation of deeper permanent water bodies for this species to use. It is understood that management plans relating to this issue have been formulated. No addition recommendations are therefore put forward.

Perth Lined Lerista *Lerisita lineata*

Status and Distribution: Listed as Priority 3 by DEC. Found in the lower west coast from Perth to Leschenault Peninsula. It has also been found at Rottnest Island and Garden Island (Storr *et al*, 1999). Found in the southern suburbs (Bush et al 2002).

Habitat: This small species of skink inhabits white sands (Storr *et al*, 1999) under areas of shrubs and heath where it inhabits loose soil and leaf litter (Nevill 2005) particularly in association with banksias (Bush *et al* 2002).

Likely presence in study area: Actual status in area difficult to determine. Potentially present in general area though no actual records from Kemerton. All recent records in the area are from within near coastal (1 or 2km) dunes (Bamford Consulting Ecologists 2008, 360 Environmental 2008).

Potential impact of proposed development: Loss of some potential habitat, but if present likely to persist and recolonise rehabilitated areas from adjoining unaffected areas. No specific management recommended.

Southern Carpet Python *Morelia spilota impricata*

Status and Distribution: The south western population is classified as Priority 4 by DEC and is also listed in Schedule 4 under the *WAWC Act (1950)*. This sub species has wide distribution within the south west but is uncommon. Occurs north to Geraldton and Yalgoo and east to Pinjin, Kalgoorlie, Fraser Range and Eyre (Storr *et al*, 2002).

Habitat: This species has been recorded from semi-arid coastal and inland habitats, Banksia woodland, Eucalypt woodlands, and grasslands. Most often found utilising hollow logs in addition the burrows of other animals for shelter. Often arboreal and will also use tree hollows for refuge.

Likely presence in study area: Recently recorded at Leschenault (360 Environmental 2008) and in coastal dunes and Tuart Woodland within Yalgorup National Park (G Harewood pers. obs.). Status within the MEA difficult to determine. If present in the general area population densities can be expected to be very low.

Potential impact of development: If the species is present it is likely to be in very low densities and therefore the greatest impact may occur during clearing when individuals may be killed or injured though the probability of encountering any is very small. This impact can be reduced if areas to be cleared are inspected (in particular hollow logs) immediately prior to works commencing and with any animals found being removed to unaffected nearby areas. Also hollow logs found in areas to be cleared should be placed in rehabilitated/unaffected areas.

Great Egret *Ardea alba*

Status and Distribution: This species of egret is listed as migratory under the *EPBC Act (1999)* and under international agreements to which Australia is a signatory. The Great Egret is common and very widespread in any suitable permanent or temporary habitat (Morcombe, 2003).

Species or species habitat listed as likely to occur in general area within EPBC database search.

Habitat: Wetlands, flooded pasture, dams, estuarine mudflats, mangroves and reefs (Morcombe 2003).

Likely presence in study area: Not recorded in the KSS property but has the potential to occasionally visit flooded areas in wetter months. No known breeding colonies or sites present in MEA.

Potential impact of development: No impact on this species is anticipated. No specific management measures recommended.

Cattle Egret *Ardea ibis*

Status and Distribution: This species of egret is listed as migratory under the *EPBC Act 1999* and under international agreements to which Australia is a signatory. The Cattle Egret is common in the north sections of its range but is an irregular visitor to the better watered parts of the state (Johnstone and Storr 1998). The population is expanding (Morcombe 2003). Often seen, in association with cattle, in the Glen Iris (Bunbury) area (Greg Harewood pers. obs.).

Species or species habitat listed as likely to occur in general area within EPBC database search.

Habitat: Moist pastures with tall grasses, shallow open wetlands and margins, mudflats (Morcombe 2003).

Likely presence in study area: Not recorded in the KSS property but has the potential to occasionally visit flooded areas in wetter months. No known breeding colonies or sites present in MEA.

Potential impact of development: No impact on this species is anticipated. No specific management measures recommended.

White-bellied Sea Eagle *Haliaeetus leucogaster*

Status and Distribution: This species is listed as migratory under the *EPBC Act (1999)* and under international agreements to which Australia is a signatory. White-bellied sea eagles are moderately common to common on Kimberley and Pilbara islands, coasts and estuaries, on Bernier, Dorre and Dirk Hartog Is., in Houtman Abrolhos and in the Archipelago of the Recherche; rare to uncommon elsewhere (Johnstone and Storr 1998). Also found in New Guinea, Indonesia, China, southeast Asia and India. Scarce near major coastal cities (Morcombe 2003).

Species or species habitat listed as likely to occur in general area within EPBC database search.

Habitat: They nest and forage usually near the coast over islands, reefs, headlands, beaches, bays, estuaries, mangroves, but will also live near seasonally flooded inland swamps, lagoons and floodplains, often far inland on large pools of major rivers. Established pairs usually sedentary, immatures dispersive (Morcombe 2003). White-bellied Sea-Eagles build a large stick nest, which is used for many seasons in succession.

Likely presence in study area: The species may occasionally fly over the site due to its proximity to the ocean and Leschenault Inlet, but it is not listed in this report as a potential species as it is very unlikely to forage or nest on site.

Potential impact of development: No impact on this species or its habitat is anticipated. No specific management measures recommended

Australasian Bittern *Botaurus poiciloptilus*

Status and Distribution: Classified as Schedule 1 under the *WAWC Act (1950*) and as Vulnerable under the *EPBC Act (1999*. The species is uncommon to rare (Morcombe, 2003), but locally common in wetter parts of south west (Johnstone and Storr 1998). Occurs north to Moora and east to Mt Arid (Johnstone and Storr 1998).

Habitat: Freshwater wetlands, occasionally estuarine; prefers heavy vegetation (Morcombe 2003) such as beds of tall dense *Typha*, *Baumea* and sedges in freshwater swamps (Johnstone and Storr 1998).

Likely presence in study area: This species is extremely difficult to observe due to its preferred habitat. Closest records are from Benger Swamp. Extent of suitable habitat with the MEA has a very limited extent (Veg units F1 to F3) and are only seasonal inundated. May occasionally be present but for only short periods while in transit.

Potential impact of proposed development: No impact on this species is anticipated. No specific management measures recommended.

Black Bittern *Ixobrychus flavicollis*

Status and Distribution: Listed as Priority 2 by DEC. Occurs north to Yanchep and Northam and east to Albany (Johnstone and Storr 1998).

Habitat: Freshwater pools, swamps and lagoons, well screen with trees. Shelters in dense waterside vegetation (Johnstone and Storr 1998).

Likely presence in study area: Very difficult to observe and therefore few records exist. Extent of suitable habitat with the MEA has a very limited extent (Veg units F1 to F3) and are only seasonal inundated. May occasionally be present but for only short periods while in transit.

Potential impact of proposed development: No impact on this species is anticipated. No specific management measures recommended.

Little Bittern *Ixobrychus minutus*

Status and Distribution: Listed as Priority 4 by DEC. Occurs north to Moora and east to Two Peoples Bay; accidental or on migration further north and east and on Rottnest Island and central district (Condingup district) (Johnstone and Storr 1998).

Habitat: In south dense beds of Freshwater pools, swamps and lagoons, well screened with trees. Shelters in dense beds of *Typha*, *Baumea* and tall rushes in freshwater swamps around lakes and along rivers (Johnstone and Storr 1998).

Likely presence in study area: Very difficult to observe and therefore few records exist. Single, old record form Benger swamp. Extent of suitable habitat with the MEA has a very limited extent (Veg units F1 to F3) and are only seasonal inundated. May occasionally be present but for only short periods while in transit.

Potential impact of proposed development: No impact on this species is anticipated. No specific management measures recommended.

Glossy Ibis *Plegadis falcinellus*

Status and Distribution: This species is listed as migratory under the *EPBC Act (1999)* and under international agreements to which Australia is a signatory. The Glossy Ibis frequents swamps and lakes throughout much of the Australian mainland, but is most numerous in the north. It is a non-breeding visitor to Tasmania and the south-west of Western Australia. The Glossy Ibis is both migratory and nomadic. Its range expands inland after good rains, but its main breeding areas seem to be in the Murray-Darling Basin of New South Wales and Victoria, the Macquarie Marshes in New South Wales, and in southern Queensland. Glossy Ibis often move north in autumn, then return south to their main breeding areas in spring and summer (Pizzey & Knight 2006).

Habitat: Well vegetated wetlands, wet pastures, rice fields, floodwaters, floodplains, brackish or occasionally saline wetlands, mangroves, mudflats, occasionally dry grasslands (Pizzey & Knight 2006).

Likely presence in study area: Infrequently recorded in south west. Small potential for it to use some inundated open areas in wetter months of year.

Potential impact of proposed development: No impact on this species is anticipated. No specific management measures recommended.

Peregrine Falcon *Falco perigrinus*

Status and Distribution: This species is listed as Schedule 4 under the *WAWC Act 1950*. Individuals of this species are uncommon/rare but wide ranging across Australia. Moderately common at higher levels of the Stirling Range, uncommon in hilly, north west Kimberley, Hamersley and Darling Ranges; rare or scarce elsewhere (Johnstone and Storr 1998).

Habitat: Diverse from rainforest to arid shrublands, from coastal heath to alpine (Morcombe 2003). Mainly about cliffs along coasts, rivers and ranges and about wooded watercourses and lakes (Johnstone and Storr 1998). The species utilises the ledges, cliff faces and large hollows/broken spouts of trees for nesting. It will also occasionally use the abandoned nests of other birds of prey.

Likely presence in study area: The species potentially utilises some sections of the study area as part of a much larger home range.

Potential impact of development: Loss of any existing nest sites has the potential to impact on this species. Retention of habitat trees where possible will reduce likelihood of impact though potential for any significant impact is small as the probability that it breeds on site is low. No specific management measures recommended.

Common Sandpiper *Tringa hypoleucos*

Status and Distribution: This species is listed as migratory under the *EPBC Act (1999)* and under international agreements to which Australia is a signatory. Visitor (all months, mostly September to March). Rare to moderately common (Johnstone and Storr 1998).

Habitat: Edge of sheltered waters salt or fresh, e.g. estuaries, mangrove creeks, rocky coasts, near coastal salt lakes, river pools, lagoons, claypans, drying swamps, flood waters, dams and sewerage ponds. Preferring situations where low perches are available (Johnstone and Storr 1998).

Likely presence in study area: Recorded in the KSS property. The species potentially utilises some of the existing manmade open seasonally inundated areas (drain/residue dam) in the MEA though probably only a rare visitor.

Potential impact of proposed development: No impact on this species is anticipated. No specific management measures recommended.

Common Greenshank *Tringa nebularia*

Status and Distribution: This species is listed as migratory under the *EPBC Act (1999)* and under international agreements to which Australia is a signatory. Visitor (all months, mostly September to March in south west). Uncommon to moderately common on coasts and coastal plains; rare to scarce elsewhere. (Johnstone and Storr 1998).

Habitat: Shallow fresh waters (claypans, lagoons, swamps, river pools, dams and sewerage ponds), and salt waters (estuaries, mangrove creeks, lakes samphire flats, reef flats and saltwork ponds) (Johnstone and Storr 1998).

Likely presence in study area: Recorded in the KSS property. The species potentially utilises some of the existing manmade open seasonally inundated areas (drain/residue dam) in the MEA though probably only a rare visitor.

Potential impact of proposed development: No impact on this species is anticipated. No specific management measures recommended.

Forest Red-tailed Black Cockatoo *Calyptorhynchus banksii naso*

Status and Distribution: Listed as Scheduled 1 under the *WAWC Act (1950)*. Found in the humid and subhumid south west, mainly hilly interior, north to Gingin and east to Mt Helena, Christmas Tree Well, North Bannister, Mt Saddleback, Rock Gully and the upper King River (Johnstone and Storr 1998).

Habitat: Eucalypt forests, feeds on Marri, Jarrah, Blackbutt, Karri, Sheoak and Snottygobble. The Forest Red-tailed Black Cockatoo nests in the large hollows of Marri, Jarrah and Karri (Johnstone and Kirkby 1999). In Marri, the nest hollows of the Forest Red-tailed Black Cockatoo range from 8-14m above ground, the entrance is 12 – 41cm in diameter and the depth is one to five metres (Johnstone and Storr 1998).

Breeding commences in winter/spring. There are few records of breeding in the Forest Red-tailed Black Cockatoo (Johnstone and Storr 1998), but eggs are laid in October and November (Johnstone 1997; Johnstone and Storr 1998). Incubation period 29 – 31 days. Young fledge at 8 to 9 weeks (Simpson and Day 2004).

J	F	M	A	M	J	J	A	S	O	N	D

Period in which breeding is most likely to commence
Period in which fledging/weening could extend through

Likely presence in study area: Several small flocks of this species were observed within the MEA during the site surveys. Previously recorded on the KSS property during other surveys. Numerous examples of foraging activity were observed (chewed jarrah nuts (though some could be attributed to Carnaby's as well) and small number of marri nuts). This species is appears to be a frequent visitor to the general area for the purposes of foraging. There are is a small number of potential nest hollows present (2) and the probability of breeding on site is considered to be low.

Potential impact of development: The jarrah woodland onsite represents foraging habitat for this species. Clearing required for mining activates will see a reduction in the area available for foraging. It is anticipated this will be temporary as it is understood that rehabilitation of mined areas will use a range of cockatoo food plants. No management measures above that already in place or planned are recommended.

Baudin's Black- Cockatoo *Calyptorhynchus baudinii*

Status and Distribution: Listed as Scheduled 1 under the *WAWC Act (1950)* and as Vulnerable under the *EPBC Act (1999)*. Confined to the south-west of Western Australia, north to Gidgegannup, east to Mt Helena, Wandering, Quindanning, Kojonup, Frankland and King River and west to the eastern strip of the Swan Coastal Plain including West Midland, Byford, Nth Dandalup, Yarloop, Wokalup and Bunbury (Johnstone and Storr 1998). On the southern Swan Coastal Plain this cockatoo is in some areas resident but mainly a migrant moving from the deep south-west to the central and northern Darling Range. Between March and September most flocks move north and are concentrated in the northern parts of the Darling Range. During this period birds forage well out onto the southern Swan Coastal Plain to areas such as Harvey, Myalup, Bunbury, Capel, Dunsborough and Meelup. While generally more common in the Darling Range this species can also be common on parts of the southern Swan Coastal Plain especially in mid-August – September when flocks begin to return to their breeding quarters (Johnstone 2008).

Habitat: Mainly eucalypt forests where it feeds primarily on the Marri seeds, (Morcombe, 2003), Banksia, Hakeas and *Erodium* sp. Also strips bark from trees in search of beetle larvae (Johnstone and Storr 1998). This species of cockatoo nests in large tree hollows, 30–40 cm in diameter and more than 30 cm deep (Saunders 1974).

Baudin's Black-Cockatoo breeds in late winter and spring, from August to November or December (Gould 1972; Johnstone 1997; Saunders 1974; Saunders *et al*. 1985). Eggs laid in October (Johnstone and Storr 1998). Incubation is 28 – 30 days. Young fledge at 8 to 9 weeks (Simpson and Day 2004).

J	F	M	A	M	J	J	A	S	O	N	D

Period in which breeding is most likely to commence
Period in which fledging/weening could extend througho

Likely presence in study area: Some specific examples of Baudin's Cockatoo foraging activity were observed within the MEA (chewed marri nuts) while numerous Banksia cones showing signs of cockatoo foraging (seeds and grubbing) were also observed though some or all of this activity could be attributed to Carnaby's and not Baudin's Cockatoos. This species is probably a seasonally controlled infrequent visitor to the general area for the purposes of foraging on Marri, Banksia and Flooded Gum. There are is a small number of potential nest hollows present (2) and the probability of breeding on site is considered to be low.

Potential impact of development: The jarrah/banksia woodland onsite represents foraging habitat for this species. Clearing required for mining activates will see a reduction in the area available for foraging. It is anticipated this will be temporary as it is understood that rehabilitation of mined areas will use a range of cockatoo food plants. No management measures above that already in place or planned are recommended.

Carnaby's Black- Cockatoo *Calyptorhynchus latirostris*

Status and Distribution: Carnaby's Black Cockatoo is listed as Scheduled 1 under the *WAWC Act (1950)* and as Endangered under the *EPBC Act (1999)*. Confined to the south-west of Western Australia, north to the lower Murchison River and east to Nabawa, Wilroy, Waddi Forest, Nugadong, Manmanning, Durokoppin, Noongar (Moorine Rock), Lake Cronin, Ravensthorpe Range, head of Oldfield River, 20 km ESE of Condingup and Cape Arid; also casual on Rottnest Island (Johnstone and Storr 1998).

Habitat: Forests, woodlands, heathlands, farms; feeds on Banksia, Hakeas and Marri. Carnaby's Cockatoo has specific nesting site requirements. Nests are mostly in smoothed-barked eucalypts with the nest hollows ranging from 2.5 to 12m above the ground, an entrance from 23-30cm diameter and a depth of 0.1-2.5m (Johnstone and Storr, 1998).

Breeding occurs in winter/spring mainly in eastern forest and wheatbelt where they can find mature hollow bearing trees to nest in (Morcombe, 2003). Judging from records in the Storr-Johnstone Bird Data Bank, this species is currently expanding its breeding range westward and south into the Jarrah – Marri forest of the Darling Scarp and into the Tuart forests of the Swan Coastal Plain including the region between Mandurah and Bunbury. There are small resident populations on the southern Swan Coastal Plain near Mandurah, Lake Clifton and near Bunbury. At each of these sites the birds forage in remnant vegetation and adjacent pine plantations (Johnstone 2008).

Carnaby's Black-Cockatoo lays eggs from July or August to October or November, with most clutches being laid in August and September (Saunders 1986). Birds in inland regions may begin laying up to three weeks earlier than those in coastal areas (Saunders 1977). The female incubates the eggs over a period of 28-29 days. The young depart the nest 10–12 weeks after hatching (Saunders 1977; Smith & Saunders 1986).

J	F	M	A	M	J	J	A	S	O	N	D

Period in which breeding is most likely to commence
Period in which fledging/weening could extend through

Likely presence in study area: Several small flocks of this species were observed within the MEA during the site surveys. Previously recorded on the KSS property during other surveys. Numerous examples of foraging activity were observed (chewed jarrah nuts and banksia cones (though some of this activity could be attributed to FRTBC/Baudin's), pine cones and small number of marri nuts). This species is appears to be a frequent visitor to the general area for the purposes of foraging. There are is a small number of potential nest hollows present (2) and the probability of breeding on site is considered to be low.

Potential impact of development: The jarrah/banksia woodland onsite represents foraging habitat for this species. Clearing required for mining activates will see a reduction in the area available for foraging. It is anticipated this will be temporary as it is understood that rehabilitation of mined areas will use a range of cockatoo food plants. No management measures above that already in place or planned are recommended.

Barking Owl *Ninox connivens connivens*

Status and Distribution: Listed as Priority 2 by DEC. Found north to Perth (formerly) and east to Northam, Katanning and nearly to Bremer Bay. Declining in south west (Johnstone and Storr 1998).

Habitat: Dense vegetation, especially forest and thickets of waterside vegetation such as melaleucas (Johnstone and Storr 1998). Roosts in tree hollows.

Likely presence in study area: Potentially present in general Kemerton area though no records appear to exist. Potential habitat within the MEA is limited in extent and of marginal quality.

Potential impact of proposed development: No significant impact on this species is anticipated given habitat to be affected is marginal and unlikely to be utilised by this species at any significant level. No specific management measures recommended.

Masked Owl *Tyto novaehollandae novaehollandae*

Status and Distribution: Listed as Priority 3 by DEC. Found north to Yanchep and east to Yealering, Gnowangerup and Albany, casual further north. Locally common in south west but generally uncommon (Johnstone and Storr 1998).

Habitat: Roosts and nests in heavy forest, hunts over open woodlands and farmlands (Morcombe, 2003). Probably breeding in forested deep south west with some autumn–winter wanderings northwards (Johnstone and Storr 1998).

Likely presence in study area: No records in or near study site suggest this species is a rare and infrequent visitor to the Kemerton area, though can be difficult to observe.

Potential impact of proposed development: This species is only likely to visit the site rarely, if at all as it would not be specifically attracted to the general area. No significant impact on this species is anticipated. No specific management measures recommended.

Fork-tailed Swift *Apus pacificus*

Status and Distribution: The Fork-tailed Swift is listed as migratory under the *EPBC Act 1999* and under international agreements to which Australia is a signatory. It is a summer migrant (Oct-Apr) to Australia (Morcombe 2003). Recent record from Preston Beach (Bill Russell pers. coms).

Habitat: Low to very high airspace over varied habitat from rainforest to semi desert (Morcombe 2003).

Likely presence in study area: It is potentially a very occasional summer visitor to the study area but is entirely aerial and largely independent of terrestrial habitats.

Potential impact of development: No impact on this species is anticipated as it is likely to be only a very infrequent visitor to the general area. No specific management measures recommended.

Rainbow Bee-eater *Merops ornatus*

Status and Distribution: This species is listed as migratory under the *EPBC Act (1999)* and under international agreements to which Australia is a signatory. The Rainbow Bee-eater is a common summer migrant to southern Australia but in the north they are resident (Morcombe 2003).

Habitat: Open Country, of woodlands, open forest, semi arid scrub, grasslands, clearings in heavier forest, farmlands (Morcombe 2003). Breeds underground in areas of suitable soft soil firm enough to support tunnel building.

Likely presence in study area: Reecorded in the KSS property. Probably a relatively common seasonal visitor to the general area.

Potential impact of development: No impact on this species is anticipated and it can be expected to continue to utilise the area, if it does now, despite any future development. No specific management measures recommended.

Chuditch *Dasyurus geoffroii*

Status and Distribution: Listed as Scheduled 1 under the *WC Act (1950)* and as Vulnerable under the *EPBC Act (1999).* Formerly occurred over nearly 70 per cent of Australia. The Chuditch now has a patchy distribution throughout the Jarrah forest and mixed Karri/Marri/Jarrah forest of southwest Western Australia. Also occurs in very low numbers in the Midwest, Wheatbelt and South Coast Regions with records from Moora to the north, Yellowdine to the east and south to Hopetoun.

Habitat: Chuditch are known to have occupied a wide range of habitats from woodlands, dry sclerophyll (leafy) forests, riparian vegetation, beaches and deserts. Riparian vegetation appears to support higher densities of Chuditch, possibly because food supply is better or more reliable and better cover is offered by dense vegetation. Chuditch appear to utilise native vegetation along road sides in the wheatbelt (CALM 1994). The estimated home range of a male Chuditch is over 15 km^2 whilst that for females is 3-4 km^2 (Sorena and Soderquist 1995). Reflecting its carnivorous nature the Chuditch occurs at low densities even in high quality habitat. Along the Murray River valley adult females den within a stable core area of 55 to 120 ha or more, while male dens are distributed over an area of 400 hectares or more. The core areas of neighbouring females typically show little or no overlap suggesting they are actively defended (Serena and Soderquist 2008).

In the Jarrah forest den sites usually consist of horizontal hollow logs or earth burrows. To be suitable as a den site, logs must have a diameter of at least 30cm (but usually >50cm), a hollow diameter of 7-20cm and the actual den typically 1m from the entrance. Most burrows are located beneath surface features such as trees, stumps, logs and rock outcrops, which offer increased protection and may facilitate den construction by supplying pre-existing channels or cavities. Over the course of a year, an average adult female Chuditch will utilise an estimated average of 66 logs and 110 burrows within her home range (Orell and Morris 1994).

Likely presence in study area: This species is rarely recorded on the coastal plain (Dell 2000) though is presence in the general area can not be discounted. The nearest, most recent record in the DEC database is from Eaton in 2000 and previous to this, Leschenault in 1997. An individual was also captured in Yalgorup National Park in 2007 (Nowicki 2007). Current status in Kemerton area is difficult to determine. Bamford *et al.* (2004) conducted a trapping survey in the western portion of the KSS property to provide specific survey information on the possible presence of the Chuditch. No Chuditch, or any other mammals, were trapped during the survey. Bamford *et al.* (2004) report that although no Chuditch were trapped during this survey, small numbers are clearly present in the region given previous records.

Potential impact of development: Potential for loss of some habitat though utilisation appears to be low. Vegetation clearance associated with the proposed mine extension has the potential to have a small impact on the habitat and population of the Chuditch. No management measures above that already in place or planned are recommended.

Southern Brush-tailed Phascogale *Phascogale tapoatafa tapoatafa*

Status and Distribution: Listed as Scheduled 1 under the *WAWC Act (1950)*. Present distribution is believed to have been reduced to approximately 50 per cent of its former range. Now known from Perth and south to Albany, west of Albany Highway. Occurs at low densities in the northern Jarrah forest. Highest densities occur in the Perup/Kingston area, Collie River valley, and near Margaret River and Busselton (DEC information pamphlet). Records are less common from wetter forests.

Habitat: This subspecies has been observed in dry sclerophyll forests and open woodlands that contain hollow-bearing trees but a sparse ground cover. A nocturnal carnivore relying on tree hollows as nest sites. The home range for a female Brush-tailed Phascogale is estimated at between 20 and 70 ha, whilst that for males is given as twice that of females.

Natural nest sites located in tree hollows. They tend to utilise a large number (approximately 20) of different nest sites throughout their range (Soderquist, 1995). A study by Rhind (1998) found no apparent preference for particular tree species but preference for nesting in older and senescent or dead trees. Females with dependant young showed particular preference for these tree forms (Rhind 1998). Breeding Season extends over a three week period between mid

May to early July varying with locality and years. Gestation is 30 days. Weening complete at about 20 weeks. Dispersal occurs in mid summer (Van Dyk and Strahan 2008).

J	F	M	A	M	J	J	A	S	O	N	D

Period in which breeding is most likely to commence
Period in which fledging/weening could extend through

Likely presence in study area: Two individuals of this species were captured during the targeted survey. Appears to be present in woodland areas containing habitat trees in low densities.

Potential impact of development: Loss of foraging habitat and trees with suitable hollows has the potential to impact on this species. Any planned clearing for the proposal will need to take into consideration the possibility that the identified habitat trees may contain hollows suitable for this species to utilise and where reasonable and practicable they should be retained if possible. Trees that need to be removed should be felled outside of the known breeding season of this species if possible. Other management measures will need to be employed if the proposal proceeds to reduce the chance of individuals being killed during clearing. The most appropriate management methods will need to be formulated in consultation with the DEC. These may involve intense trapping within areas just prior to clearing followed by either translocation of individuals by DEC personal or relocation of individuals to nearby suitable habitat. The proposed relocating of habitat trees as part of the cockatoo management plan will also assist in phascogale management. The provision of nest boxes in rehabilitated areas or adjoining areas with few hollow trees should also be considered.

Quenda *Isoodon obesulus fusciventer*

Status and Distribution: Listed as Priority 5 by DEC. Widely distributed in the south west from near Cervantes north of Perth to east of Esperance, patchy distribution through the Jarrah and Karri forest and on the Swan Coastal Plain, and inland as far as Hyden. Has been translocated to Julimar State Forest, Hills Forest Mundaring, Tutanning Nature Reserve, Boyagin Nature Reserve, Dongolocking Nature Reserve, Leschenault Conservation Park, and Karakamia and Paruna Sanctuaries (DEC information pamphlet) and Nambung National Park (DEC pers. coms.)

Habitat: Dense scrubby, often swampy, vegetation with dense cover up to one metre high, often feeds in adjacent forest and woodland that is burnt on a regular basis and in areas of pasture and cropland lying close to dense cover. Populations inhabiting Jarrah and Wandoo forests are usually associated with watercourses. Quendas can thrive in more open habitat subject to exotic predator control (DEC information pamphlet).

Likely presence in study area: Previously recorded in the KSS property. Several tracks and diggings observed within the MEA indicate the presence of this species though it appears to be restricted to limited areas having dense groundcover. Previous trapping results (Chuditch trapping) did no capture any individuals of this species also suggesting low population level. No individuals were captured during the Phascogale trapping program but it should be noted that small Elliot's are not idea as only smaller young individuals could fit into the traps and habitat trees were generally in relatively cleared areas with little dense groundcover.

Potential impact of development: The loss of a small amount of potential habitat and the potential for individuals to be killed during clearing. This can be managed by intensive trapping using suitable traps (concurrent with proposed phascogale trapping where overlapping habitat present) and the translocation/relocation of captured individuals. The slow progressive clearing of groundcover vegetation so as to allow animals to flee into retained vegetation is also considered adequate in some circumstances.

Western Ringtail Possum *Pseudocheirus occidentalis*

Status and Distribution: Listed as Scheduled 1 under the *WAWC Act (1950)* and as Vulnerable under the *EPBC Act (1999).* Common in suitable habitat (de Tores 2008). The highest densities of this species were recorded in Peppermint habitat near Busselton area; relatively high densities were found in Jarrah/Marri forest at Perup (de Tores 2008).

The Western Ringtail Possum has a restricted distribution in south-western Western Australia. Most known populations (natural and translocated) are now restricted to near coastal areas of the south west from the Dawesville area to the Waychinicup National Park. Inland, it is also known to be relatively common in a small part of the lower Collie River valley, the Perup Nature Reserve and surrounding forest blocks near Manjimup. It was recently recorded in stands of Peppermint near the Harvey River and in Jarrah/Marri forest near Collie; however, the long term persistence of the species in these areas is not confirmed (de Tores et al. 2004). The Western Ringtail was formerly more widespread: in the 1970s it was known from Casuarina woodlands in the wheatbelt near Pingelly (south-east of Perth), and it is thought to have once occurred throughout much of south-western Western Australia (but not necessarily continuously distributed) (Maxwell et al. 1996; de Tores 2008).

Widespread and relatively common in vegetated remnants within the Swan Coastal Plain and along the Whicher Scarp between Bunbury and Busselton (G. Harewood per. obs.). Most northern known natural population is centred on the Binninup townsite. This population extends eastwards within remnant vegetation along Binningup Road (G. Harewood per. obs.) at least as far as a property located on Wellesley Road/Old Coast Road corner (reported by property owner in Chuditch Call newsletter Feb 2008).

Habitat: The Western Ringtail Possum was once located in a variety of habitats including Coastal Peppermint, Coastal Peppermint-Tuart, Jarrah-Marri associations, Sheoak woodland, and eucalypt woodland and mallee. Coastal populations mostly inhabit Peppermint-Tuart associations with highest densities in habitats with dense, relatively lush vegetation. In these areas the main determinants of suitable habitat for WRPs appears to be the presence of *Agonis flexuosa* either as the dominant tree or as an understorey component of Eucalypt forest or woodland (Jones *et al*. 1994a). Inland, the largest known populations occur in the Upper Warren area east of Manjimup (Wayne *et al* 2005). In this area the peppermint tree is naturally absent and jarrah-marri associations constitute the species refuge and foraging habitat.

Likely presence in study area: A targeted search for the Western Ringtail Possum (WRP) did not find any evidence of this species utilising the study area. The results suggest that WRPs are either absent from the site or are present in very low numbers, possibly just as occasional transient individuals. As far as the author is aware the closest documented record of this species is about 5km west of the MEA (Chuditch Call newsletter Feb 2008). Habitat within the MEA is considered by the author to be mostly unsuitable for this species or at best marginal due to relatively open nature, dominance of low shrubland or absence/low density of preferred foraging species and possibly the low nutritional value of foraging species when present. The most suitable habitat (Peppermint dominated woodland/forest is limited to a very small proportion of the site (mapped as C2).

Potential impact of development: No impact in this species is anticipated as it does not appear to be utilising the site. Potential loss of some habitat but the author does not consider this to represent an area “critical” for the survival of the species. No species specific management measures are recommended.

Quokka *Setonix brachyurus*

Status and Distribution: Listed as Scheduled 1 under the *WC Act* (1950) and as Vulnerable under the *EPBC Act* (1999). Rare and restricted in south west W.A. from south of Perth to Two Peoples Bay. The distribution of the Quokka includes Rottnest and Bald Islands, and at least 25 known sites on the mainland, including Two Peoples Bay Nature Reserve, Torndirrup National Park, Mt Manypeaks National Park, Walpole-Nornalup National Park, and various swamp areas through the south-west forests from Jarrahdale to Walpole. Population recently identified just south of Bunbury.

Species or species habitat listed as likely to occur in general area within EPBC database search.

Habitat: Mainland populations of this species are currently restricted to densely vegetated coastal heaths, swamps, riverine habitats including tea-tree thickets on sandy soils along creek systems where they are less vulnerable to predation. The species is nocturnal

Likely presence in study area: Generally considered to be locally extinct. Not listed in this report as a potential species.

Potential impact of development: No impact is anticipated as this species is unlikely to be present. No species specific management measures are recommended.

Western Brush Wallaby *Macropus irma*

Status and Distribution: Listed as Priority 4 by DEC. The Western Brush Wallaby is distributed across the south-west of Western Australia from north of Kalbarri to Cape Arid (DEC information pamphlet).

Habitat: The species optimum habitat is open forest or woodland, particularly favouring open, seasonally wet flats with low grasses and open scrubby thickets. It is also found in some areas of mallee and heathland, and is uncommon in karri forest (DEC information pamphlet).

Likely presence in study area: Previously recorded in the KSS property area and also observed during the most recent survey reported on here.

Potential impact of proposed development: Potential for loss of some habitat. Presences of significant areas of remnant vegetation in the area should ensure species persist despite proposal proceeding. Likely to utilise rehabilitated areas. No species specific management measures are recommended.

Western False Pipistrelle *Falsistrellus mackenziei*

Status and Distribution: Listed as Priority 4 by DEC. Listed as vulnerable by the ICUN. Confined to south west W.A. south of Perth and east to the wheat belt. Most records from Karri forests but also recorded in wetter stands of jarrah and tuart and woodlands on the Swan Coastal Plain (Menkhorst and Knight 2001). Range appears to be contracting southwards, presumably due to drying climate. Not recorded north of Collie in recent times (Bob Bullen pers. coms.)

Habitat: This species of bat occurs in high forest and coastal woodlands. It roosts in small colonies in tree hollows and forages at canopy level and in the cathedral-like spaces between trees.

Likely presence in study area: Not recorded in the KSS property area but records form adjoining areas. This species is a likely inhabitant of the study area as suitable habitat is present though its actual status is unknown.

Potential impact of proposed development: Loss of habitat trees has the potential to impact on this species and they should be retained where ever possible. The proposed relocating of habitat trees as part of the cockatoo management plan will also assist in this species management.

Water Rat *Hydromys chrysogaster*

Status and Distribution: Listed as Priority 4 by DEC. The water rat is widely distributed around Australia and its offshore islands, New Guinea and some adjacent islands. It occurs in fresh brackish water habitats in the south-west of Western Australia, but occurs in marine environments along the Pilbara coastline and offshore islands. Previous survey work in the south west suggested this species was relatively common and widespread though difficult to capture (Christensen et al 1985, How et al 1987).

Habitat: The water rat occupies habitat in the vicinity of permanent water, fresh, brackish or marine. Likely to occur in all major rivers and most of the larger streams as well as bodies of permanent water in the lower south west (Christensen et al 1985).

Likely presence in study area: Previously recorded in the KSS property. Seasonal nature of the wetland areas with the MEA would precluded permanent population of this species being present. May occasionally forage/pass through the site during wetter months of the year but would not reside on site.

Potential impact of development: The MEA would not support permanent populations of this species but it has the potential to spread into this area on a temporary basis in wetter months/years. There is therefore potential for this habitat to be changed or access to it restricted by changes in surface hydrology. There is also the potential, with proper management, for habitats to be enhanced for this species e.g. creation of permanent water bodies with suitable micro-habitats for aquatic vertebrates and invertebrates species. It is understood that management plans relating to this issue have been formulated. No addition recommendations are put forward.

APPENDIX 14:
KEMERTON TERRESTRIAL INVERTEBRATE SRE SURVEY
DECEMBER 2007

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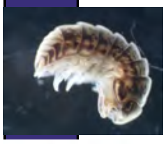
SCHOOL OF NATURAL SCIENCES
EDITH COWAN UNIVERSITY



Kemerton Terrestrial Invertebrate SRE Survey.

Report to MBS Environmental
December 2007.

Adrianne Kinnear
and
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EXECUTIVE SUMMARY

This report describes selected SRE taxa (millipedes, mygalomorph spiders and slaters) surveyed in upland vegetation of a proposed extension to the current mine site, proposed offset areas and the Kemerton Nature Reserve, all areas within the boundary of the Kemerton Silica Sand Pty Ltd mininig propert north of Bunbury. The results are summarised as follows:

• Millipedes (all Polydesmida) were well dispersed throughout all sampling areas. However, only two adults were collected and only one was a male. If further evaluation of the millipede fauna is required, it is recommended that sampling be carried out in early winter to maximise the collecting of male adults. The single male species was identified as *Antichiropus variabilis*. (*Antichiropus variabilis* is regarded as a non-SRE species).

• None of the remaining invertebrate morphospecies were found to be unique to the area within the proposed mine site. All species collected from the proposed mine site were also collected from one or more of the proposed offset sites or Nature Reserve. One species of mygalomorph spider (*Aname* sp.) and four species of oniscid slater (*Buddelundia* sp., *Eurygastor* sp., *Laevophiloscia* sp., and a philosciid species) were collected from 120 pit traps and selected hand searching.

• No single offset site yielded the entire range of species, and for this reason, it is recommended that all of the proposed offset sites and the Nature Reserve be retained and managed for conservation purposes.

1.0 Introduction

Short-range endemics (SREs) are taxonomic groups (generally invertebrates) whose species have small natural distributions. Harvey (2002), in one of the first reviews of Australian SREs, suggested a benchmark maximum range for such species of 10 000 km^2 (100 x 100 km). While there are a large number of terrestrial invertebrate taxa likely to contain SREs (see Appendix 1 in Harvey, 2002), poor taxonomic and ecological knowledge of much of our endemic invertebrate fauna, particularly in Western Australia, restricts their use in management and conservation to all but a few main taxa. Commmonly-surveyed SRE terrestrial invertebrate taxa in this state are the Diplopoda (millipedes), Mygalomorph spiders and Gastropoda (land snails).

Members of all these groups exemplify the characteristics of SREs –species with limited distributions, narrow habitat requirements and poor dispersal abilities. Many of the Western Australian SRE taxa are also highly speciose. This combination of characteristics makes SRE taxa and their diversity particularly vulnerable to habitat disturbance and destruction on local scales.

1.1 Background to the project

The Kemerton Silica Sand Pty Ltd project area is located 27 km north northwest of Bunbury, on gently-undulating Bassendean sands. The vegetation of the area has been mapped (Mattiske Consulting Pty Ltd, 2002) and the upland vegetation of *E. marginata* – *Banksia* spp open woodland is typical of the Swan Coastal Plain Bassendean (Central and South) Complex.

There is a proposal to extend the mine site by 258 ha immediately to the east of the current site. At the same time, three proposed offset sites have been identified to the north and south of the current mine site, totalling approximately 140 ha. In addition, a conservation zone of significant area within the company's boundary, the Kemerton Nature Reserve, links two of the offset sites and provides further potential conservation capacity (Appendix 1).

The proposed mine site contains important wetland areas within its boundaries which have been identified as being of significant conservation category. The upland vegetation in the proposed mine site extension (87 ha) and offset areas is the focus of this study, and is typical of the mixed eucalypt-Banksia woodland remaining on the Bassendean sands throughout the area. The area within the company's boundary generally shows little relief with only periodic gently sloping rises. As a result, there are no specific areas or landform features (eg granite outcrops, boulders, gullies, shaded south-facing strongly-pitched slopes) that could be focus sites for SRE fauna. The Nature Reserve, also of little relief, displays a degree of vegetation degradation, reflecting its disturbance history. There are large areas devoid of vegetation and the upland vegetation which is present often appears sparse and in poor condition.

2.0 Scope and aims of the project

The proposed expansion of mining activities to the east of the current mine site (Appendix 1) is likely to impact on the upland eucalypt-Banksia woodland and hence on the invertebrate faunal communities present throughout the proposed mine extension area. There have been no previous invertebrate surveys of this area, though it is typical of the mixed Banksia woodland throughout the area.

This project had, as its brief, to survey selected SRE taxa in the proposed mining extension and proposed offset areas, with a particular focus on the millipede taxa. Any collected Mygalomorphae spiders would also be included. To these taxa, we have added the Isopoda: Oniscidea (slaters), a less surveyed taxa but one that is also highly likely to contain endemic SRE species. The Isopoda share the habitat requirements of millipedes; their mode of respiration restricts them to the most humid habitats, their dispersal abilities are very poor, and their breeding activity is restricted to the winter rainfall period when humidity in the soil/litter interface is at its maximum. The recent work of Judd (2004) which provides the first distribution analyses of Western Australian species, has shown that the Isopoda have a high capacity for speciation, have exceptional diversity with high beta diversity, and highly-localised endemics. All this renders this taxon a useful addition to the SRE toolkit for evaluating faunal similarities between the sites in this project.

The specific aims of the project are to conduct a survey of the selected SRE terrestrial invertebrates of the upland areas in order to compare the fauna of

- (i) the proposed mining extension;
- (ii) the already-conserved Kemerton Nature Reserve, and
- (iii) the rest of the Kemerton property, particularly the proposed offset areas,

in order to make recommendations on the likely impact of the proposed mining extension on the diversity of the selected SRE taxa.

3.0 Methods

3.1 Sample sites

Three main areas were identified for invertebrate sampling, the proposed mine extension area (approximately 258 ha) immediately to the west of the current mining area (identified as Sample Area E in Appendix 1), the proposed offset areas north and south of the current mining area (totalling approximately 142 ha; Sample Areas A, B and C) and Kermerton Nature Reserve adjacent to the north and eastern boundaries of the mining area (Sample Area D in Appendix 1). Within each of these areas, upland sites were selected to ensure as broad coverage of the sites as possible. Within each area, sites were selected with characteristics such as high vegetation quality, overstorey shading and substantial litter cover in order to maximise the invertebrate SRE catch.

At each sampling site, line transects were established extending into the woodland for positioning of pit traps with care taken to avoid edge effects due to tracks, firebreaks, or other obvious disturbed areas. GPS locations were recorded for each transect. Twelve transects were established, 6 within the proposed mining extension, 5 spread across the proposed offset areas and one in the Nature Reserve. Transect positions are approximately indicated in Appendix 1. Table 1 provides GPS locations and brief site descriptions. The vegetation descriptions are as described by Mattiske Consulting Pty Ltd (2002). Only one transect was established in the Nature Reserve because of the degraded nature of the vegetation in the easily-accessable areas. Photos along the line transects at each of the sites are presented in Appendix 2.

Over the period of sampling, most sites had areas of deep, very moist litter and the soil was sufficiently moist that it held a shovel-shape when dug. At all sites, with the exception of the Nature Reserve, there was substantial faunal activity in the moist litter and at the soil/ltter interface. Earthworms, termites, isopods and amphipods were evident, indicative of conditions of high humidity. Also centipedes, mites, spiders and cockroaches were visually observed frequently at all sites during hand searches.

3.2 Faunal sampling and identification

Pit traps were used for general invertebrate collection. Hand searching was also used for millipedes and isopods. The pit traps consisted of square 2-litre plastic ice cream containers (16.5 x 16.5 x 9.0 cm) containing approximately 500 ml of ethylene glycol. Once each transect line was established, ten pit traps were dug in along the line 10 metres apart, and an indentification label was placed in each (Plate 1). This gave a total of 60 pit traps in the proposed mine extension site, 50 in the proposed offset sites and 10 in the Nature Reserve. The traps were left open for 12 days over the period 26th September – 8th October. The weather during the trapping period was cool to mild with maximum temperatures ranging between 18.6 and 22.7^{o}C. The rainfall recorded for Bunbury over the period was approximately 23 mm (Bureau of Meterology). Within the study area, the rainfall was sufficient to more than double the fluid levels in some traps by the end of the trapping period.

Plate 1. Pit trap in situ.

Once each set of 10 traps was set, litter accumulations well beyond the line transect were hand-searched for millipedes (and occasionally isopods) for at least 90 minutes. Millipedes were well-dispersed and tended to be found in situations towards the edges

Table 1. Locations of pit trap transects for SRE invertebrate sampling of upland vegetation areas.

Area	Site	Location	Description
Proposed Mine Extension	E1	6334350 0286467	Northwards off bore track extending from the eastern margin of the proposed extension site. Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia*. Site is somewhat degraded with open areas and reduced shrub canopy; considerable litter and dead/burnt CWD.
	E2	6334550 0384653	North-west corner of proposed extension site. Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia* with scattered *Agonis flexuosa.*; relatively open compared with offset site B; sparse understorey with bare sand patches. Litter very think around tree bases and very moist.
	E3	6332826 0284685	Western boundary of proposed extension site. Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia*. Good litter layer, shrub understorey. Soil appears more organic than other sites; all very moist.
	E4	6333875 0385492	Central area of proposed extension site, north of talings dump, off end of access track. Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia* with scattered *Nuytsia floribunda*. Open areas and CWD evident; tall shrub understorey.
	E5	6333336 0385232	North off access track into mid-area of proposed extension site. Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia* with *Hibbertia*/shrub understorey.
	E6	6333353 0384925	West of E5 and south off access track in proposed extension site. Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia* with scattered *Agonis flexuosa*.
Proposed Offset Areas July 2007	A1	6332216 0386622	One transect only in southern area of offset site; Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia* with scattered *Nuytsia floribunda*.
	B1	6330284 0386924	Off access track delineating eastern boundary of offset site; south-east corner. Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia*; south facing on very slight slope; thick litter moist concentration over much of the site.
	B2	6330666 0386573	Off access track delineating western border of offset site; extends east into site. Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia;* very moist litter on site.
	B3	633928 0386574	Immediately north of B2; also extends east into site. Open woodland of *Eucalyptus marginata* – *Banksia attenuata* – *Banksia illicifolia* with relatively thick shrub understory; very thick *Banksia* litter evident.
	C1	6333869 0386653	Northernmost offset site; southern area of site, off pipeline access track. Closed heath of Myrtaceae species; some open degraded areas; low rush ground cover dominant; relatively close to wetland area. Some open areas.
Kemerton Reserve	D1	6333925 0387424	Only transect on the reserve site. Mainly closed heath of Myrtaceae species; Some *E. marginata* present; disturbed open patches in transect.

of litter accumulations, where the litter was less dense and both litter and surface soil were damp but not saturated (Plate 2). Specimens were removed with forceps and placed into 70% alcohol.

Plate 2. Typical millipede leaf litter habitat

Pit traps were transported back to the laboratory and placed in a cool room until the fauna could be sorted into 70% alcohol. Specimens of the three relevant SRE groups, millipedes, mygalomorph spiders and isopods were separated out from the other invertebrates. Millipedes were sorted into male and female adults, and juveniles and identified to order (Harvey & Yen, 1989) and then genus and morphospecies where possible. Isopods were identified to genera and morphospecies (Judd, 2004). Mygalomorph spiders were also identified to genera and morphospecies (Raven, 1981; Raven, 1985; Raven et al., 2002). Data on the other invertebrate taxa are the basis of a second report in progress. All voucher specimens are held in the School of Natural Sciences, ECU.

3.3 Possible survey limitations

The timing of the survey, while appropriate to capture invertebrate diversity when the landscape is at its most productive (mid-spring) may not have been optimal for the millipede taxa. Identification of millipedes relies on the gonopod morphology of adult males. These animals become active and emerge when the first winter rains moisten the litter (April-May), and then die over the winter period as the litter subhabitat begins to dry out. However, the continuation of substantial rains well into September and October resulted in retention of very moist winter-like soil and litter. Our own observations of earthworm and isopod activity within the litter layer supported this. As a result, in coastal areas, populations of adult male millipedes were still active and being caught at the time of this survey (Mark Harvey pers. comm.).

4.0 Results

4.1 Diplopoda (millipedes)

A total of 46 millipede specimens, all belonging to the order Polydesmida, were collected, 24 in hand searches and 22 in pit traps (Table 2). Of these, only two individuals were adults and only one of these was male. Millipedes were well dispersed

Table 2. Diplopoda (millipedes) found in the KSS sites. PF = pitfall trap; HS = hand-searching.

Area	Site	Location	T axon	Comments	Number	Sampling Method
Proposed mining extension	E2	6334550	Polydesmida	Juvenile male	3	HS
		0384653	Polydesmida	Juvenile female	1	PF
			Polydesmida	Juvenile female	2	PF
	E3	6332826	Polydesmida	Juvenile male	2	HS
		0284685	Polydesmida	Juvenile female	2	HS
			Polydesmida	Juvenile female	5	PF
	E4	6333875	Polydesmida	Juvenile male	3	HS
		0385492	Polydesmida	Juvenile female	1	HS
	E5	6333336	*Antichiropus* (*variabilis*?)	Adult male (sp. 1)	1	HS
		0385232	Polydesmida	Juvenile male	3	HS
			Polydesmida	Juvenile male	1	PF
	E6	6333353	Polydesmida	Juvenile female	3	HS
		0384925	Polydesmida	Adult female	1	PF
			Polydesmida	Juvenile male	1	PF
Proposed offset Areas July 2007	A1	6332216	Polydesmida	Juvenile male	1	HS
		0386622	Polydesmida	Juvenile female	1	PF
			Polydesmida	Juvenile male	1	PF
	B1	6330284	Polydesmida	Juvenile male	1	HS
		0386924	Polydesmida	Juvenile female	2	HS
			Polydesmida	Juvenile female	2	PF
			Polydesmida	Juvenile male	1	PF
	B2	6330666	Polydesmida	Juvenile male	1	HS
		0386573	Polydesmida	Juvenile male	4	PF
			Polydesmida	Juvenile female	1	PF
	B3	633928	Polydesmida	Juvenile male	1	HS
		0386574				
Kemerton Reserve	D1	6333925	Polydesmida	Juvenile female	1	PF
		0387424				

across all the sampling areas. The majority of the juveniles were later instars and while they appeared to be of similar taxa, they could not be identified beyond the ordinal level.

Comparisons of the gonopod morphology of the single adult male specimen with the generic and species descriptions (Attems, 1911; Shear (1992) provisionally identify this male adult as *Antichiropus* sp. (probably *variablilis*) in the family Paradoxosomatidae (Appendix 3). This genus contains the most abundant millipede group in Western Australia and to date, 90 species have been separated on the basis of the male gonopods (Harvey, 2002). All except *A. variabilis* are considered to be SREs (Harvey, 2005). *A. variabilis* inhabits the jarrah forests of south-western Australia and it has been found south east of the Swan River on the Bassendean Dune System and the Ridge Hill Shelf (How et al., 1996). So the possible location of this wider-ranging species within the Kemerton boundary is not surprising.

The lack of additional male adults in the collections prevent us making conclusions about the likely similarity of the millipede fauna between proposed mining and conservation sites, and whether millipede SREs are present within the Kemerton boundaries. We have found that millipedes are present at all sites sampled, and in reasonable numbers. If necessary, sampling in early winter should produce the adult males necessary to make faunal site comparisons.

4.2 Mygalomorphae (trap-door spiders and their relatives)

Five male individuals of a species of mygalomorph spider, *Aname* and one female were found in the pit traps, three in site within the proposed mine extension and three in proposed offset sites (Table 3). Only the two northern offset sites provided mygalomorph specimens. None were found in the Nature Reserve. The morphology of the male palpal structures and maxillae as well as other features suggest that all the males are a single morphospecies (Appendix 3),

Table 3. Species and locations of Mygalomorph spiders found during the survey.

Area	Site	Location	Family	Genus/Species	Number	Sampling Method
Within Proposed Extension boundary	E3	6332826 0284685	NEMESIIDAE	*Aname sp.*	1 male	PF
	E5	6333336 0385232	NEMESIIDAE	*Aname* sp. 1	1 male	PF
	E6	6333353 0384925	NEMESIIDAE	*Aname* sp. 1	1 male	PF
Proposed Offset Areas July 2007	A1	6332216 0386622	NEMESIIDAE	*Aname* sp. 1 (?)	1 female	PF
	C1	6333869 0386653	NEMESIIDAE	*Aname* sp. 1	2 males	PF

Microscope observations suggest that the female is also of this same species, but it is not possible to be sure. The genus *Aname* occurs widely across the continent and within Western Australia, including the Swan Coastal Plain (How et al., 1996; Raven, 1981). Members of this group build simple silk-lines tubes under logs or may dig an open-holed burrow in the ground (Main, 1884). The genus is not considered to contain relictual species likely to have fragmented distributions (Main, 1999).

4.3 Isopoda: Oniscidea (slaters): potential SRE taxa

Native isopods were found in at all sampled sites, with four species representing two families and at least three genera. All species were found at both the proposed mine extension site and the proposed offset sites. The slater species richness (4) found at the Kemerton site is rated as 'intermediate" and is typical of wooded sites on the coastal fringe of the Swan Coastal Plain Bioregion (Judd, 2004).

Table 4. Species and locations of slaters (Isopoda: Oniscidae) collected during the survey.

Area	Site	Location	Family	Genus/Species	Morpho-sp. No.	Number	Sampling Method
Proposed extension boundary	E1	6334350	Armadillidae	*Buddelundia* sp.	1	1	PF
		0286467	Philosciidae	Sp.1	2	10	PF
	E2	6334550	Philosciidae	Sp.1	2	2	PF
		0384653	Philosciidae	*Laevophiloscia* sp.	4	1	PF
	E3	6332826	Armadillidae	*Buddelundia* sp.	1	1	PF
		0284685	Philosciidae	Sp.1	2	6	PF
			Philosciidae	*Eurygastor* sp.	3	1	PF
	E4	6333875	Armadillidae	*Buddelundia* sp.	1	2	PF
		0385492					
	E5	6333336	Armadillidae	*Buddelundia* sp.	1	1	PF
		0385232	Philosciidae	Sp.1	2	2	PF
			Philosciidae	*Eurygastor* sp.	3	1	PF
	E6	6333353	Armadillidae	*Buddelundia* sp.	1	3	PF
		0384925	Philosciidae	Sp.1	2	6	PF
			Philosciidae	*Eurygastor* sp.	3	1	PF
Proposed Offset Areas July 2007	A1	6332216	Philosciidae	*Laevophiloscia* sp.	4	1	PF
		0386622	Philosciidae	*Laevophiloscia* sp.	4	2	HS
	B1	6330284	Philosciidae	Sp.1	2	9	PF
		0386924	Philosciidae	*Eurygastor* sp.	3	1	PF
	B2	6330666	Armadillidae	*Buddelundia* sp.	1	2	PF
		0386573	Philosciidae	Sp.1	2	8	PF
			Philosciidae	*Eurygastor* sp.	3	2	PF
			Philosciidae	*Laevophiloscia* sp.	4	3	HS
	B3	633928	Armadillidae	*Buddelundia* sp.	1	2	PF
		0386574	Philosciidae	Sp.1	2	2	PF
			Philosciidae	*Eurygastor* sp.	3	1	PF
	C1	6333869	Philosciidae	Sp.1	2	13	PF
		0386653	Philosciidae	*Eurygastor* sp.	3	1	PF
Kemerton Reserve	D1	6333925	Philosciidae	Sp.1	2	7	PF
		0387424					

5.0 Discussion

With the the exception of the millipede taxon for which insufficient data are available, the results of the survey indicate that there is total similarity of the collected SRE taxa between the proposed mine extension area and the proposed conservation areas. Collectively, the proposed offset sites and the Nature Reserve provided equivalent species and abundances to the proposed mine extension site (for equivalent sampling intensity). No species occurred only in the proposed mine extension area; all were found in one or more proposed offset sites.

Unfortunately, despite the winter-like moisture levels within the litter and soil and apparently sufficient humidity (as indicated by the presence of active earthworms throughout the litter at all sites) insufficient male adult millipedes were collected to evaluate the taxon similarities across the sites. The presence of relatively abundant late instar juveniles at all sites indicates that the area collectively supports a widely dispersed millipede community and re-sampling of the populations in early winter should provide adult individuals suitable for evaluating morphospecies distributions. It is noteworthy that the only individual identified appears to be *Antichiropus variabilis*, a widely-ranging, non-SRE species.

No single offset site yielded the entire range of species, and for this reason, it is recommended that all of the proposed offset sites be retained and managed for conservation purposes. The larger Nature Reserve area occupies a significant position with respect to the proposed offset areas – it links the two northernmost offset areas so that collectively, the proposed offsets and the Nature Reserve provide for an almost continuous potential conservation corridor within and along the eastern boundary of the Kemerton property. A second report in progress will provide a baseline evaluation of the ground-active invertebrate diversity of this corridor against which future surveys can be assessed.

Within the Nature Reserve, the accessable upland vegetation areas contain substantial disturbed sections where vegetation is lacking and sandy areas are completely exposed. In fact, beyond the more heavily vegetated riparian zones, we found it difficult to locate sufficiently well-vegetated areas in which to lay out a 100 m transect for pit traps. Because of the significant area of the reserve, and its position, we recommend that the reserve continue to be considered an important conservation area and that consideration be given to a revegetation program to restore the upland areas. This will add significantly to the invertebrate diversity value of the total conservation area.

6.0 References

Attems C.G. (1911). Myriopoda exkl. Scolopendridae. In *Die Fauna Sudwest-Australians.* (W. Michaelsen & R. Hartmeyer eds). Gustav Fischer, Jena. Vol 3: 147-204.

Harvey M.S. (2002). Short-range endemism among the Australian fauna: some examples from non-marine environments. *Invertebrate Systematics* 16: 555-570.

Harvey M.S. & Yen A.L. (1989). *Worms to wasps. An illustrated guide to Australia's terrestrial invertebrates*. Oxford University Press.

How R.A., Harvey M.S., Dell J.M. & Waldock J.M. (1996). *Ground fauna of urban bushland remnants in Perth*. Report to the Australian Heritage Commission. Western Australian Museum.

Judd S. (2004). *Terrestrial isopods (Crustacea: Oniscidea) and biogeographical patterns from south-western Australia*. Unpublished PhD Thesis. School of Natural Sciences, Edith Cowan University.

Main B.Y. (1984). *Spiders*. Australian naturalist library series, Collins Publ,. Sydney.

Main B.Y. (1999). Biological anachronisms among trapdoor spiders reflect Australia's environmental changes since the Mesozoic. In The other 99%. The conservation and biodiversity of invertebrates. W. Ponder & D. Lunney Eds. *Transactions of the Royal Zoological Society of New South Wales*, pp 236-245.

Mattiske Consulting Pty Ltd. (2002). *Flora and vegetation.* Gwalia Consolidated Limited. Kemerton sand project.

Raven R.J. (1981). A review of the Australian genera of the Mygalomorph spider subfamily Diplurinae (Dipluridae: Chelicerata). *Australian Journal of Zoology* 29: 321-363.

Raven R.J. (1985). The spider infraorder Mygalomorphae (Aranae): cladistics and systematics. *Bulletin of the American Museum of Natural History* 182, Article 1. 180pp.

Raven R.J., Baehr B.C. & Harvey M.S. (2002). *Spiders of Australia*. CSIRO Publishing.

Shear W .A. (1992). A new genus and two new species of millipedes from the Cape range, Western Australia (Diplopoda, Polydesmida, Paradoxosomatidae*). Records of the Western Australian Museum*. 15: 777-784.

APPENDIX 1. Kemerton Silicon Sand Pty ltd Bunbury site showing the SRE sampling areas and transect positions.

NOTE: This site map is only available in the hard copy format of the document.

APPENDIX 2. Pit trap transect lines


Transect 1 in Offset site B


Transect 2 in Offset site B


Transect 3 in Offset site B


Transect in offset site C


Transect in Nature Reserve D


Transect in offset site A

Transect 1 in proposed mine extension site E.

Transect 2 in proposed mine extension site E.

Transect 3 in proposed mine extension site E.

Transect 4 in proposed mine extension site E.

Transect 5 in proposed mine extension site E.

Transect 6 in proposed mine extension site E.

APPENDIX 3. Selected microscope images of sampled SRE fauna.

Plate 3.1 a. Male adult *Antichiropus* collected from mine-extension site E. (x7). b Gondopds (x 25).

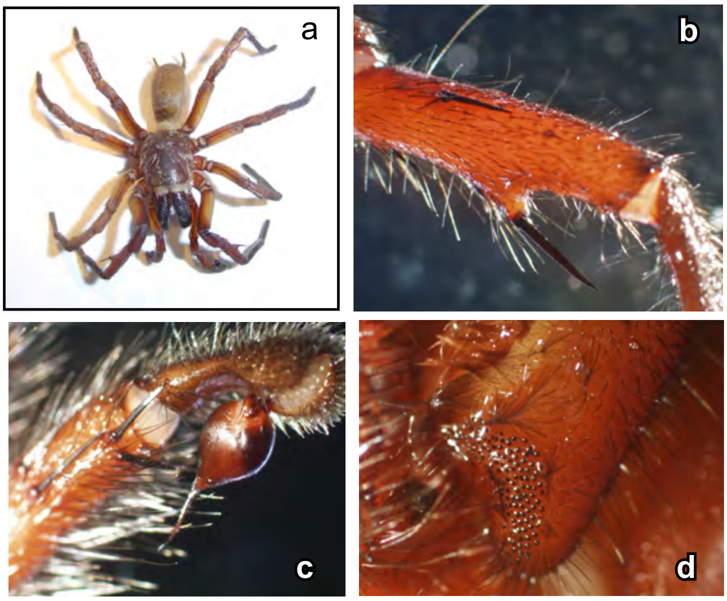


Plate 3.2 Male *Aname* sp. a. Male adult (x). b Tarsal apophysis with spur (x10). c. Male palp (x15). d. Male maxillae showing cupules (x20).

Plate 3.3. Isopod (slater) species:
a. *Buddelundia* sp. (x25).
b.*Laevophilloscia* sp. (x10)
c.Philosciidae sp.1 (x20)
d. *Eurygastor* sp.

APPENDIX 15:
COMMUNITY CONSULTATION INFORMATION
OCTOBER 2006

KSS Site NEWS

Volume 1, Issue 1

October 2006

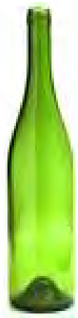
Introducing Kemerton Silica Sand

Aerial view of the Kemerton minesite showing the settlement pond in the foreground and the plant and dredge pond in the background.

Kemerton Silica Sand is located on 1600 hectares of freehold land north of the Kemerton Industrial Park which is approximately 35km north of the port of Bunbury. Kemerton Silica Sand is an Australian company jointly owned by Itochu Corporation (50%) and Tochu Corporation (50%). Mining commenced in April 1996.

Kemerton Silica Sand has established itself as a supplier of high quality silica sand for the container glass, glass shell and sheet glass markets in Japan and the Asian region. The current production capacity is 550,000 tonnes per annum. The total project resource is approximately 200 million tonnes.

Earlier this year KSS Silica Sand was used to create a beach scene at local Bunbury restaurant Tarantinos.



Uses of Silica Sand

The silica sand produced by Kemerton Silica Sand is used predominately by manufacturers of glass containers, computer monitors and TV screens. Silica Sand in general is also used in the manufacture of sheet glass, ceramics and for foundry and filtration sand.

Are you interested in hearing our latest news? Please contact our site office if you wish to receive future newsletters or if you no longer need to be on our mailing list.

Brunswick Show

Saturday 28th of October 2006 Kemerton Silica Sand will be setting up an information display at the Brunswick Agricultural Show at the Brunswick Showgrounds. Gates open at 9:00am.

Contact Us:

Site

PO Box A283

Australind WA 6233

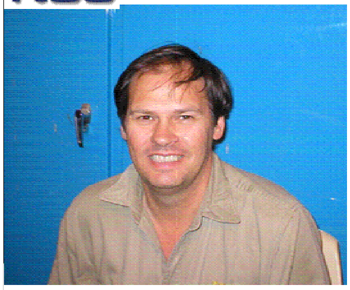
☎: (08) 9720 0000

Fx: (08) 9720 1406

Website:

www.ksspl.com.au

New Operations Manager



New Operations Manager Mark Gell

Firstly I would like to welcome you to our first newsletter. We will be producing this newsletter on a regular basis and if you wish to receive a copy please contact us.

Having just recently taken over I would like to briefly introduce myself. I am a Mining Engineer but I also have a Masters degree in Business Administration.

I have over 25 years experience in Mining and Construction, including areas such as Rehabilitation, Safety, Environmental and Community Relations. In this time I have worked for some of Australia's biggest companies including Rio Tinto, Alcoa and Iluka.

My vision is for Kemerton Silica Sand is to be;

- A place where all employees happily go to work and return home again safely
- Actively involved in and a valued member of the local community,
- An environmental leader in wetland preservation and rehabilitation.

Over the next 12 months Kemerton Silica Sand (KSS) will be undertaking a Public Environmental Review (PER) process with the view of obtaining approval to continue its mining operations once our current approved area is completed. If you wish to become involved or would like to be informed throughout the process please contact us.

I would like to conclude by inviting you to contact us at Kemerton Silica Sand if wish to discuss any aspect of our operation.

Regards

Mark Gell

Operations Manager

☎: (08) 9720 0022

Mobile: 0419 939 430

E-mail: mark.gell@ksspl.com.au

Environmental Update: Did you know?

A threat to our local aquatic biodiversity is the Mosquito Fish (Gambusia holbrooki). Mosquito Fish were introduced from Central America to help control mosquitoes but are more inclined to eat the larvae of native fish. Mosquito Fish do not lay eggs but give birth to live young throughout summer, at between 50 to 100 young in a single brood. The introduction of Mosquito Fish into any natural habitat can disrupt the ecological balance of the environment particularly native fish and frog populations.

Mosquito Fish (Gambusia holbrooki) a threat to our local

Our Process In Detail….

Flat Bed Classifier

Flat Bed Classifiers (FBCs) are used at Kemerton for primary sizing of raw sand.

(1) Water and sand enter the flat bed classifier through a central feed well.

(2) The sand and water enter the settling chamber where an upcurrent of water is injected from the base of (4) plenum chamber.

(3) As the up current of water travels to the top of the settling chamber carrying the smaller size sand particles (product) over the lip. (5) The coarser product (or waste) which is heavier settles to the bottom of the flat bottom classifier. A sensor monitors the density of the sand and water mixture, allowing valves under the FBC to open releasing the coarse product (waste). The solids which discharge from the underflow are then pumped away for further processing.

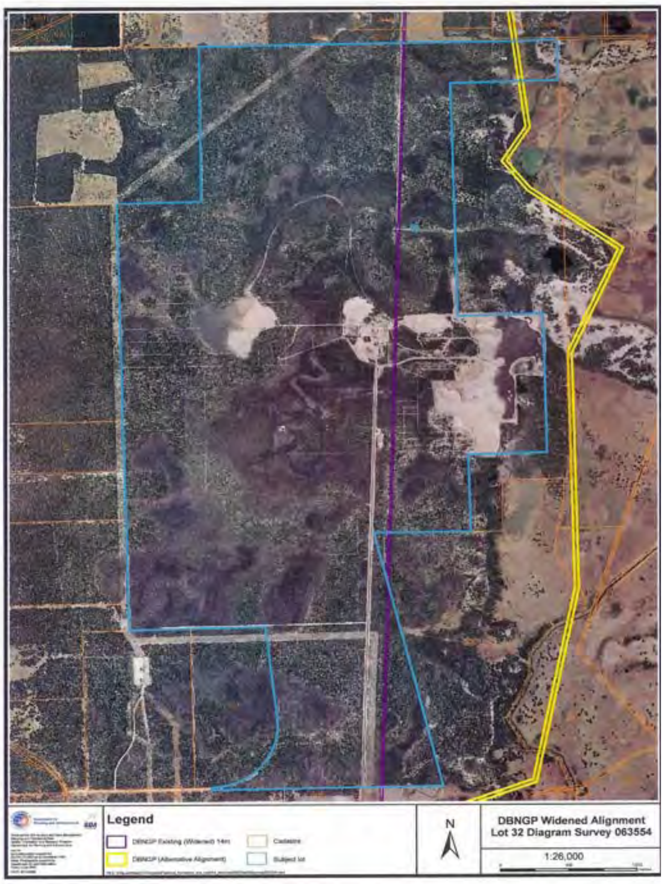
KSS Site NEWS

Issue 2 December 2006

DBNGP Final Draft Alignment

WA Government release preferred Kemerton route for Expanded Dampier to Bunbury Natural Gas Pipeline. The preferred route follows an existing Western Power line corridor through the Kemerton Nature Reserve, deviating around wetlands and lakes.

"The alignment protects environmentally sensitive wetlands and makes use of existing infrastructure corridors in a way that reduces the impact of future expansions, " Mr McRae MLA said.



KSS Management & Staff would like to wish you all a very happy and safe Holiday Season and a prosperous New Year

RECORD SHIPMENT

At the beginning of December KSS achieved its highest shipment in its 10 years of operation. A record 50,019.0 MT was loaded onto the MV Fujisuka designated for Japanese ports. This is 4,000 MT greater than our previous record.

Are you interested in hearing our latest news? Please contact our site office if you wish to receive future newsletters or if you no longer need to be on our mailing list.

Brunswick Show

KSS's display at the Brunswick Show was a great success. All of the KSS management team took the opportunity to explain our operations to the general public.

KSS wish to thank all the people who took the time to view our display.

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Operations Manager

Mark Gell

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Mobile: 0419 939 430

Production Coordinator Mining & Rehabilitation

Fred has been involved in the mining industry for thirty six years, eleven of those with Kemerton Silica Sand. Being the Production Co-ordinator Mining and Rehabilitation involves the management of the mining operation and the rehabilitation of disturbed areas. The mining is done by a dredge which can mine down to 16.5m below the water level it floats on. Rehabilitation of the disturbed areas involves the creation of lakes, frog ponds, islands and beaches. To achieve the desired outcome careful planning is required to ensure the maximisation of the ore body and the planning of topsoil movement to rehabilitation areas for maximum re-growth.

Fred Savickis

Prior to joining Kemerton Silica Sand Fred worked in the mineral sands industry at Capel and Eneabba in the exploration, geological drafting, mine planning, dry mining and dredging areas.

Environmental Update...

Do you know your Carnaby's from your Baudin's?

Both are white tailed black cockatoos but the Carnaby's black cockatoo was called the short billed form and the Baudins used to be called the long billed form.

Baudins

Carnaby's

Our Process In Detail….

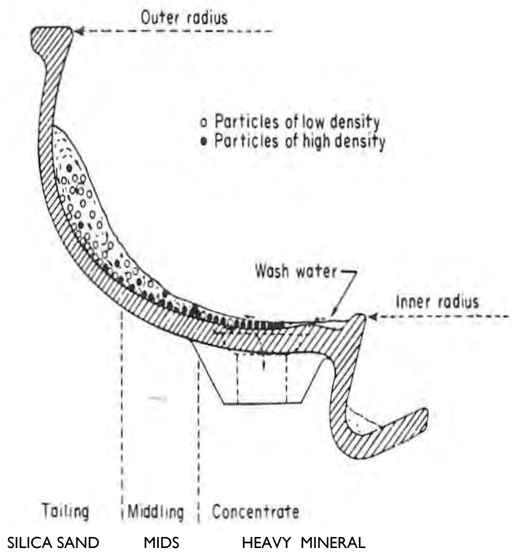
Spiral Gravity Separators

Spirals are used at Kemerton to remove heavy minerals such as Iron, Ilmenite Zircon etc from our silica sand product.

Water and sand enter the spirals from a central distribution box to the top of each spiral at a predetermined density.

The sand and water gravitates down the spiral in a circular motion until it reaches the bottom of the spiral.

In this process a combined effect of centrifugal force (volume of water spinning around and down the spiral) and the different settling rates of the individual minerals causes the lighter sand and the heavy minerals to separate.



Splitters or fingers can be adjusted at the bottom of each spiral to direct the different individual streams for further online processing.

KSS Site NEWS

Issue 3 May 2007

KSS Supports Constable Care Roadshow at Brunswick Junction

Kemerton Silica Sand was a proud sponsor of prizes for school children from both Brunswick and St Michael's Catholic Primary schools at the recent visit by the Constable Care Roadshow to Brunswick.

Constable Care presenters involved the children with a live theatre performance, puppets and interaction with a theme of safety issues and appropriate social behaviour.

KSS Frisbees will continue to be handed out at Brunswick schools throughout the year.

Mark Gell Operations Manager KSS, Brunswick Junction Primary school students Tabetha Tyrrell, Michelle Rodwell, Paris Le Monnier, Jethro Watkins, Brodie Cooke, Royston Christie Robert Gatt, Constable Care Child Safety presenter Anelisa Bell.

Kemerton Silica Sand was pleased to support this program at Brunswick Junction. Brunswick is an important community to KSS as well as being it's closest town as more than one in every four dollars KSS spends goes to Brunswick businesses. KSS hopes to be active in the local communities such as Brunswick well into the future.

Active Industries Donation

Kemerton Silica Sand recently supplied Active Industries with a second delivery of sand which they use to make sand bags for St Johns Ambulance.

Are you interested in hearing our latest news? Please contact our site office if you wish to receive future newsletters or if you no longer need to be on our mailing list.

Binningup Spring Festival Saturday 6th October

Stall Bookings now being taken

Contact

Narelle James on
☎9720 1772

or

Pam Offer on
☎9720 1658

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Operations Manager
Mark Gell
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Mobile: 0419 939 430

Gary Meek

PRODUCTION COORDINATOR FOR PROCESSING, TRANSPORT, WAREHOUSING AND SHIPPING

My name is Gary Meek and at Kemerton I am responsible for maintaining a dedicated team of personnel who run our operation. We have a strong emphasis on safety, quality control and cost per ton produced. One of my main areas involves the processing plant which consists of washing, cleaning, sizing and stockpiling of our final product. Emphasis is placed on producing a quality product for our customers and minimising operational costs. Our final product is then trucked into the port of Bunbury where we ship it to our customers in the Asian region in up to 55,000 ton capacity ships.

I have has spent the last 28 years in the mining industry and have worked throughout Western Australia in the Alumina, Manganese, Gold, Diamonds water and exploration drilling industries. I have been at Kemerton since it's commissioning in 1996 and look forward to our future.

Environmental Update… Narrow leaf Cotton Bush

Narrow leaf Cotton Bush is a Declared plant in WA, and within the shire of Harvey it is subject to control categories P1 & P4. Landowners are obliged to control and aim to irradiate this weed. This plant which grows in thickets to 2m tall is an escaped garden shrub originally from South Africa. It occurs in many disturbed, moist sites on the Swan Costal Plain. The plant is poisonous and has caused deaths in cattle, sheep and poultry. The weed should be sprayed with herbicide in September to December or manually removed prior to fruiting.

Category P1: The movement of plants or their seeds is prohibited within the State. This prohibits the movement of contaminated machinery and produce including livestock and fodder.

Category P4: The infested area must be managed in such a way that prevents the spread of seed or plant parts within and from the property on or in livestock, fodder, grain, vehicles and/or machinery.

Treat to destroy and prevent seed set all plants:

- within 100 metres inside of the boundaries of the infested property,

- within 50 metres of roads and high water mark on waterways,

- within 50 metres of sheds, stock yards and houses.

Treatment must be done prior to seed set each year. Properties with less than 2 hectares of infestation must treat the entire infestation. .

For more information visit www.agric.wa.gov.au

Our Process In Detail….
Suction Cutter Dredge

Dredging at Kemerton Silica Sand involves the use of a Jaden "Platypus" dredge capable of mining at rates of up to 350tph.

Dredging is a very cost efficient method of mining and transportation of materials and is used widely throughout the mining industry where the depth of mining creates dewatering and transportation problems.

KSS Dredge Crown Head Cutter

The dredge operates using a hydraulically driven cutter head to disturb the material which in turn is then sucked up by a pump which is situated on board.

A four winch system is used, two stern winches which pull the cutter into the face and two slew winches to traverse the face.

Kemerton's dredge is capable of dredging to a depth of sixteen metres. The material is then pumped to the plant.

KSS Site NEWS

Spring Festival Issue

October 2007

Introducing Kemerton Silica Sand

Aerial view of the Kemerton minesite showing the settlement pond in the foreground and the plant and dredge pond in the background.

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Kemerton Silica Sand has established itself as a supplier of high quality silica sand for the container glass, glass shell and sheet glass markets in Japan and the Asian region. The current production capacity is 550,000 tonnes per annum. The total project resource is approximately 200 million tonnes.

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Visit us on our Website...

www.ksspl.com.au

Are you interested in hearing our latest news? Please contact our site office if you wish to receive future newsletters or if you no longer need to be on our mailing list.

Uses of Silica Sand

The silica sand produced by Kemerton Silica Sand is used predominately by manufacturers of glass containers, computer monitors and TV screens. Silica Sand in general is also used in the manufacture of sheet glass, ceramics and for foundry and filtration sand.

The unique properties of the Silica Sand makes it ideal for a glass bottle and plasma televisions production. Currently specialty Japanese glass factory's produce 80% of the whole worlds Plasma Televisions using Silica Sand sourced from here in Kemerton.

Why we should use glass for packaging...

Glass adds so much to our lives and is good for the environment—Glass promises to be infinitely recyclable

Glass plays a valuable role in packaging.

* ***Keeping food and drinks safe and fresh***

In households everywhere it keeps food and drink safe and fresh. Glass uses its inert properties to remain untainted when it comes into contact with food, drinks, medicines or cosmetics. Many glass bottles and jars can be resealed after opening.

* ***Glass looks and makes food and drink taste good***

Glass packaging looks great—a large number of consumers prefer food products packaged with glass and believe that food and drink taste better out of glass.

* ***Glass chills for longer***

Glass bottles kept in the fridge chill the contents for longer.

* ***Glass is practical***

Glass allows heating in the microwave and keeping things cold in the fridge. Glass bottles and jars are able to be resealed or reused reducing wastage.

* ***Glass allows you to clearly see the contents***

Transparent glass allows you to see what you are about to consume or purchase.

* ***Glass Promises to be infinitely recyclable***

The glass recycling process of turning used bottles and jars into new containers can be repeated indefinitely without any reduction in quality.

How using glass saves the environment

Glass can be recycled again and again indefinitely.

To conserve resources, manufacturers are making glass bottles lighter than they used to. For example a 1986 stubby weighed 260gms compared to todays 180gms.

Glass recycling extends the life of our landfill sites by reducing the amount of waste.

Glass bottles and jars can be washed and reused therefore reducing the amount of energy used to produce new packaging.

The energy saving from recycling one glass bottle or jar will:

* Power a 100watt light bulb for almost an hour
* Power a computer for 25 minutes
* Power a colour TV for 20 minutes
* Power a washing machine for 10 minutes

Confidence in the future

Kemerton Silica Sand (KSS) is currently undertaking a Public Environmental Review (PER) process with the view of obtaining approval to continue its mining operations once our current approved area is completed. If you wish to become involved or would like to be informed throughout the process please contact us.

Operations Manager

☎: (08) 9720 0022

Mobile: 0419 939 430

Kemerton Silica Sand in the Community

Kemerton Silica Sand (KSS) has been proudly supporting the local community, for over 10 years. KSS being a small but highly efficient operation manages to sponsor some smaller events and programs every year. KSS understands that using local contactors and suppliers is not only good for the community it is also good for us.

KSS has implemented a new community relations strategy where the vision is for KSS to be actively involved in and a valued member of the local community. The focus of the new program is identifying opportunities in the local community where we can work side by side with the community on programs that add value and benefit everyone's future. The strategy acknowledges that KSS ability to fund programs is limited, but it also identifies a core asset of KSS is its knowledge and expertise in wetland rehabilitation and wetland conservation. Therefore KSS is looking to form partnership programs with the local community either in wetland education or actual wetland restoration projects.

KSS are committed to keeping the local community fully informed. As well as updating the KSS website KSS is now producing and distributing a regular site newsletter .

Rehabilitation and the Environment at Kemerton Silica Sand

KSS's vision is to be an environmental leader in wetland preservation and rehabilitation. To facilitate the attaining of this vision KSS has engaged the services of Edith Cowan University's (ECU) Centre for Ecosystem Management and the Centre of Excellence for Sustainable Mine Lakes (CSML). The team from ECU will study and research the unique Kemerton ecosystem and help KSS implement rehabilitation that adds environmental value.

ECU will conduct research through the PhD program into the Black-striped Jollytail. This native fish is currently fighting for its survival due mainly to the introduction into the wild of the exotic Mosquito Fish originally from Central America. The aggressive Mosquito fish eat the larvae and eggs of native fish and frogs.

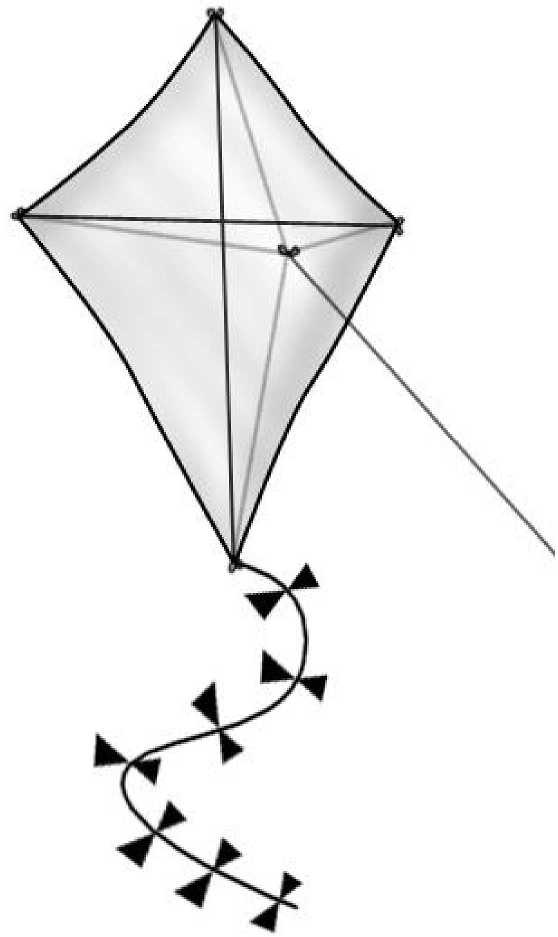
A successful strategy has been developed to ensure that native frog populations survive. This involves building frog ponds which are separate from the lakes and which dry out in summer. The mosquito fish unlike the native fish and frogs cannot survive if a wetland completely dries out. These frog ponds have been successful developed at the Capel Wetland Centre. It is hoped that through a better understanding of the Black-striped Jollytail and the Mosquito Fish a strategy can be introduced to protect these small native fish in a similar way that has been implemented for the native frogs.

These are just some examples that show KSS acknowledging that rehabilitation and environmental management are core parts of its business.

KSS are committed to protect and manage the unique ecosystem in which it operates. As sign of this commitment and confidence KSS have also agreed to donate a further 132 Ha of its Rehabilitated wetlands to the Kemerton Wetland Reserve once the area is fully rehabilitated. This will bring the Kemerton Wetland Reserve to a total of 347 Ha and will entrench it as a significant asset for future

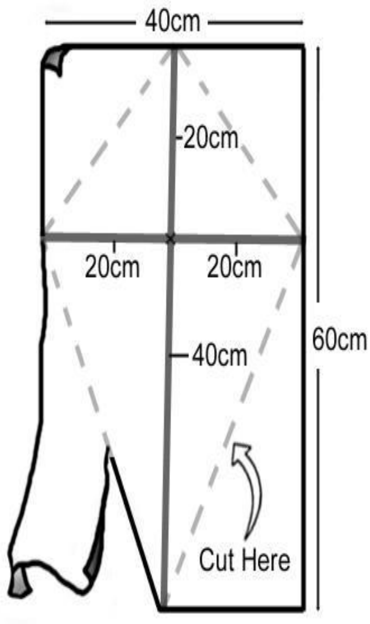
Please enjoy the Kite Kenetics display at the 2007 Binningup Spring Festival. Proudly sponsored by Kemerton Silica Sand.

Making a simple Kite



You will need:

- Two pieces of thin bamboo or dowel (one 60cm and the other 40cm)
- Glue
- Scissors
- Fishing line and string
- Ribbons to decorate the tail
- A Large Sheet of Paper at least 60cm in length and 40cm wide.



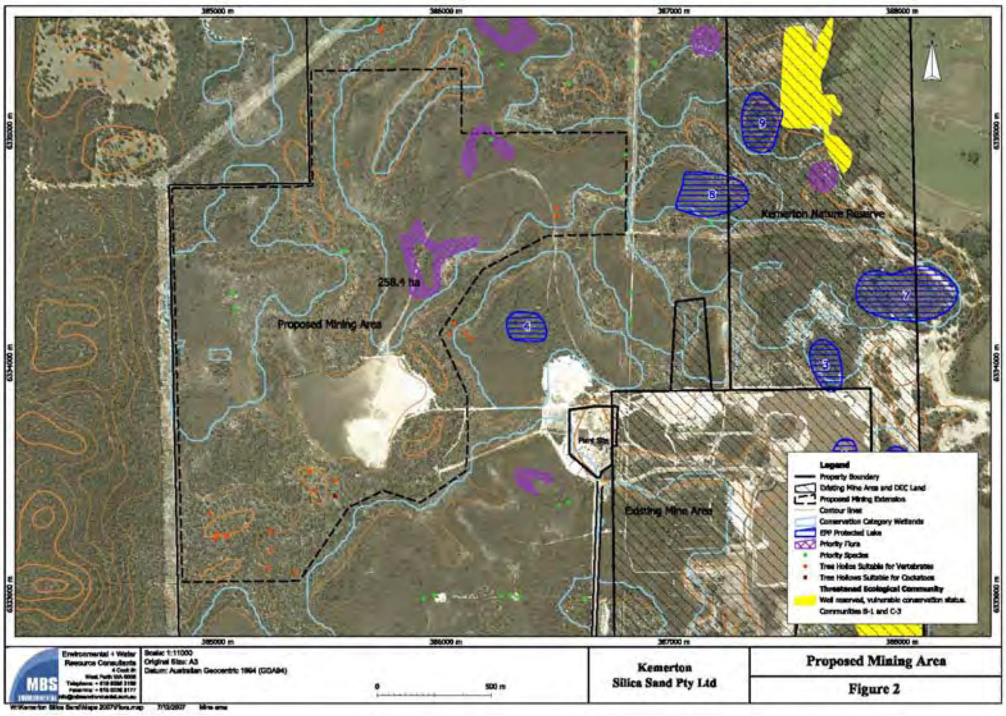
1. Place the shorter stick across the longer stick about 20cm from the top of the long stick and tie securely .
2. Cut the paper into a diamond shape..
3. Decorate the paper on one side.
4. Attach the tied bamboo to the kite with glue.
5. Tie a piece of string or fishing line from the top to the bottom of the kite. Tie another piece from side to side.
6. Tie another piece of string where the two pieces of string meet.
7. Attach ribbon to bottom of kite for tail.

KSS Site NEWS

Issue 5 May 2008

Public Environmental Review (PER) Nearing Completion

Kemerton Silica Sand is investing in the future. The size (in excess of 200mt) and uniqueness (only one of its type) of the Kemerton Silica Sand deposit makes it a major asset for both KSS and the community. To ensure this lasting benefit KSS has been undertaking a Public Environmental Review (PER) process with the view of obtaining approval to continue its mining operations once the current approved area is completed. The PER studies and consultation is nearing completion, with documentation submission to the EPA expected within the next month.



Port Open Day

The KSS display at the Port open day gave the public an opportunity to discover all about KSS, Silica Sand and the glass industry.

This was another successful day following on from simular displays at the Brunswick Junction and Bunbury shows as well as the Binningup Spring festival.

Are you interested in hearing our latest news? Please contact our site office if you wish to receive future newsletters or if you no longer need to be on our mailing list.

Switch to Glass -

It is;

- Safer
- Versatile
- Sustainable
- Infinitely recyclable

WA Glass recycling ?

Since the closure in 2003 of WA's only glass bottle manufacturing facility only about 20% of our recycled glass is trucked to Adelaide to be reused.

Contact Us:

Site

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Website:

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Operations Manager

Mark Gell

☎: (08) 9720 0022

Mobile: 0419 939 430

Introducing Yoshihiro Abe—Deputy Managing Director, Plant Engineering

Mr Abe is a specialist in glass chemistry currently working on site at KSS looking at developing international markets for KSS sand and product quality issues in the process. Mr Abe is originally from Kobe City in Japan and has spent the last 38 years working for Japans biggest container glass company which included 3 years as Operations Manager at a Joint Venture in the Philippines.

Mr Yoshihiro Abe

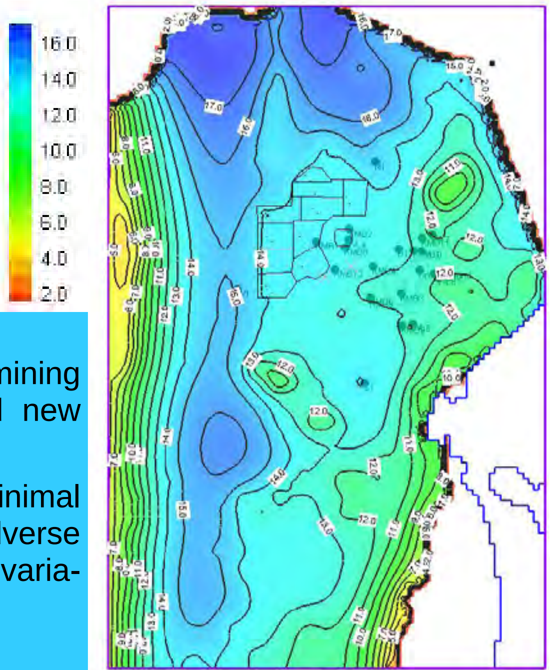
Mr Abe has been involved with KSS since the development of the deposit in 1995. Mr Abe says "KSS is important to the glass producers of Japan as the Silica Sand that is mined at KSS is special on the world market due to the alumina content and the size of the resource."

Groundwater Modelling

As part of the Public Environmental Review an investigation of potential changes in groundwater patterns was undertaken, so that an environmental assessment of the proposed new mine area could be undertaken.

The main objectives of the investigation included groundwater modelling of the impact of current and new mining on local groundwater levels and post mining salinity evolution and the impacts of the proposed new western mining area on the wetlands.

The results of the modelling showed that the minimal change in groundwater level is unlikely to cause adverse impact in the surrounding environment as the natural variations in the groundwater level is in the order of 1.5m.



Predicted groundwater levels at the end of mining

Black Stripped Minnow (Jolly Tail) Research Project

During Macro Invertebrate sampling Jolly Tails were discovered in some of the wetlands within the Kemerton Nature Reserve. Jolly Tails are one of only eight endemic freshwater fish species found in the south west and are categorised by DEC at Priority 1, the highest level.

Due to widespread degradation of suitable habitat on the Swan Coastal Plain, Jolly Tails are now only found at Kemerton and Muchea north of Perth.

In order to conserve this species KSS has sponsored a two year Masters Research Program where Dave Galeotti from the School of Natural Sciences at Edith Cowan University will undertake the "Biology of Black striped Jollytail Research Project".

The results of this research project will help KSS design and construct rehabilitation that best enhances the Jolly tails long term survival prospects, particularly if the trend of decreasing rain fall continues and the natural wetlands continue to dry out. The research will also investigates ways of protecting the Jolly tail from the introduced Mosquito Fish (Gambusia holbrooki) which eats the eggs and larvae of native fish and frogs.

MINING & RESOURCES

DECEMBER 2006

WORKING WITH THE COMMUNITY

KEMERTON SILICA SAND

- Business Silica Sand production
- Address: Cnr Treasure & Wellesley Rds Kemerton
- Years of Operating: 10
- No of Employees: 12
- Website: www.ksspl.com.au

Small operations can still significantly contribute to the Community

Kemerton Silica Sand (KSS) mines export quality silica sand at Kemerton north of Bunbury. Up to 500,000 tonnes per year of Silica Sand is shipped out through the Port of Bunbury to overseas destinations such as Japan where it is converted into high quality glass products. The unique properties of the Silica Sand makes it ideal for a glass bottle and plasma televisions production. Currently Kemerton Silica Sand is used to produce 80% of the world's Plasma Televisions.

Kemerton Silica Sand (KSS) has been proudly supporting the local community, in which all its employees live for over 10 years. KSS being a small but highly efficient operation manages to sponsor some smaller events and programs every year. KSS understands that using local contractors and suppliers is not only good for the community it is also good for us.

KSS under the guidance of a new Operations Manager is implementing a new community relations strategy where the vision is for KSS to be actively involved in and a valued member of the local community. The focus of the new program is identifying opportunities in the local community where KSS can work side by side with the community on programs that add value and benefit everyone's future. The strategy acknowledges that KSS's ability to fund programs is limited, but it also identifies a core asset of KSS is its knowledge and expertise in wetland rehabilitation and wetland conservation. Therefore KSS is looking to form partnership programs with the local community either in wetland education or actual wetland restoration projects.

As part of our new strategy KSS are committed to keeping the local community fully informed. This has already started when all the key KSS staff took the opportunity to meet the public at the recent highly successful Brunswick Junction Show. As well as updating the KSS website KSS is now producing and distributing a regular site newsletter.

Confidence in the future

Kemerton Silica Sand is investing in the future. The size (in excess of 200mt) and uniqueness (only one of its type) of the Kemerton Silica Sand deposit makes it a major asset for both KSS and the community. To ensure this lasting benefit KSS will be over the next 12 months undertake a Public Environmental Review (PER) process with the view of obtaining approval to continue its mining operations once the current approved area is completed. Details will be available shortly on our new website www.ksspl.com.au .

Environment a core part of business

Kemerton Silica Sand (KSS) has again demonstrated its commitment to conserving the environment with another donation of high conservation value wetlands to the government conservation estate. When Calm (DEC) recently discovered that an area approved for mining was an example of the now rare Muchea Limestone community KSS agreed to donate the 17 Ha site to the government's conservation estate.

This latest donation of 17 Ha of Muchea Limestone Threatened Ecological Community (TEC) which also contains a Environmental Protection Policy (EPP) wetland will be added to the 198 Ha that KSS had already donated to the government conservation estate to form the Kemerton Wetland Reserve. The Kemerton Wetland Reserve protects the habitat of several endangered species including the Western Pygmy and Honey Possums, Water Rat, Chuditch and a small native fish called the Black-striped Jollytail. The addition of the Muchea limestone TEC to the conservation estate further adds to the biodiversity of the now 215 Ha Kemerton Wetland Reserve which now includes 7 EPP wetlands.

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KEMERTON SILICA SAND PTY LTD
REHABILITATION
AREA
KEEP OUT

REGIONAL MINING SERIES

Mining the South West

27 - 28 February 2008

Abbey Beach Resort, Busselton

ANSWERING THE CHALLENGE. RESPONDING TO GROWTH. DEVELOPING THE REGION

Featuring case studies from

Alcoa Australia

Griffin Coal

Wesfarmers Premier Coal

HIsmelt Rio Tinto

Grange Resources

Kemerton Silica Sand

Simcoa Operations

Supported by:

The Busselton Chamber of Commerce

South West Development Commission

Kwinana Industries Council

Western Australia's South West Area Consultative Committee Inc

Key Speakers Include:

Bill Knight, *WA Manager of Mines,* Alcoa Australia

Patrick Warrand, Wesfarmers Premier Coal

Mark Gell, *Operations Manager,* Kemerton Silica Sand

Richard Campbell, *Operations and Planning Manager,* The Griffin Coal Mining Company

Senior Representative, Grange Resources

Lisa Shreeve, *Executive Officer,* South West Area Consultative Committee

Don Punch, *CEO,* South West Development Commission

Brett Belstead, *Regional Manager South West,* Main Roads WA

Mark Cooper, *General Manager Commercial,* Dampier Bunbury Pipeline

Stephan Weber, *Managing Director,* HIsmelt Rio Tinto

Jim Brosnan, *General Manager,* Simcoa Operations

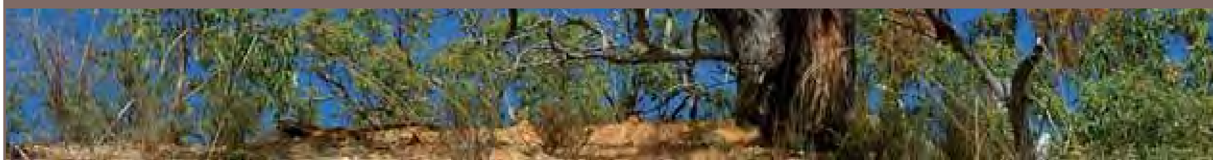
Key areas to be addressed:

Current mining operations

Resource projects under development

Infrastructure in the South West Region

Labour retention and resource industry skill shortages



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DOIR Director General Dr. Jim Limerick, Western Australia Prospect Magazine, 2007

Dear Executive,

Investment activity in the South West of Western Australia is booming and is fast becoming one of Australia's richest mineral provinces.

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With the WA economy experiencing unprecedented growth the mining, exploration and mineral processing industries will have the opportunity to be a part of IIR's inaugural **Mining the South West** Conference.

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I look forward to welcoming you to the conference in February.

Luke Hartcher
Conference Project Manager – Mining the South West
IIR Conferences

Mining the South West

CONFERENCE DAY ONE: Wednesday February 27th, 2008

8.30 Registration and morning coffee

9.00 Welcome from IIR

9.10 Opening remarks from the Chair

WELCOMING ADDRESS

"...Western Australia is going through its most successful period of economic growth, courtesy of the State's resource sector,"

DOIR Director General Dr. Jim Limerick,
Western Australia Prospect Magazine, 2007

9.20 **The growth of the South West: Updating achievements in resource development for the area and the discussion of major plans for the future**

Western Australian Government Representative

SOUTH WEST REGIONAL OVERVIEW

9.40 Don Punch, *CEO,* South West Development Commission

10.00 Lisa Shreeve, *Executive Officer,* South West Area Consultative Committee

10.20 MORNING TEA

MINING OPERATIONS

Representatives of leading mining and resource companies will update you on current developments in mining operations for the South West of WA.

10.50 **CASE STUDY: Applying sustainability principles to Alcoa's Mining Operations in the South West**

- Alcoa Australia's 45 years of profitable growth in the South West of WA
- Jarrah Forest rehabilitation story
- Achieving excellence through people

Bill Knight, *WA Manager of Mines,* Alcoa Australia

11.30 **Case Study: Wesfarmers Premier Coal**

- Premier Coal operates a major open cut coal mine in Collie, Western Australia, and provides nearly 50% of the fuel for the States' south-west integrated electricity grid.
- Premier Coal is an important contributor to the local economy provides employment for nearly 300 people and supporting a wide range of regional industries and community-based activities
- This presentation will look at current operation developments for the mine site

Patrick Warrand, *General Manager,* Wesfarmers Premier Coal

12.10 Lunch for speakers and delegates

SPOTLIGHT ON MINING AND RESOURCE PROJECTS

Gain practical case study information on current mining and resource projects for the South West region

1.10 **CASE STUDY: Griffin Coal Projects**

- By contributing to the successful future of the coal industry through its investment in sustainability, Griffin is delivering social, economic and environmental benefits to Collie and the South West
- The Griffin Group - recognising its key role in developing sustainable solutions for the continued use of coal in Western Australia's energy mix
- Current project update, including the proposed char plant for Griffin Coal's Ewington Mine and investment in clean coal technologies

Richard Campbell, *Operations and Planning Manager,* The Griffin Coal Mining Company Pty Ltd

1.50 **Update on Boddington mine expansion**

Invited: *Senior Representative,* Newmont Asia Pacific

2.30 Afternoon tea

3.00 **CASE STUDY: The Albany Iron Ore Project**

- Developing the Southdown Mine
- Expansion of Albany Port
- Infrastructure Challenges on Freehold Land

Neil Marston, *General Manager – Commercial & Company Secretary,* Grange Resources

3.40 **Kemerton Silica Sand**

- Kemerton Silica Sand has established itself as a supplier of high quality felspathic silica sand to the container glass and sheet glass markets in Japan and the Asian region
- This presentation will cover current developments for the company and an update into plans for future expansion.

Mark Gell, *Operations Manager,* Kemerton Silica Sand

4.20 **Insight into the operations at Talison's Greenbushes mine site.**

The Greenbushes operation has grown over more than 100 years from a collection of small labour-intensive alluvial tin mining operations into the world's largest single operating tantalum and spodumene mine.

Invited: Pat Scallan, *General Manager,* Talison – Greenbushes, Operations

5.00 Closing remarks from chair

5.10 Networking drinks

6.30 Official conference dinner

27 - 28 February 2008, Abbey Beach Resort, Busselton

CONFERENCE DAY TWO: Thursday February 28, 2008

9.15 Morning Coffee

9.40 Opening remarks from chair

FUTURE PLANNING FOR THE SOUTH WEST

Communicating key initiatives to develop and improve community services and amenities for the South West region to further capitalise on the resources boom

9.50 **Exploring opportunities for the community in a booming resource industry**

10.20 **Environmental, social and economic value of an integrated industrial zone**
Chris Oughton, *Director,* Kwinana Industries Council

10.50 Morning tea

INFRASTRUCTURE IN THE SOUTH WEST REGION

"Hopetoun, in the State's South-West, is one example of a single commodity town struggling to cope for lack of infrastructure,"

Fran Cusworth, The Weekend Australian, 2007

11.20 **Strengthening road infrastructure in the South West**

- Insight into issues and challenges for Main Roads WA for roads in the South West region
- Update on current road infrastructure projects
- Looking ahead – further developing the South West region in a time of economic growth

Brett Belstead, *Regional Manager South West,* Main Roads WA

11.50 **CASE STUDY: Dampier-Bunbury Pipeline**

- Developments in the expansion of the Dampier to Bunbury Natural Gas Pipeline
- Future pipeline expansion plans
- Gas supply options, opportunities and constraints, including developments in both the North West and the South West

Mark Cooper, *General Manager Commercial,* Dampier Bunbury Pipeline

12.20 Lunch for speakers and delegates

HIGHLIGHTING THE HOUSING AND LABOUR CHALLENGES IN THE BOOMING RESOURCES INDUSTRY

1.30 **Strategies for sourcing and retaining labour for WA's South West region – nationally and offshore**
Ashley McKinnon, *Director,* Resources and Energy, Australia, Hudson

2.00 **Discussing the real estate boom in the South West**
Invited: Rob Gelderton, Southern Districts Professionals

2.30 Afternoon tea

INDUSTRIAL PROCESSING AND MINERAL REFINING

3.00 **CASE STUDY: HIsmelt Rio Tinto**
The HIsmelt Kwinana Joint Venture facility has now produced in excess of 83,000 tonnes of metal, with the second shipment scheduled to depart later this quarter. Their main focus has been on improving availability and production rates to meet current levels of demand.
Stephan Weber, *Managing Director,* HIsmelt Rio Tinto

3.30 **CASE STUDY: Doral Mineral Sands**

- Doral Mineral Sands Pty Ltd was established in 2001 to acquire, mine and process heavy mineral sands near Dardanup and at Picton
- The operations began with an initial mine life of 10 years, but the identification of other resources on company ground nearby has extended that for a further 5-10 years

Mike Ferraro, *Operations Manager,* Doral Mineral Sands

4.00 Closing remarks from chair

4.10 Close of conference

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For details on how we can work together, contact David Lewis on +61-(0)2-9080 4054 or dlewis@iir.com.au

APPENDIX 16:
KEMERTON SILICA SAND
ACID SULFATE SOIL MANAGEMENT PLAN
MARCH 2009
MBS ENVIRONMENTAL

Kemerton Silica Sand Project
Acid Sulphate Soil
Management Plan

Prepared for:

Kemerton Silica Sand Pty Ltd

March 2009

Prepared by:

Martinick Bosch Sell Pty Ltd
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MBS
ENVIRONMENTAL

KEMERTON SILICA SAND PROJECT
ACID SULPHATE SOIL MANAGEMENT PLAN

MARCH 2009

PREPARED FOR

KEMERTON SILICA SAND PTY LTD

This report has been prepared for **Kemerton Silica Sand Pty Ltd** on the basis of instructions and information provided by **Kemerton Silica Sand Pty Ltd** and therefore may be subject to qualifications which are not expressed.

No other person may use or rely on this report without confirmation in writing from MBS Environmental. MBS Environmental has no liability to any other person who acts or relies upon any information contained in this report without confirmation.

This report has been checked and released for transmittal to **Kemerton Silica Sand Pty Ltd**.

PREPARED BY:

David Allen Senior Environmental Geochemist	Signature:	Date: 20/3/09

CHECKED BY:

Kristy Sell Director - Environmental Science	Signature:	Date: 20/3/09

Kemerton Silica Sand Project
Acid Sulfate Soil Management Plan

March 2009

Prepared for

Kemerton Silica Sand Pty Ltd

By

MBS Environmental

4 Cook Street
West Perth WA 6005
Australia

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Appendix 1: Kemerton Silica Sands Project: Acid Sulfate Soils Assessment MBS Environmental, November 2007

Appendix 2: Acid Sulfate Soil Field Testing Procedures

1. INTRODUCTION

This plan describes the Acid Sulfate Soil (AAS) management practices that will be implemented during operation of the extension of the Kemerton Silica Sand Dredge Mining project. The plan has been developed in conjunction with a Public Environmental Review (PER) document for this project. Preparation and implementation of this plan during operations is a commitment of the PER document.

1.1 OBJECTIVE

The objective of this plan is to ensure that all mining activities with the potential to disturb ASS materials protect environmental values.

The plan has been developed in accordance with guidelines provided by the Department of Environment and Conservation (DEC). The guiding principles are:

- Planning mining operations to minimise potential disturbance of ASS materials.
- Implementing appropriate monitoring programs to measure soil and water quality.
- Establish appropriate 'Action Criteria' to provide an early warning system for disturbance of ASS materials.
- Identify appropriate remediation strategies to minimise potential environmental impacts resulting from ASS disturbance.

2. EXISTING ENVIRONMENT

2.1 REGIONAL SETTING

The KSS property is located in the Shire of Harvey, 2.5 kilometres north of Kemerton Industrial Park and 12 kilometres south-west of the town of Harvey, in the south-west of Western Australia (Figure 1). The KSS property consists of 1,326 hectares of freehold land owned by the proponent; mineral rights are to the landowner.

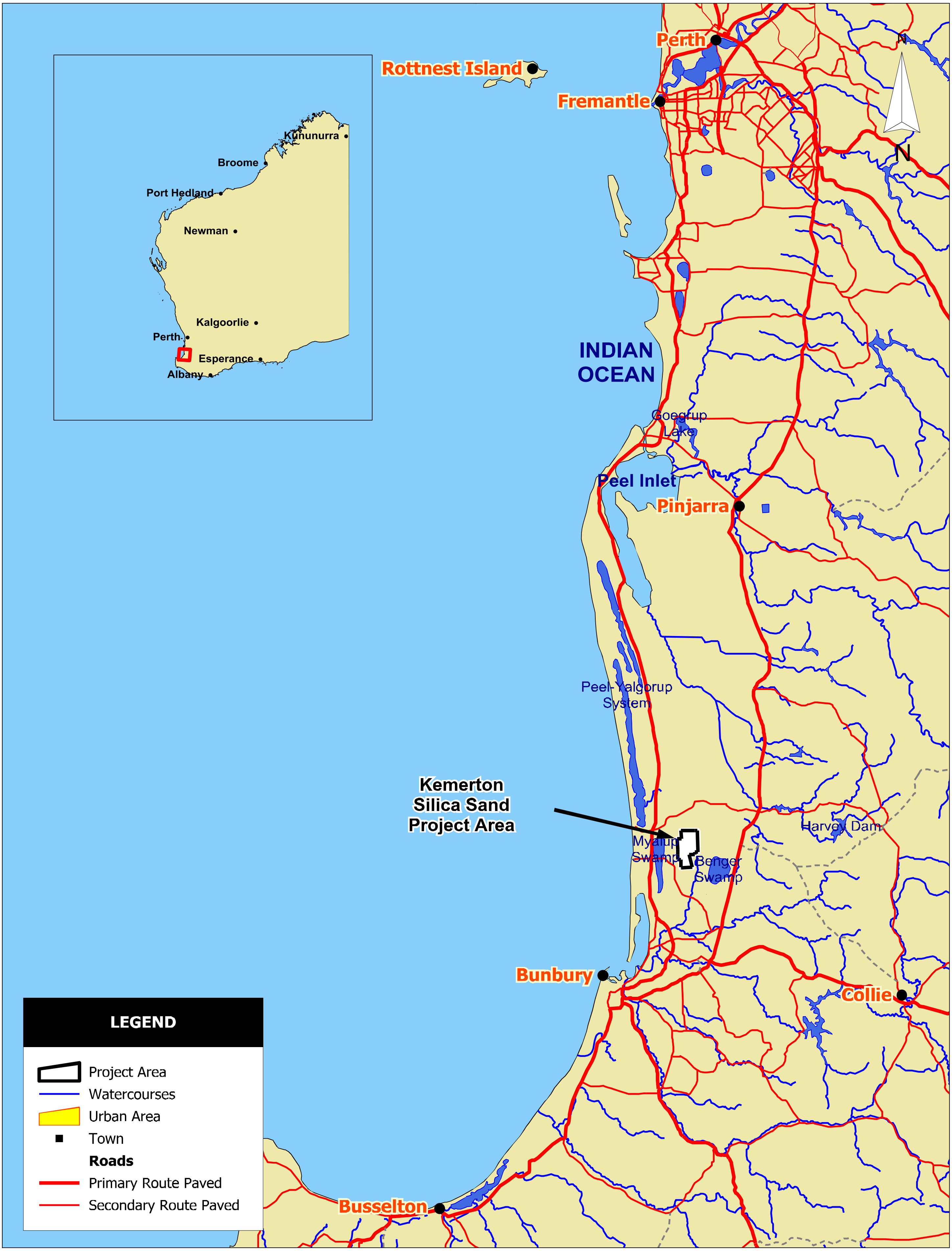
The project area is located on the Bassendean Dune system of the Swan Coastal Plain as mapped and described by Churchward and McArthur (1980).

2.2 GEOLOGY AND LANDFORMS

The geology and landforms of the Darling System have been described and mapped by the Department of Mines Geological Survey Branch (1978), Churchward and McArthur (1980) and more recently by Barnesby and Proulx-Nixon (2000).

The KSS property is situated within the Perth Basin, which extends approximately 20 kilometres eastwards from the coast to the Darling Escarpment. The Swan Coastal Plain is made up of five major geomorphological systems running roughly parallel to the coast. From east to west they include the Ridge Hill Shelf at the base of the Darling Scarp, the flat Pinjarra Plain, followed by the aeolian Bassendean, Spearwood and Quindalup Dune Systems (McArthur, 1991). The Bassendean Dune System forms a north–south strip approximately three kilometres wide between Pinjarra Plain to the east and Spearwood Dune System to the west. Dune crests in the Bassendean Dune System reach elevations of approximately 25 mAHD (metres above Australian Height Datum) and low areas have elevations of approximately 10 mAHD. Dune crests in the Spearwood Dune System reach elevations of approximately 50 mAHD immediately west of the KSS property. The general elevation of the Pinjarra Plain is 15 to 20 mAHD. The three landform systems in relation to KSS are shown in Figure 2.

Underlying the surficial sediments of the Swan Coastal Plain are the Ascot or Guildford Formations. The Ascot Formation is a Pliocene marine deposit comprising shelly calcarenite, silty clays and glauconitic clay. The Guildford Formation is a more recent Pleistocene alluvial sands and clays formed in either shallow marine or estuarine environments. AAS materials are often associated with the soils of the Guildford Formation at Kemerton, although preliminary survey work has shown that this formation is unlikely to be encountered in the mining extension area. Both of these formations are unconformably underlain by the Leederville Formation dated as early Cretaceous.



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Kemerton Silica Sand Pty Ltd

Location Plan

Figure 1

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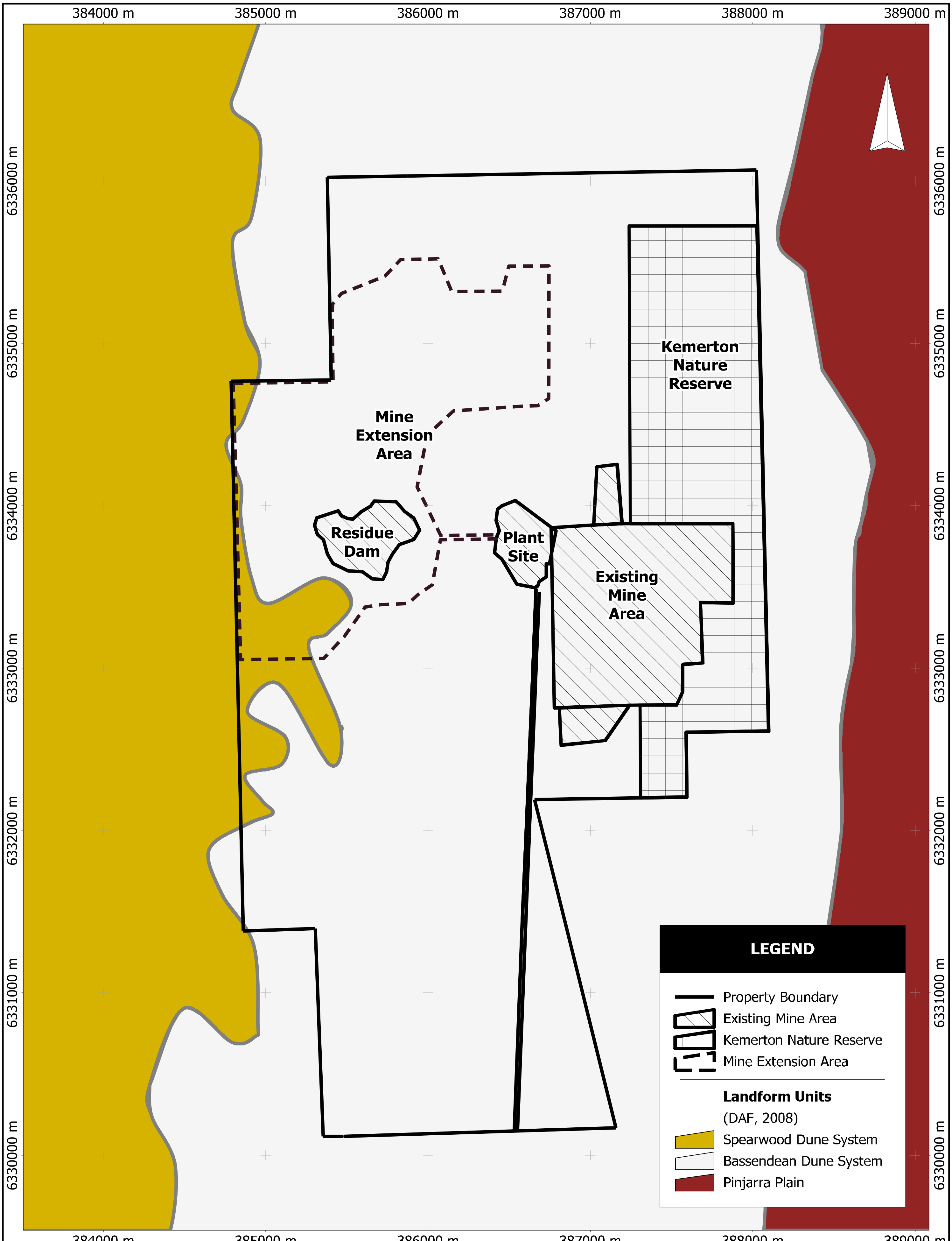


Environmental + Water Resource Consultants 4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale: 1:30000 Original Size: A4 Grid: MGA94(50) 0 500 m	Kemerton Silica Sand Pty Ltd	Landform Systems in Relation to Kemerton Silica Sand Figure 2

W:\Kemerton Silica Sand\Drawings\Maps 2009\Soil System Units.map 18/02/2009 Landform Layout

2.3 SOILS

The dominant soil type of the KSS property is the highly leached, grey siliceous sand of the Bassendean Dune System. The Department of Agriculture, (now the Department of Agriculture and Food (DAF)) published a series of land resource maps for the Swan Coastal Plain, which have now been reproduced and can be accessed electronically from NRM Info (DAF, 2008). Soil units are shown in Figure 3 and descriptions are presented in Table 1.

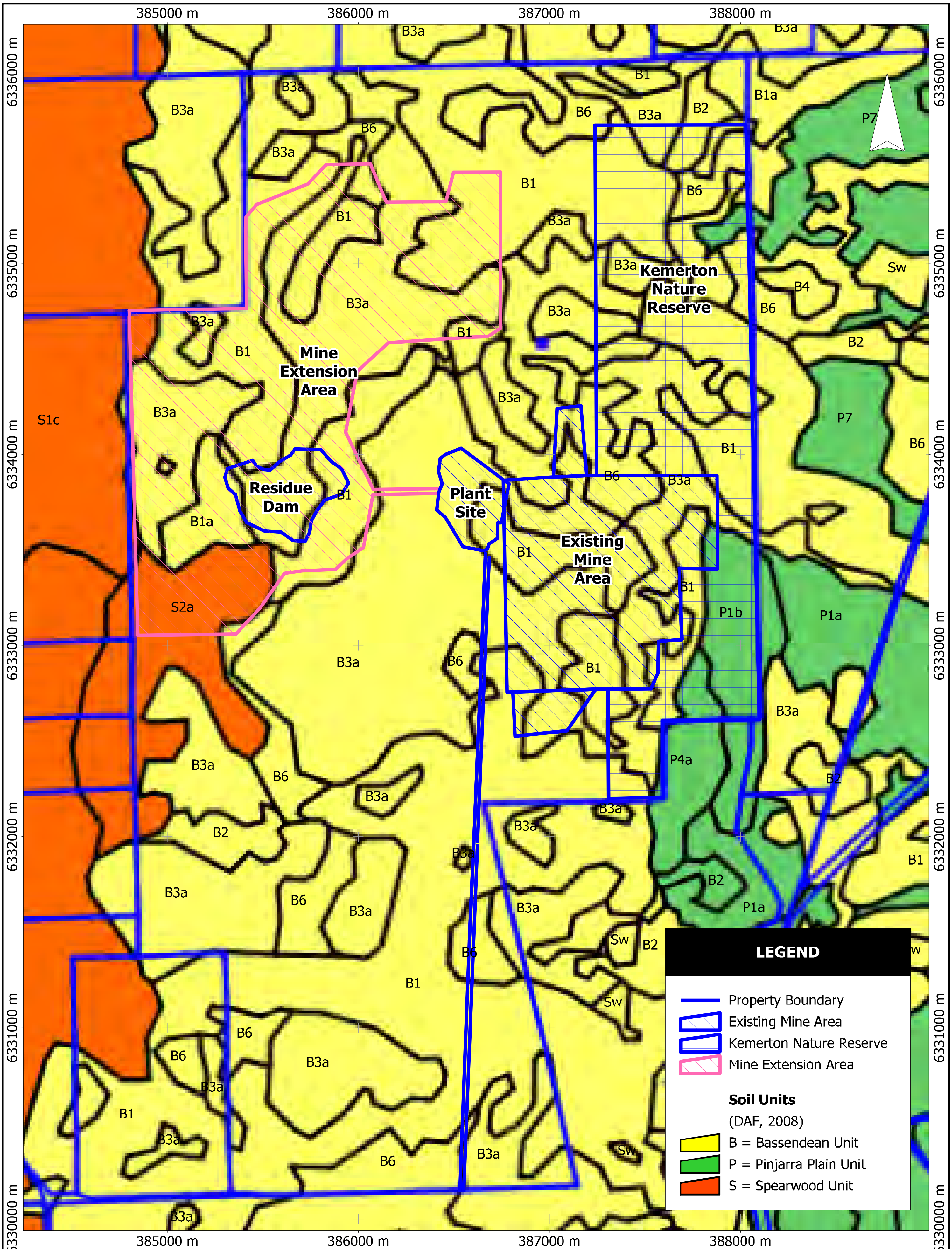
Table 1: Soil Units Within the KSS Mine Extension Area

Soil Unit	Description
B1	Extremely low to very low relief dunes, undulating sandplain and discrete sand rises. Deep bleached grey sands sometimes with a pale yellow B horizon or a weak iron-organic hardpan at depths generally greater than 2 metres. *Banksia* dominant.
B1a	Extremely low to very low relief dunes, undulating sandplain and discrete sand rises. Deep bleached grey sands with an intensely coloured yellow B horizon occurring within 1 metre of the surface. Marri and jarrah dominant.
B2	Flat to very gently undulating well drained sandplain of the surface. Deep bleached grey sands with a pale yellow B horizon or a weak iron-organic hardpan at 1 - 2 metres.
B3a	Broad depression and narrow swales between sand ridges. Poorly drained grey and brown sands, with an iron-organic (or siliceous) hardpan at generally <1 metre.
B6	Imperfectly drained sandplain and broad extremely low rises. Deep or very deep grey siliceous sands.
S1c	Dune ridges with slopes up to 15%. Deep bleached grey sands with yellow-brown subsoils.
S2a	Lower slopes (1 - 5%) of dune ridge with minor limestone outcrop. Moderately deep to deep siliceous yellow-brown sands or pale sands with yellow-brown subsoils.

Source: DAF (2008)

The following summary points are made in relation to soils of the KSS property:

- The property is predominately located within the Bassendean Dune System, which is characterised by naturally acidic soils present as either low dunes or swales.
- Portions of the eastern side of the property interface with the Pinjarra Plain System. These areas are now within the Kemerton Nature Reserve.
- The western side of the property merges with the Spearwood Dune System.
- The upland (*Banksia/Jarrah*) woodland predominately corresponds to the B1, B1a and B2 soil units; some upland areas in the west also correspond to S1c and S2a soil units as mapped by DAF (2008).
- The low-lying wetlands generally correspond to the B3a to B6 soil units mapped by DAF (2008).



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Kemerton Silica Sand Pty Ltd

Soil Units of Kemerton Silica Sand

Figure 3

W:\Kemerton Silica Sand\Drawings\Maps 2009\Soil System Units.map 18/02/2009 Soil System Layout

2.4 GROUNDWATER

2.4.1 Local Hydrogeology

GHD (2002) undertook a hydrological review of the proposed mine extension areas. The review identified that the KSS property occurs within the Perth Basin and is underlain by superficial sediments that rest unconformably on the Leederville formation at a depth of approximately 30 metres. The Leederville formation is approximately 120 metres thick beneath the site and rests unconformably on the Cockleshell Gully formation. The superficial sediments contain an unconfined to confined aquifer system, termed superficial aquifer, which extends between the Darling Scarp and the coast. The superficial aquifer has variable hydraulic connection with the underlying Leederville aquifer, depending on permeability of the sediments.

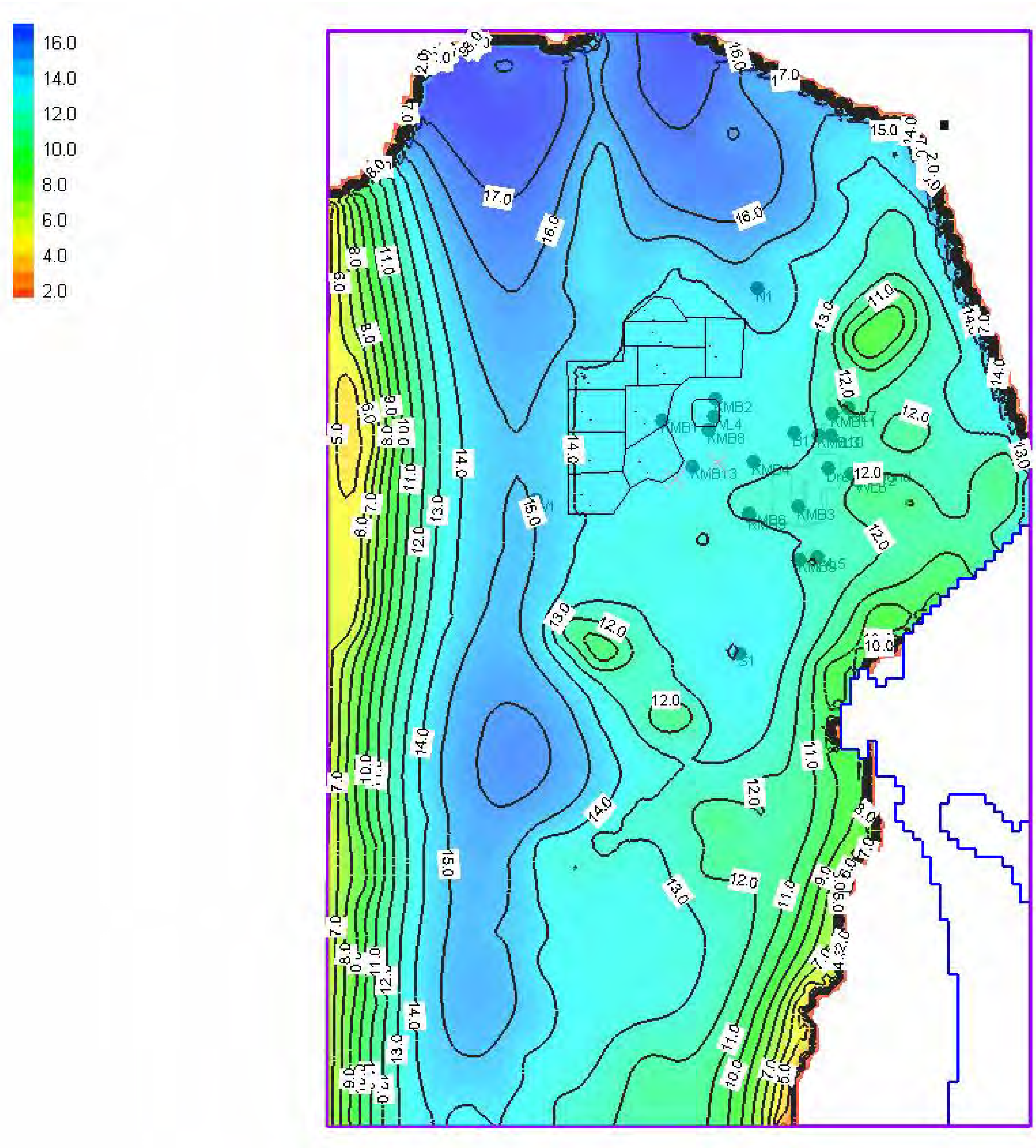
The KSS property is within the Serpentine groundwater flow system near the crest of the Mialla mound approximately 300 metres west of the mine extension area (Figure 4). Recharge to the aquifer system is by direct infiltration of rainfall, particularly in winter and spring when rainfall is more intense. In areas of the KSS property with higher elevations, the water table occurs at depths of more than ten metres while in the lower areas it may intersect the surface seasonally (GHD, 2002).

The water table fluctuates seasonally by approximately two metres in response to seasonal variations in groundwater recharge. Groundwater flow from the Mialla mound is constrained by hydraulic barriers formed by Harvey River to the north, the coast to the west, Leschenault Inlet to the south and Wellesley River to the east. Groundwater flow on the eastern side of the mound (where mining is planned) is predicted to be to the east to south-east towards the Wellesley River. West of the planned mine extension area, flow direction changes so that groundwater flows to the west (Bishnu Gautam (2008) pers. comm.). Groundwater discharge occurs by evapo-transpiration from wetlands and by discharge to the river. Some leakage occurs to the Leederville aquifer at the base of the superficial aquifer.

2.4.2 Groundwater Levels

Groundwater monitoring within the KSS property has been undertaken for over 10 years as a licence requirement for existing operations. Groundwater levels in monitoring bores within the KSS property have historically ranged between 10 to 16 mAHD (Rockwater, 2008). The data suggest a low hydraulic gradient across the property to the south-east.

Figure 4: Model of Predicted Groundwater Levels at Conclusion of Mining



2.4.3 Groundwater Quality

Rockwater (2008) triennial monitoring report provides an assessment of data and trends on the KSS property from 2005 to 2008, which is required under the conditions of groundwater licence GWL 60367(3). Groundwater chemical characteristics are highly variable across the KSS property.

Groundwater in the monitoring bores was acidic to slightly alkaline during the review period, with pH values ranging from 3.2 (KMB6 in December 2007) to 8.6 (KMB4 in October 2005) (Rockwater, 2008). Acidic groundwater pH values recorded for some bores may be a result of oxidation of ASS and organic material in wetland deposits, affecting down-gradient water quality. High pH values have been recorded previously for KMB4 (2001 to 2004), but the pH recorded throughout the current review period was neutral. KSS has previously investigated potential causes for these high pH values and found no evidence to suggest they were influence by their operations. Chemical analyses of groundwater from the monitoring bores for various other analytes during the review period indicated no anomalous results. Results for other analytes are within drinking water guidelines, but tend to be variable.

2.5 SURFACE WATER

2.5.1 Wetlands

The KSS property is located in an area that contains wetlands of the Jandakot consanguineous wetland suite (Semeniuk, 1987). Primary wetlands identified for this wetland suite are damplands and sumplands, which occur in peat or peaty sand or humic sand overlying quartz sand where the groundwater level is at or near the surface developing water table basins.

KSS contains a number of wetlands protected under the *Environmental Protection (Swan Coastal Plains Lakes) Policy 1992* and wetlands designated by the Waters and Rivers Commission in 2001 as being of Conservation significance.

2.5.2 Water Quality of Wetlands

McCullough and Lund (2008) measured chemical water quality parameters as part of an aquatic macro invertebrate abundance survey of KSS wetlands.

Results of the survey were:

- pH was variable with natural wetlands generally slightly acidic with pH values ranging from <7 to 4.6, whereas EPP1 and the artificial water bodies were slightly alkaline with pH>7 up to 8.5.
- Specific conductance was moderate and typical of seasonal wetlands of the Swan Coastal Plain, ranging from 0.15 to 2.06 milliSiemens per centimetre, indicating fresh to brackish water quality. Measured values were highly variable within and between wetlands.

- Oxidation Reduction Potential (ORP) was very variable, but positive in all but one of the wetlands, at around 100 milliVolts.
- Turbidity was low in all EPP wetlands, but moderate in artificial water bodies and Conservation category wetlands.
- Dredge ponds and satellite lakes had significantly different water chemistry to natural KSS wetlands. Relative to natural KSS wetlands, the rehabilitated dredge pond North Lake had higher water temperatures, turbidity, DO, pH, sulfate, ammonia and total nitrogen concentrations.

3. ACID SULFATE SOILS

3.1 DEFINITIONS

Acid Sulfate Soil (ASS) is the common name given to naturally occurring soil and sediments containing iron sulfides. These naturally occurring sulphides are generally formed under anaerobic conditions such as swamps and estuarine sediments. Although benign in their natural state, when exposed to air they oxidise and produce sulphuric acid, iron precipitates, and concentrations of dissolved heavy metals such as aluminium iron and arsenic (Planning Bulletin Western Australia Number 64, WA Planning Commission, November 2003). For a full list of impacts see the WA Planning Commission Bulletin Number 64 as well as other government publications covering ASS listed in Section 3.2.

AAS materials include both Actual Acid Sulfate Soils (AASS) and Potential Acid Sulfate Soils (PASS). AASS are ASS materials that have been previously oxidised. PASS are AAS materials that have not been oxidised, but have the potential to produce acid when oxidised.

Identification of AASS and PASS materials is based on results for two field tests:

- pH_F is the field pH of the soil, measured on a 1:5 soil:water paste.
- pH_{FOX} is the pH of the soil after oxidation with hydrogen peroxide solution.

AASS soils are characterised by pH_F values of <4.

PASS samples are typically neutral to alkaline, but react with peroxide to produce free sulphuric acid. pH_{FOX} values for PASS materials are usually <3.

It is important to note that whilst a useful exploratory tool, soil field pH_F and pH_{FOX} tests are indicative only and cannot be used as a substitute for laboratory analysis to determine the presence or absence of ASS. Recent review of field pH_F and pH_{FOX} tests in Western Australian soils indicates that these tests provide an accurate identification of ASS in only 60% to 80% of cases and are capable of providing both false positives and false negatives (i.e. may underestimate or overestimate acid-generating potential).

3.2 RELEVANT STANDARDS AND GUIDELINES

The following documents provided by the DEC were used in the preparation of this ASS Management Plan.

- *Preparation of Acid Sulfate Soil Management Plan (ASSMP).* DEC Acid Sulfate Soils Guideline Series, April 2003.
- *Draft Identification and Investigation of Acid Sulfate Soils*. DEC Acid Sulfate Soils Guideline Series, May 2006.
- *General Guidance on Managing Acid Sulfate Soils*. DEC Acid Sulfate Soils Guideline Series, August 2003.

- Western Australian Planning Commission (WAPC) *Planning Bulletin No. 64. Acid Sulfate Soils.* (November 2003).

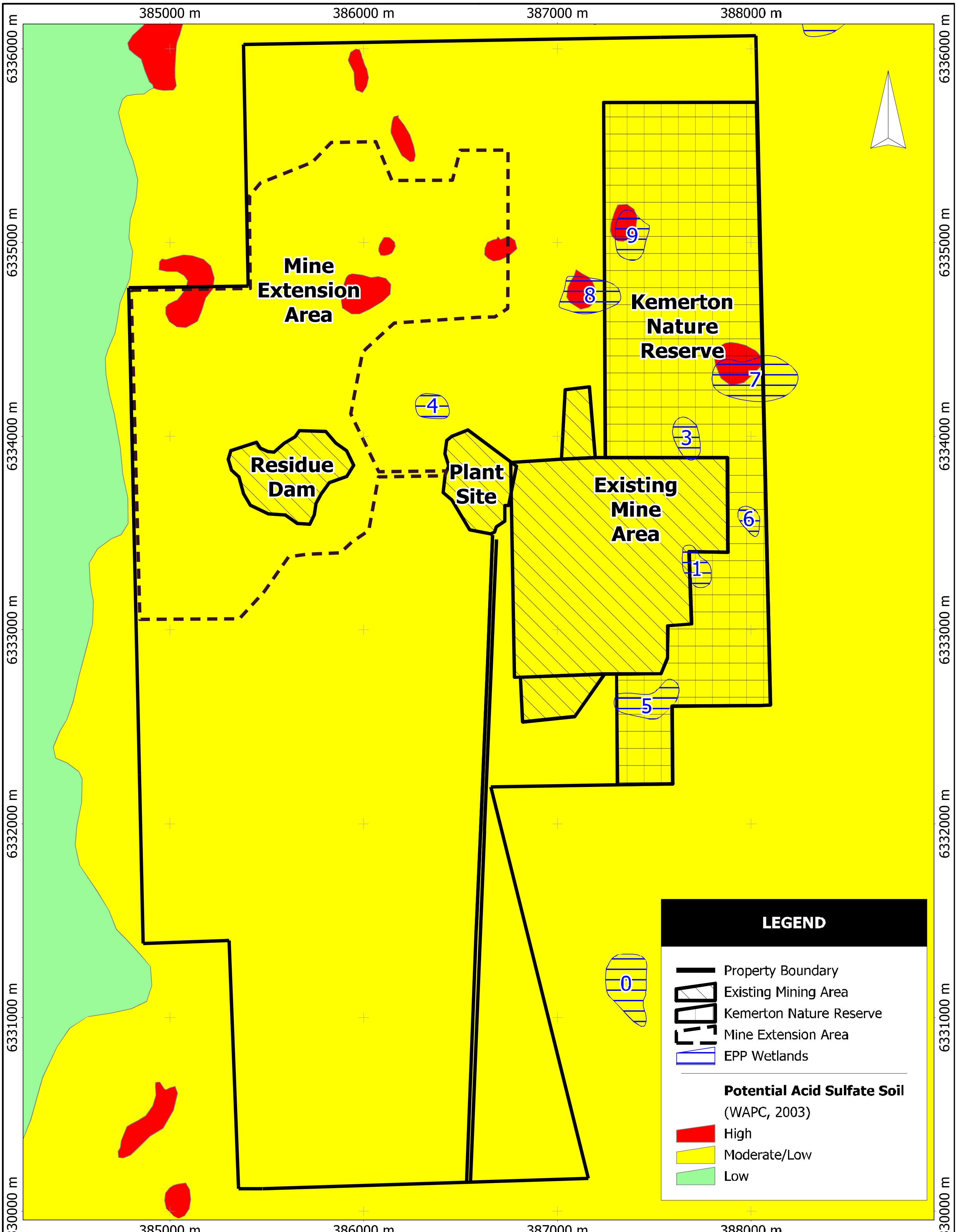
3.3 DESKTOP STUDY

The WAPC (2003) Bulletin 64 provides broad scale mapping of the ASS risk status of the Swan Coastal Plain. Figure 5 shows that most of the KSS property is located within an area mapped on the WAPC (2003) Bulletin 64 maps as having a moderate to low risk of ASS occurring generally at depths of greater than three metres. However, also present are two areas listed as being high risk of ASS at less than three metres from the surface.

Within the mine extension area, the available information indicates there are three separate zones, each with different potential to generate ASS. These are described in Table 2.

Table 2: Zones of ASS Generating Potential

Zones	Risk level	Description
Zone 1	Very Low	The elevated Bassendean dunes permanently above the highest water table level. This resource is overlaid with a cemented ironstone (coffee rock) layer, approximately one to two metres thick. Some of this sand is resource and some is waste, the latter categorised as overburden.
Zone 2	Low to Moderate	The profile between Zones 1 and 3. The highest grade silica sand resource is located below the natural water table. Sand extraction occurs via a wet mining process, that is, a dredge. The dredge has a maximum dredging depth of 15 metres.
Zone 3	High	Soil horizon containing PASS material.



MBS ENVIRONMENTAL Environmental + Water Resource Consultants 4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale: 1:25000 Original Size: A4 Grid: Australia MGA94 (50) 0 500 m	Kemerton Silica Sand Pty Ltd	Potential Acid Sulfate Soil Locations within Kemerton Silica Sand Figure 5

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3.4 PREVIOUS SOIL ASSESSMENT AT KSS

MBS undertook a baseline ASS assessment of the proposed mine extension area (MBS, 2007).

The field assessment comprised the following elements:

1. Sampling sites were selected from a transect alignment using existing drill lines and access tracks to minimise the need for further clearing of native vegetation. Drill cores were provided from 30 holes to depths of up to 20 metres. Complete soil descriptions for provided each location.
2. In line with the low to moderate ASS risk ranking indicated for the mine extension area, sampling was undertaken at 250 metre spaced holes in the five to ten year mine area and at 500 metre intervals in future mine areas on transect lines.
3. Field pH (pH_F) and pH after oxidation (pH_{FOX}) measurements of all soil samples were completed for all samples to provide an indication of the likelihood of ASS presence. Based on these results, a selection of samples showing the highest ASS field results were submitted for laboratory analysis using the Suspension Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) analysis method. The SPOCAS method is a standardised set of procedures used in assessing the environmental impact of soils suspected of containing pyrite and other iron sulphides which might lead to an ASS problem if disturbed.

The field and laboratory testing undertaken in 2007, which is presented as Appendix 1 to this document, indicated the following:

- Field assessment shows the more highly reactive soils were located at depths below 15 metres.
- A significant number of the samples selected for laboratory analysis exceeded the DEC action criteria specified for sandy soils of a Titratable Peroxide Acidity (TPA) level greater than 18 moles H^+/tonne. This confirms there are soil locations within the proposed mine profile that are Potentially Acid Forming (PAF). However, they are not universally below 15 metres and are not perfectly correlated with high field measurement results.
- A number of samples recorded extremely high Acid Neutralising Capacity (ANC) values.
- None of the samples tested recorded pH_{KCl} <4.5, indicating that additional testwork is not required to measure retained acidity.

4. POTENTIAL ENVIRONMENTAL IMPACTS

4.1 PROJECT DESCRIPTION

Dredge mining at the KSS proposed mine extension area will begin in a new dredge pond in the property's west. The mine extension area will consist of 10 cells each with a mine life of about five years. The dredge pond will move in a west then northerly direction. Following rehabilitation, reformed dredge ponds will remain as lakes and ephemeral wetlands interspersed with upland areas.

It is proposed to extract approximately 30 million cubic metres of sand from the site over a period of 50 years at an annual rate of 500,000 to 1,000,000 tonnes per year. The maximum depth of dredging varies between 15 and 22 metres below the water table. Mining is carried out by a suction cutter dredge capable of mining at a rate of 350 tonnes per hour. Sand is pumped from the dredge pond to the Run of Mine (ROM) stockpiles at the processing plant using booster pumps. Slurry from the pond is dewatered using cyclones and sand is discharged onto stockpiles for processing. The water and slimes fraction are returned back to the dredge pond.

Dredge mining operations have occurred for the last ten years at KSS, to a depth of approximately 15 to 22 metres. The base of the silica sand resource is usually bounded by the interface of Bassendean sand system and the Ascot Formation, characterised by the presence of shells and limestone rather than siliceous sand. Groundwater monitoring undertaken over this period as part of environmental licence conditions has not shown development of significant amounts of acidity in the dredge pond or surrounding monitoring bores, suggesting a very low risk of acid generation for future dredging operations. A significant proportion of the returned sand residue is backfilled below the water table in the rehabilitation cell, thereby minimising exposure to oxygen and reducing the rate of any possible acidification from PASS material in these soils. The residue deposited in the rehabilitation cell above the water table is unlikely to contain PASS material, but will be tested if there is any indication of acidity being generated.

4.2 ENVIRONMENTAL IMPACTS OF ASS DISTURBANCE

Mining within an area in which ASS materials exist can result in acidic drainage from either AASS materials or oxidation of PASS materials. Acidic drainage from soil can result in adverse effects on groundwater, surface water quality, mining infrastructure, environmental values and the success of post-mining rehabilitation.

Oxidation of ASS materials at KSS can occur by either

- Exposure of ASS materials in soil stockpiles to air.
- Lowering of the water table to allow exposure of ASS materials previously located in an anaerobic environment to air.

The potential environmental impacts associated with the current proposal are:

- The effect dewatering the Bassendean sand profile during the winter will have on activating potential acidity in the sand profile to be mined.
- The effect dewatering the Bassendean profile has on activating potential acidity in the underlying Guildford Formation.
- The effect dewatering the Bassendean profile within the open pit has on the surrounding environment.

5. MANAGEMENT STRATEGIES

The principal strategy to manage ASS and acid drainage issues at KSS will be to avoid their disturbance. This will be achieved by

- Undertaking soil surveys in accordance with DEC guidelines prior to commencement of mining operations.
- Evaluating survey data to fully delineate the lateral and vertical distribution of ASS materials within the proposed mining area.
- Planning the mining program to avoid disturbance of areas identified by the survey to either contain ASS materials, or having a high probability of containing ASS materials. Results from a preliminary survey (Section 6.1) have shown that most of the ASS materials are present below the mining floor.

A groundwater monitoring program will be established to ensure that mining operations do not have a measurable effect on groundwater levels and water quality. Site specific 'Action Criteria' will be determined and used to instigate an appropriate management response should they be exceeded. Monitoring data will be evaluated on a regular basis to determine whether or not mining operations are responsible for long term changes in groundwater quality. The DEC will be advised immediately in the event of any indication of acidification of soil, groundwater or surface water at KSS.

If disturbance of ASS materials cannot be avoided, mitigation strategies will involve

- Minimising exposure of ASS materials to the atmosphere, preferable by storage beneath the water table.
- Use of acid neutralising materials to prevent production of acid drainage.
- Use of acid neutralising materials to treat acidic waters.

The final component of the management strategy is additional testing to verify the effectiveness of preventative or remedial action.

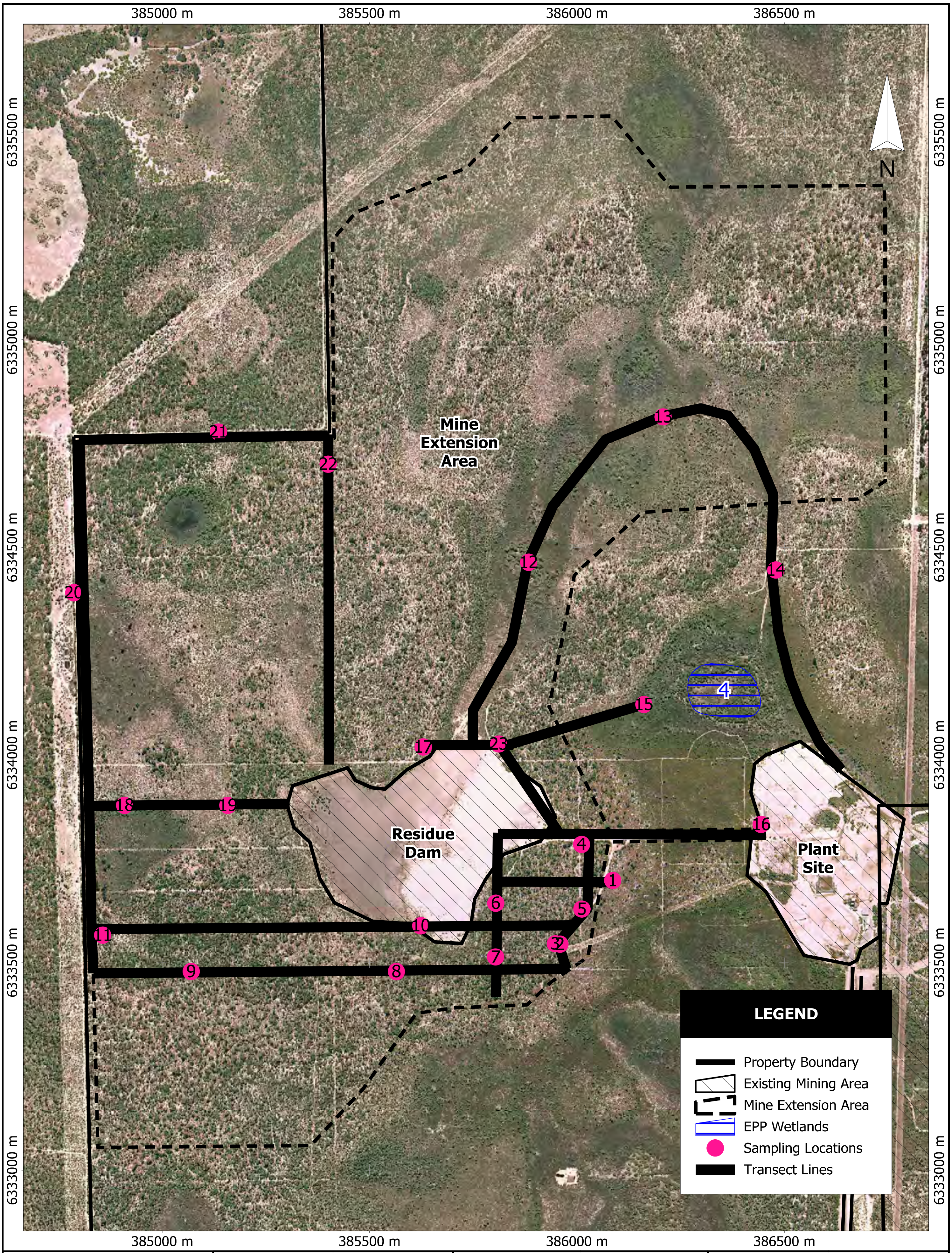
6. MONITORING PROGRAMS

6.1 SOIL SURVEY

DEC Guidelines (DEC 2003, DEC 2006) provide recommended sample frequencies for types of projects such as urban developments and infrastructure projects requiring trench excavations that may result in disturbance of ASS materials. For non-linear disturbances such as mining operations, the recommended sampling frequency is two locations per hectare. However, DEC has acknowledged that for large projects (>50 hectares), a reduced sampling frequency may be acceptable. These guidelines also recommend a sampling interval of four samples per vertical metre to a depth at least one metre below the maximum depth of soil likely to be disturbed by the proposed activity.

Results from the soil survey conducted in 2007 indicated there was very little ASS material present in the first ten metres of the soil profile. On this the basis of this observation and the typical homogenous nature of Bassendean sand subsoils, the recommended sample interval for field testing is two metres. Material at depths greater than ten metres should be sampled for field testing at one metre intervals.

The sampling frequency adopted for the 2007 survey was based on holes drilled at 250 metre spacing within the five to ten year mine area and 500 metre spacing in the future mine area (Figure 6). Future soil surveys should be based at 250 metre spacings. Areas designated at Medium to High Risk according to the WAPC (2003) Bulletin 64 will be sampled if such areas are likely to be impacted by the proposed mining operations.



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Kemerton
Silica Sand Pty Ltd

Acid Sulphate Soil Survey

Figure 6

W:\Kemerton Silica Sand\Drawings\Maps 2008\ASS.map 25/09/2008 Acid Sulfate Soils Survey Layout

6.1.1 Requirements for Soil Testing

Field soil testing will be undertaken in the following situations or circumstances:

- When planning to mine areas that have not been previously sampled at a frequency of 250 metre spacing.
- If unexpected soil types are encountered during mining operations. Indications of the presence of AAS materials are described in Section 6.1.5.
- Selection of soil for rehabilitation of previously mined areas.
- If mining operation requirements identify a need to stockpile soil for an extended period. This is discussed in Section 6.1.5.

6.1.2 Field Test Procedures

A summary of the procedure for conducting field tests for pH_F and pH_{FOX}, based on that recommended by the *Draft Identification and Investigation of Acid Sulfate Soils* Guidelines (DEC 2006) is presented in Appendix 2.

In the MBS (2007) Acid Sulfate Soils Assessment at KSS, a pH_F value of less than 4.5 was used to select soils for laboratory assessment to verify the suspected presence of AASS materials. To confirm the suspected presence of PASS materials, samples were submitted for laboratory assessment of the difference between pH_F and pH_{FOX} was greater than 4.0.

6.1.3 Criteria for Selection of Samples Requiring Laboratory Analysis

A comparison between the field test results (pH_F) and the subsequent laboratory results (Titratable Actual Acidity (TAA) and pH_{KCl}) was conducted to validate the current assessment levels for selecting soils requiring laboratory analysis to confirm the possible presence of AASS or PASS materials.

Although the results for the measuring of pH_F were not highly correlated with the pH_{KCl}, the pH value measured in the laboratory (r^2 = 0.29), there was a reasonable correlation between pH_F and TAA (r^2 = 0.43). Only one of the samples tested contained significant amounts of TAA (28 mole H^+/tonne) and it corresponded with the lowest pH_F value of 4.99.

Based on these observations, it is ***recommended that the pH_F value be increased from 4.5 to 5.0 for identifying field samples requiring laboratory analysis*** to confirm the presence of AASS materials

pH_{FOX} values recorded in the field were highly correlated with pH_{OX} measured in the laboratory (r^2 = 0.79). pH_{FOX} was a better predictor of TPA measured in the laboratory (r^2 = 0.40) compared with the difference between pH_F and pH_{FOX} (r^2 = 0.23). Of the 12 samples identified by laboratory analysis as exceeding the DEC action criteria value (TPA of 18 mole H^+/tonne), 11 had pH_{FOX} values below 3.0. All but one of the soils exceeding the DEC action criteria had values for (pH_F - pH_{FOX}) greater than 3.0. Nine of the twelve samples exceeding the DEC action criteria had values for (pH_F - pH_{FOX}) greater than 4.0

Based on this assessment, it is ***recommended that the criteria used to select samples for laboratory analysis be based on differences between pH$_F$ and pH$_{FOX}$ field measurements greater than 3.0.***

6.1.4 Action Criteria for ASS Soil Management

Although Western Australia was the first Australian state to recognise the impact of disturbance of acid sulfate soils, most of the recent research into ASS has been conducted in Queensland and New South Wales. The Western Australian DEC has adopted action criteria adopted by Queensland regulators based on the recommendations provided by Ahern *et al.* (1998).

These 'Action Criteria' (or Trigger Levels) are based on the sum of existing plus potential acidity. This is usually calculated as equivalent sulfur (eg. S-TAA + S_{CR} in %S units) or equivalent acidity (e.g. TAA + acidity-S_{POS} in mol H^+/tonne units). Different values have been established for different soil types, depending on the texture or clay content of the soil.

For the sand textured soil present at KSS, the Action Criteria values are:

- 0.03% Peroxide Oxidisable Sulphur (S_{POS}).
- 18 mole H^+/tonne of Titratable Peroxide Acidity.

6.1.5 Stockpile Management

KSS mining operations generally do not require stockpiling of soil suspected or known to contain ASS materials. Should this occur, the stockpile will be periodically inspected for oxidation of PASS materials. Indications of the presence of AAS materials include:

- Presence of corroded shells.
- Sulphurous ('rotten egg') odours.
- Appearance of yellow/brown iron stains or mottling.

Long term soil stockpiles showing signs of oxidation of PASS materials will be assessed for their acid generating potential. The minimum number of samples which will be collected will be dependent on the volume of the stockpile. The DEC *Draft Identification and Investigation of Acid Sulfate Soils* guidelines (DEC 2006) provides guidelines for stockpile sampling frequency, as summarised in Table 3.

Table 3: Recommended Stockpile Sampling Frequency

Stockpile Volume (m^3)	Number of Samples
<250	2
251 - 500	3
501 - 1,000	4
>1,000	1 per 500 m^3

6.2 GROUNDWATER MONITORING

In accordance with requirements for current and previous licences issued by DoW to extract groundwater, KSS has an extensive network of monitoring bores. Groundwater levels and water quality are measured on a regular basis in accordance with the licence requirement and the results are reported in Annual and Triennial Reviews, with the most recent reported for the period July 2005 to June 2008 published by Rockwater in September 2008.

Locations of existing monitoring bores are shown in Figure 7. As the general direction of groundwater flow is to the south-east, existing bores KMB1, KMB2, KMB4, KMB7, KMB 8, KMB13 and KMB14 are well placed to record any impact of ASS disturbance on groundwater quality. Two new production bores will be installed for the project extension. These bores will be included in the groundwater quality monitoring program.

The Triennial Groundwater Monitoring Review by Rockwater (2008) provides water quality testing data for both production and monitoring bores. Monthly samples of water from the production bores are tested for pH and salinity. Four of the monthly samples collected between July 2005 and June 2008 were also tested for nitrate, phosphorus, chloride and sulfate.

Samples of water from monitoring bores are collected on a monthly basis and tested for pH and salinity. Additional testing is undertaken every six months for chloride, sulfate and iron. There is also data available between 1998 and 2001 for nitrate, cobalt, copper, manganese, nickel and total phosphorus.

6.2.1 Groundwater Action Criteria

Based on the results of groundwater monitoring presented in the Triennial Groundwater Monitoring Review by Rockwater (2008), ‘Action Criteria’ for further investigation and management have been developed for:

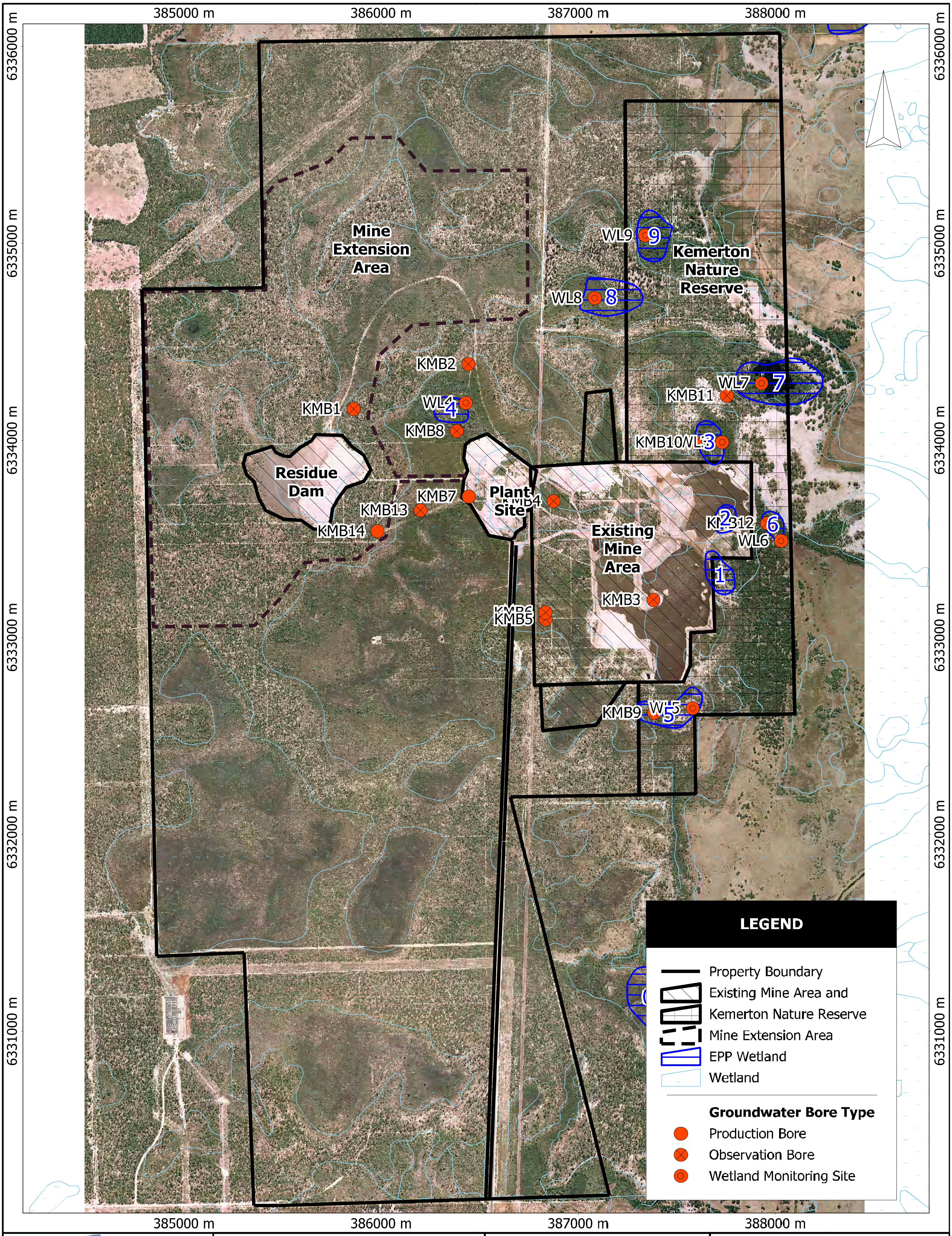
- Groundwater Levels.
- Groundwater Quality.
  - pH.
  - Chloride:sulfate ratios.
  - Metals and metalloids.

6.2.1.1 Groundwater Level Action Criteria

Decreasing groundwater levels are a major cause of oxidation of PASS materials on the Swan Coastal Plain. Investigations into the potential exposure of ASS materials will be undertaken if groundwater levels in selected monitoring bores fall below historical low levels. Based on the water level data listed in Appendix II of the Rockwater (2008) report, the corresponding action levels are listed in Table 4.

Table 4: Recommended Action Criteria for Groundwater Levels

Monitoring Bore	Minimum Groundwater Level (m A.H.D Reduced Level)
KMB1	13.5
KMB2	13.5
KMB4	13.0
KMB6	12.5
KMB8	13.0
KMB9	11.5
KMB10	12.5
KMB11	12.5
KMB12	12.0
KMB13	13.0



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Original Size: A4
Air Photo: 2006
Grid: Australia MGA94 (50)
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Kemerton Silica Sand Pty Ltd

Groundwater Bore Locations

Figure 7

6.2.1.2 pH Action Criteria

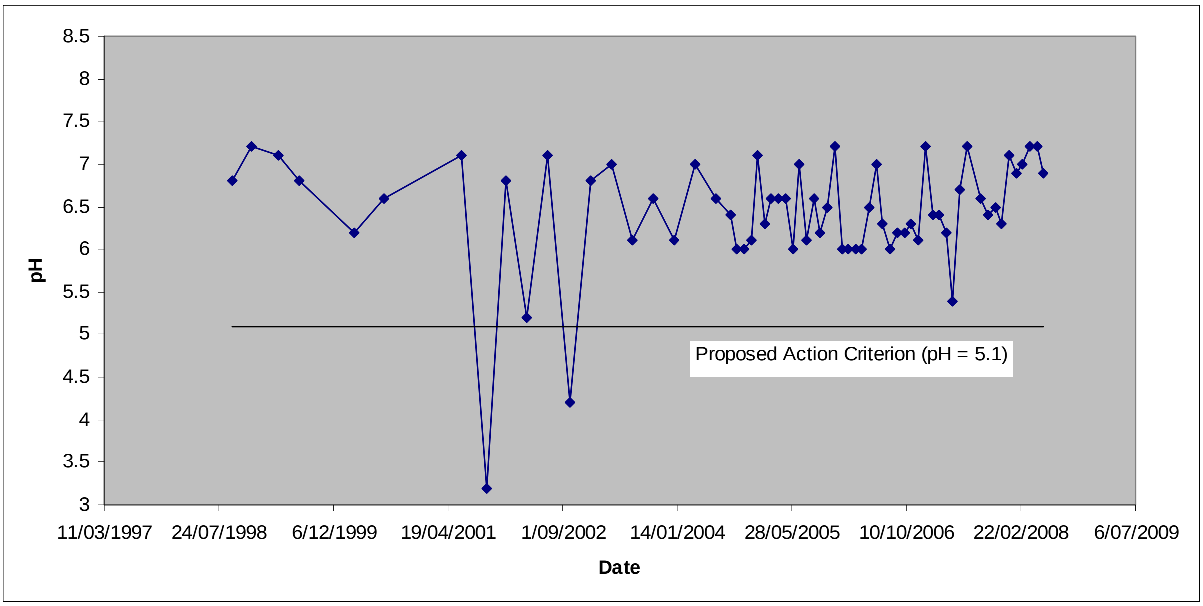
pH values have been measured at most of the KSS monitoring bores since 1998. Under requirements of the current license, bores are monitored on a monthly basis. Examination of data presented in the Rockwater (2008) report indicates wide variations in pH values, both between different locations and from month to month. Chart 1 shows the pH values recorded for monitoring bore KMB8 between September 1998 and June 2008.

Although the results vary significantly from month to month, there is no indication of a long term decreasing trend in pH values that may be indicative of oxidation of PASS materials. However, the very low pH values recorded in October 2001 and October 2002 may be associated with transient oxidation of PASS material.

An environmental 'Action Criterion' for KMB8 was calculated from the 10 years of pH data using the mean (6.44) and standard deviation (0.68) values. Using a 95% confidence level, the corresponding Action Criterion to indicate possible oxidation of PASS material was pH = 5.1.

Note that a single exceedence of the proposed 'Action Criteria' value should not instigate an immediate management response. Based on the statistical approach used to calculate these 'Action Criteria', exceedences due to natural variation can be expected once every 40 observations. However, exceedence of the proposed "Action Criteria" in successive monitoring periods is extremely unlikely by chance and will trigger a response to identify the cause of acidification.

Chart 1: Monthly pH Values for Water Samples from Monitoring Bore KMB8



A similar approach has been used to determine appropriate Trigger Levels for other KSS monitoring bores. The calculated 'Action Criteria' values for selected monitoring bores are listed in listed in Table 5.

Table 5: Recommended Action Criteria for pH of Monitoring Bores

Monitoring Bore	Minimum pH
KMB1	4.0
KMB2	Insufficient data
KMB4	6.0
KMB6	3.1
KMB7	6.4
KMB8	5.1
KMB9	Insufficient data
KMB10	3.1
KMB11	4.8
KMB12	6.4
KMB13	5.3
KMB14	5.6

6.2.1.3 Chloride to Sulfate Mass Ratio Criteria

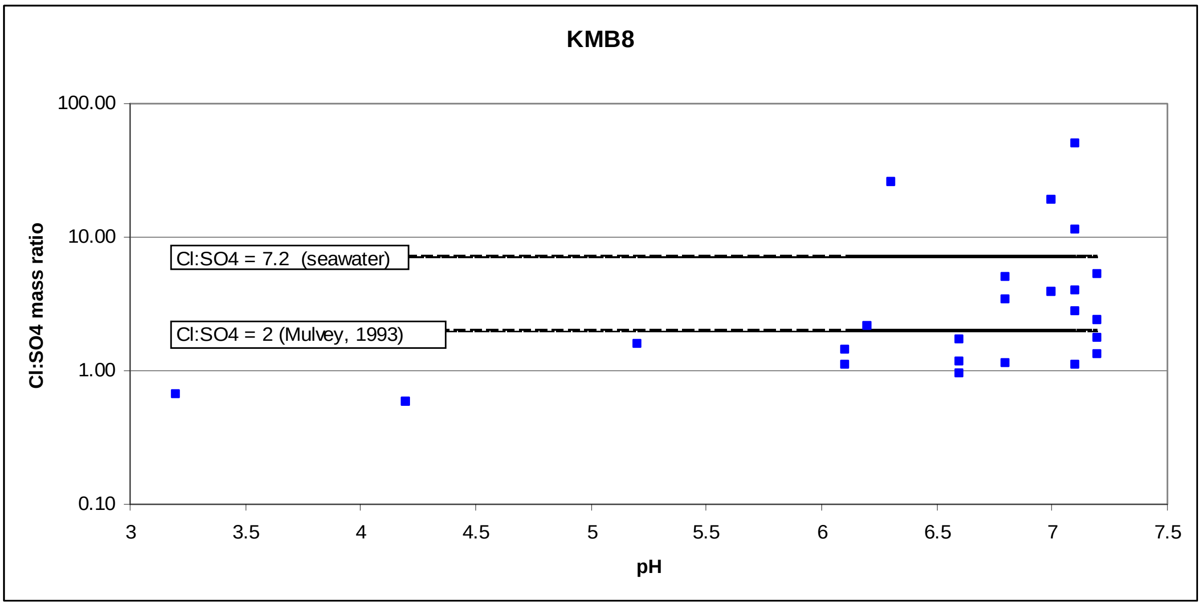
In addition to monitoring pH, changes in the chloride to sulfate ratio[1] of groundwater and surface water can also provide an indication of early stages of oxidation of ASS materials. Mulvey (1993) suggested that a chloride to sulfate mass ratio of less than four and certainly less than two, is a strong indication of an extra source of sulfate from sulfide oxidation.

Examination of substantial amounts of chloride and sulfate data from KSS monitoring bores indicates the chloride to sulphate mass ratios are highly variable and not significantly correlated with pH, as shown for bore KMB8 in Chart 2 (noting the logarithmic y-axis scale to indicate the wide range of chloride to sulphate ratio values). However, the results for KMB8 also indicate that the chloride to sulphate ratios for all samples with pH values below 6.0 were less than the critical value proposed by Mulvey (1993).

KSS will adopt a Trigger Level for chloride to sulfate mass ratio of less than two if the corresponding pH value is less than 6.0.

[1] Chloride:sulphate ratios may be reported on a mass ratio or a mole ratio. McCullough and Lund (2008) used a molar ratio in their reports to KSS. In this memorandum, chloride:sulphate ratios are presented on a mass ratio. The multiplication factor for converting values from a mass ratio to a molar ratio is 2.708.

Chart 2: Comparison of Chloride to Sulfate Ratios with pH for Bore KMB8



6.2.1.4 Dissolved Metals and Metalloids

Release of toxic metals and metalloids such as arsenic, aluminium, copper, manganese and nickel from oxidation of PASS materials and leaching from AASS materials can result in significant environmental impacts.

KSS will adopt the Australian Guidelines for Fresh and Marine Quality Trigger Levels for these elements in fresh waters as stated in the DoW Groundwater Licence. The relevant values for protection of 90% of species in slightly to moderately disturbed systems are listed in Table 6.

Table 6: Trigger Values for Toxicants for Slightly to Moderately Disturbed Freshwater Ecosystems

Element	Freshwater Trigger Values (mg/L)
Aluminium	80
Arsenic	94
Copper	1.8
Manganese	2,500
Nickel	13

6.3 DEWATERING AND PROCESS WATER MONITORING

The DEC (June 2006) document *Dewatering Effluent and Groundwater Monitoring Guidance for Acid Sulfate Soil Areas* describes a process for dewatering and treatment of effluent water.

However, the KSS proposal has major components that differ significantly from the process shown in the DEC documentation. The major differences are:

1. Mine pit dewatering does not occur at KSS in the manner shown in the DEC (2006) document. Mine pit dewatering does not require a bore system. Thus, no dewatered cone of depression will develop below the pit, which would alter the oxygen and water regime in the underlying Guildford Clay formation. Dewatering at KSS does not affect the underlying PASS layer. Sand extraction occurs via a wet mining process, that is, a dredge. The suction cutter dredge is electric powered and is capable of mining at a rate of 350 tonnes per hour to a vertical depth of 15 metres. The PASS material is most likely located at or below the final level of the dredge pond. Based on experience gained over ten years of mining at Kemerton, KSS anticipate that the dredge pond will not acidify due to the layer of acid-neutralising limestone from the Ascot formation that is often present at the depth of the proposed dredge pond.

2. Water collected in the dredge pond is sourced from:

   - Groundwater inflow when the water table is above the level of the pond floor.
   - Rainfall.
   - Recycled water from the process plant.

   All this water is collected and is used by the process plant to wash the heavy mineral sand component from the remaining silica sand.

3. The slurry is pumped from the dredge to the plant where it is dewatered with cyclones (a cylinder using a centrifugal action) and the excess water is pumped back to the dredge pond. The sand is then discharged to stockpiles where it is fed by conveyor belt over a coarse screen to remove large material such as wood and rocks, and then Flat bed classifiers to remove any oversized particles. The silt and clay fraction is then removed from the remaining sand using hydrocyclones. The sand can be cleaned by agitating the slurry in attritioning cells. The clean sand is then fed to trommels that remove the grains that are greater than 425 microns in size.

4. The sand less than 425 microns is then fed into a spiral circuit which separates heavy minerals from the sand before it could go to a wet high intensity separator removes any remaining iron minerals. The remaining sand is pumped to cyclones on stackers where it is dewatered for a second time prior to placement in stockpiles where remaining moisture, usually less than 5% and drains naturally from the stockpiles.

5. The process water dam is topped up with water from the superficial aquifer and recycled process water from the thickener.

As a result of these key differences, variation to the groundwater monitoring program is proposed to produce a system that reflects the nature of the Kemerton mining process, allows for early detection of changes in acidity and for management action to avoid, minimise or mitigate this effect. The process is shown in Figure 8 and explained as follows:

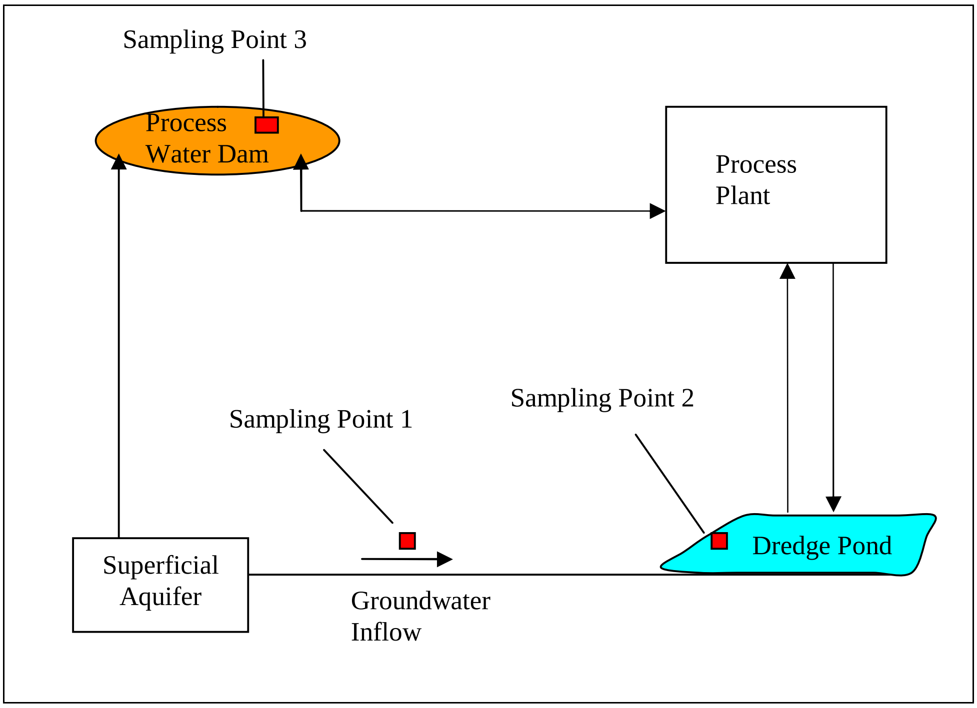
1. A lined site water dam is the central water storage point for the site. Water from the open pit, Leederville bores and process plant all go through this dam.

2. Three monitoring points are proposed:

- Sampling Point 1 provides an indication of the quality of groundwater inflow in the mine pit (the 'before' state).
- Sampling Point 2 is process water recovered by the drainage system in the current dredge pond and represents the water quality after it has been through the process (the 'after' state).
- Sampling point 3 is from the process water dam. This water includes water sourced from the Leederville bores and represents the 'average' water quality from all sources on site.

3. A significant difference between water quality at Sampling Points 1 and 2 may relate to changes in acidity that occur as a result of the process activating potential acidity sources in the mined profile. Trigger values will be developed to determine action levels for lime dosing of the water to return the monitored values at Sampling Point 2 to below trigger levels.

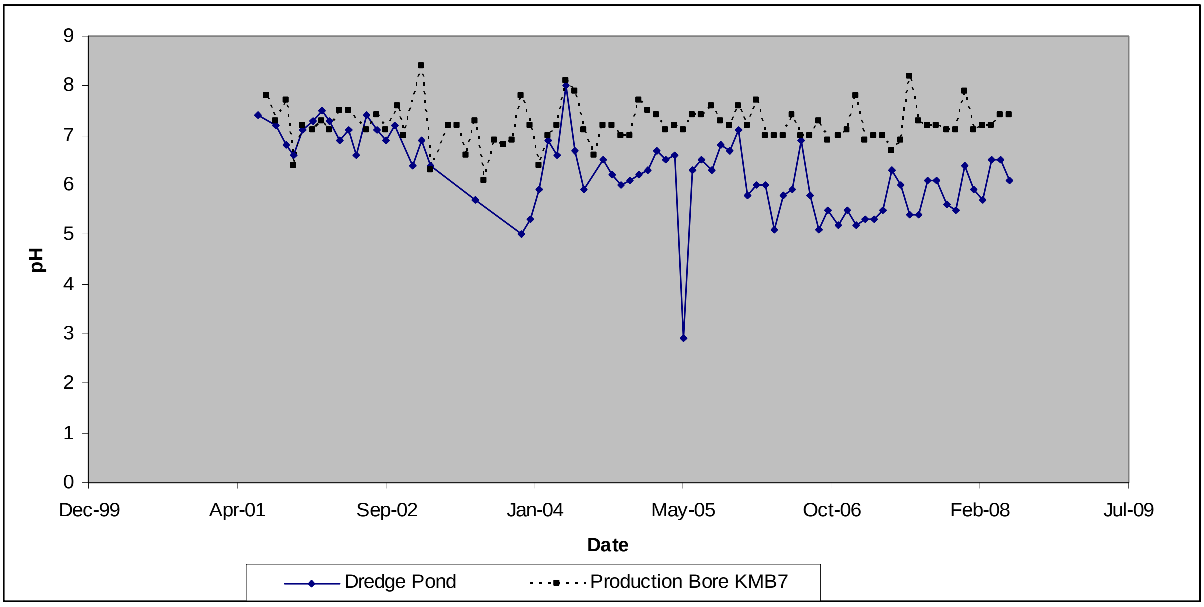
Figure 8: KSS Mine and Process Water Management



The procedure described above has been used to monitor changes in acidity of the dredge pond used for the current mining operation. Chart 3 compares the pH values of the dredge pond (Sampling Point 2) with production bore KMB7, which has been selected as a surrogate for the local groundwater (Sampling Point 1). Comparison of the data presented in Chart 3 indicates there has been a slight difference between the acidity of the groundwater surrogate and the dredge pond water since September 2002, but the recorded pH levels of the dredge pond are unlikely to present a significant effect to the surrounding environment.

KSS propose to adopt a similar approach to monitor the potential for acidification of the dredge pond in the proposed mining extension. Water samples from the dredge pond will be included in the monthly sampling program for existing monitoring bores and the data will be statistically evaluated on a regular basis.

Chart 3: Comparison of pH Data for Water in the Current KSS Dredge Pond and Monitoring Bore KMB7



6.4 SURFACE WATER MONITORING

Biannual water samples from four KSS wetlands (designated WL3, WL4, WL6 and WL7) have been analysed since July 2002. The monitoring data is reviewed as part of the KSS Triennial Groundwater Review to determine whether or not changes to water quality, including acidity, have occurred. The monitoring program will continue for the duration of the proposed extension of mining.

7. CONTINGENCY MANAGEMENT

7.1 SOIL

As described previously, disturbance of PASS materials by the extension to mining operations at KSS is considered unlikely. An extensive soil survey conducted in 2007 demonstrated that almost all of the PASS material is located at a depth greater than 15 metres, which is below the maximum depth likely to be disturbed by the mining operation. Furthermore, most of the soil collected from the dredge pond is processed immediately and the process residue is then returned to the dredge pond with minimal exposure to air. There is unlikely to be a need to stockpile soil suspected of containing PASS materials for an extended period.

If unexpected soil materials are encountered in the mining operations or a need arises to stockpile suspected ASS materials, the contingency plan outlined below will be implemented.

- KSS Management to be advised immediately.
- Visual observations and field testing of the material will be undertaken based on the frequency prescribed in Sections 6.1 and 6.1.5.
- If the presence of PASS material is indicated, the feasibility of transferring the excavated material beneath the permanent water table will be assessed by management and implemented if practical.
- If extended exposure to air cannot be avoided, samples suspected of containing PASS material from the results of the field test will be submitted to a NATA accredited laboratory for analysis by the SPOCAS procedure. Criteria for selection of samples for laboratory testing are described in Section 6.1.3.
- The stockpile will be treated with an appropriate neutralising material, usually lime sand or crushed limestone at a rate calculated on the basis of results for SPOCAS testing of samples of soil, the Effective Neutralising Value (ENV) of the product (to be provided by the supplier) and a safety margin factor of 1.5.
- The effectiveness of the remedial procedures will be assessed by additional field testing. A second application of neutralising material may be required if the Action Criteria specified in Section 6.1.4 are exceeded.

7.2 GROUNDWATER

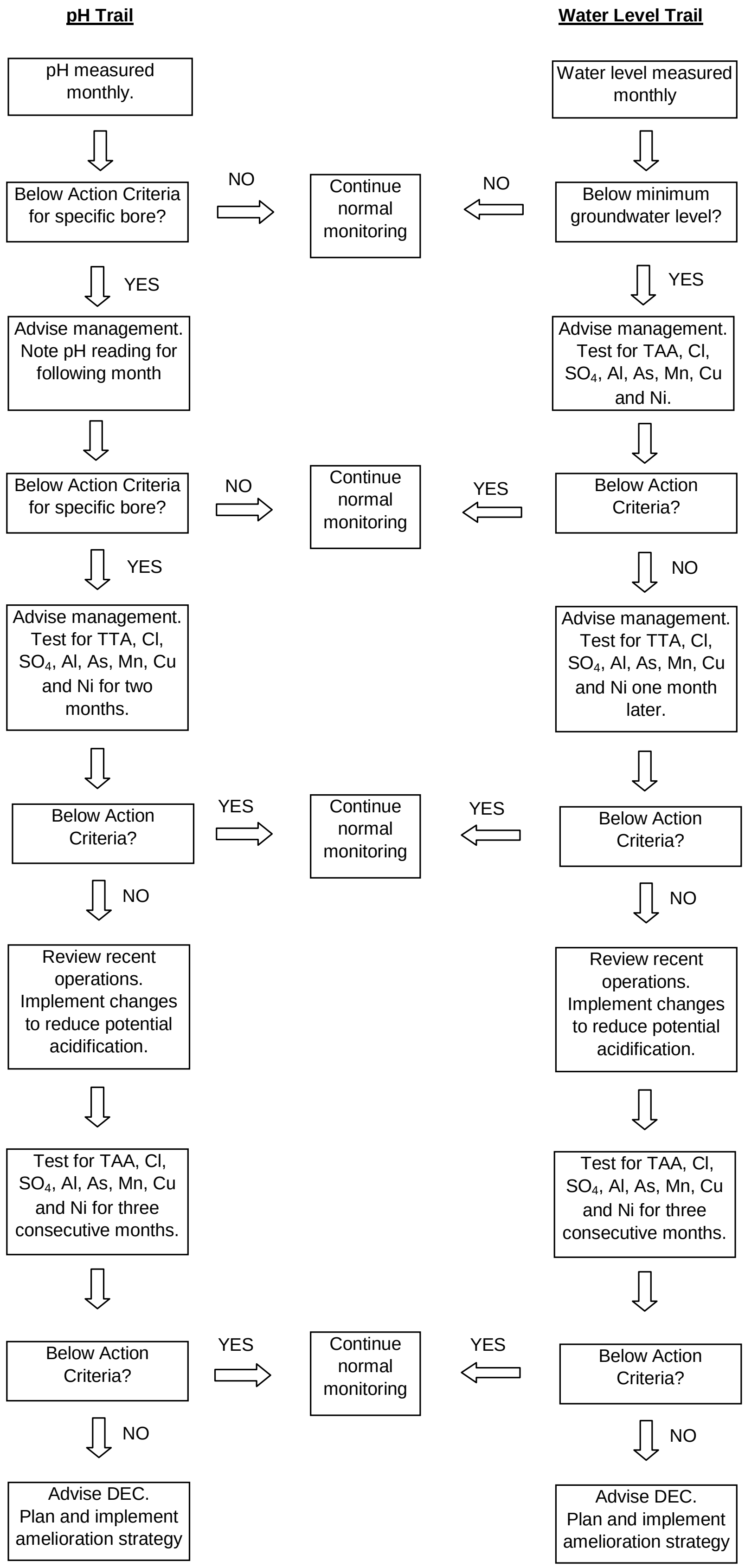
Sudden or systematic changes in groundwater depth or key water quality parameters such as pH, TAA, chloride to sulfate mass ratio and soluble metals or metalloids can provide an earlier indication of oxidation of PASS materials caused by mining operations.

An Action Trigger Flowchart for the early warning of excessive acidification of groundwater has been developed for KSS operations, as shown in Figure 9. The key steps in the process involve early identification of pH values and/or minimum groundwater levels below the Action Criteria values determined in Section 6.2.1.1 for specific monitoring bores, delineating the affected areas, determining if the acidity is localised or regional, reviewing recent changes to mining operations, implementing appropriate changes if the acidity is caused by mining operations and assessing the effectiveness of these changes.

Should these changes be ineffective for reducing acidification produced by mining operations, appropriate ameliorative strategies will be developed in consultation with DEC. Such strategies may include:

- Recovery and treatment of contaminated water by dosing with hydrated lime.
- Installing barriers to prevent transport of contaminated water.
- Altering mining and backfilling operation to minimise potential impacts.

Figure 9: Action Trigger Flowchart for Identification and Management of Groundwater Acidification



8. REVIEW AND REPORTING

The ASSMP will be reviewed annually and amended if necessary to ensure that it remains relevant, practical and effective.

All results for soil and groundwater monitoring undertaken in the year will be included in KSS's Annual Environmental Report (AER) for the DEC. The AER will also present the findings from any ASS related investigations resulting from exceedence of relevant trigger levels. The report will propose any amendments to the ASSMP.

Results of future field survey assessment in the next ten year stage of mining will be provided to DEC.

9. REFERENCES

Ahern C.R., Ahern M.R. and Powell B., 1998. *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland.* QASSIT, Department of Natural Resources, Resources Sciences Centre, Indooroopilly.

Barnesby, B.A. and Proulx-Nixon, M.E., 2000. Land resources from Harvey to Capel on the Swan Coastal Plain, Western Australia - Sheets 1 and 2. Land Resources Maps No. 23/1 and 23/2. Agriculture Western Australia.

Churchward, H.M. and McArthur, W.M., 1978. Landforms and Soils of the Darling System. In Atlas of Natural Resources of the Darling Region, Western Australia. Prepared for the Department of Conservation and Environment. Government Printer, Perth.

Department of Environment, August 2003. General Guidance on Managing Acid Sulfate Soils.

Department of Environment and Conservation Land and Water Quality Branch, 2006. Draft Identification and Investigation of Acid Sulfate Soils. Acid Sulfate Soils Guideline Series.

Department of Mines Geological Survey Branch, 1978. Geology and Mineral Resources of the Darling System. Atlas of Natural Resources, Darling System, Western Australia. Prepared for the Department of Conservation and Environment.

GHD, 2002. Groundwater Well Licence 60367, Groundwater Monitor Report July 2001–June 2002. Unpublished Report prepared for Kemerton Silica Sand Pty Ltd.

Martinick Bosch Sell Environmental Pty Ltd (MBS), 2007. Kemerton Silica Sand: Acid Sulfate Soil Assessment. Unpublished report for Kemerton Silica Sand.

McCullough, C. and Lund, M., 2008. Aquatic Macroinvertebrates in Seasonal and Rehabilitated Wetlands of the Kemerton Silica Sand Pty Ltd Project Area. Mine Water and Environment Research/Centre for Ecosystem Management Report No. 2008-16, Edith Cowan University, Perth, Australia. Unpublished report to Kemerton Silica Sand Pty Ltd.

Mulvey P.J., 1993. 'Pollution prevention and management of sulfidic clays and sands', in R Bush (ed.), *Proceedings of the National Conference on Acid Sulfate on Acid Sulfate Soils,* pp. 116–129, Cooloongatta, June 1993, NSW Department of Agriculture, Wollongbar, NSW.

Rockwater Pty Ltd, 2008. Kemerton Silica Sand Pty Ltd. Groundwater Monitoring Review. July 2005 to June 2008 (GWL 60367(2&3)). Unpublished report prepared for Kemerton Silica Sand Pty Ltd, September 2008.

Semeniuk, C.A., 1987. Wetlands of the Darling System-a Geomorphic Approach to Habitat Classification. J. Roy. Soc. West. Aust. **69**: 95-111.

Western Australian Planning Commission, November 2003. *Planning Bulletin No. 64. Acid Sulfate Soils.*

10. GLOSSARY OF TERMS

AASS	Actual Acid Sulfate Soils.
ANC	Acid Neutralising Capacity.
ASS	Acid Sulfate Soils.
EIL	Ecological Investigation Level.
NATA	National Association of Testing Authorities.
PASS	Potential Acid Sulfate Soils.
pH_F	pH of a soil paste measured under field conditions.
pH_{FOX}	pH of a soil paste measured in the field following reaction with hydrogen peroxide.
pH_{KCl}	pH of a soil paste in 1 M KCl measured in the laboratory.
SPOCAS	Suspension Peroxide Oxidation Combined Acidity and Sulfate method.
S_{POS}	Peroxide-oxidisable sulphur in soil samples.
TAA	Total Actual Acidity of soil samples.
TPA	Titratable Peroxide Acidity of soil samples.
TTA	Total Titratable Acidity of water samples.

MBS Environmental Report Distribution Record

Report Title: **Kemerton Silica Sand Project**
Acid Sulphate Soil Management Plan

Project Code: **KSSENV**

Name/Title	Company	Copy No.	Date	Authorised By
Doug Betts Senior Environmental Officer	DEC – EPA Service Unit	01	27/03/2009	David Allen
Mark Gell General Manager	Kemerton Silica Sand Pty Ltd	02	27/03/2009	David Allen
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Approval Signature:

APPENDICES

APPENDIX 1: KEMERTON SILICA SANDS PROJECT: ACID SULFATE SOILS ASSESSMENT MBS ENVIRONMENTAL, NOVEMBER 2007

KEMERTON SILICA SANDS PROJECT
ACID SULFATE SOILS ASSESSMENT

NOVEMBER 2007

PREPARED FOR

KEMERTON SILICA SANDS PTY LTD

BY

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Appendix 1: Acid Soil Test Results

1. INTRODUCTION

The Kemerton Silica Sands (KSS) property is freehold land owned by the proponent. Continuation of dredge mining at the KSS project area is proposed by extending the dredge pond in a generally westwards direction. Following rehabilitation, reformed dredge ponds will remain as lakes and ephemeral wetlands.

The KSS property is located in the Shire of Harvey on the Swan Coastal Plain in the southwest of Western Australia. The KSS property has been mapped on the WAPC (2003) Bulletin 64 maps as generally having moderate to low risk of Acid Sulfate Soil (ASS) occurring at depths of greater than three metres (Figure 1). However, also present are two areas listed as being high risk of ASS at less than three metres from the surface.

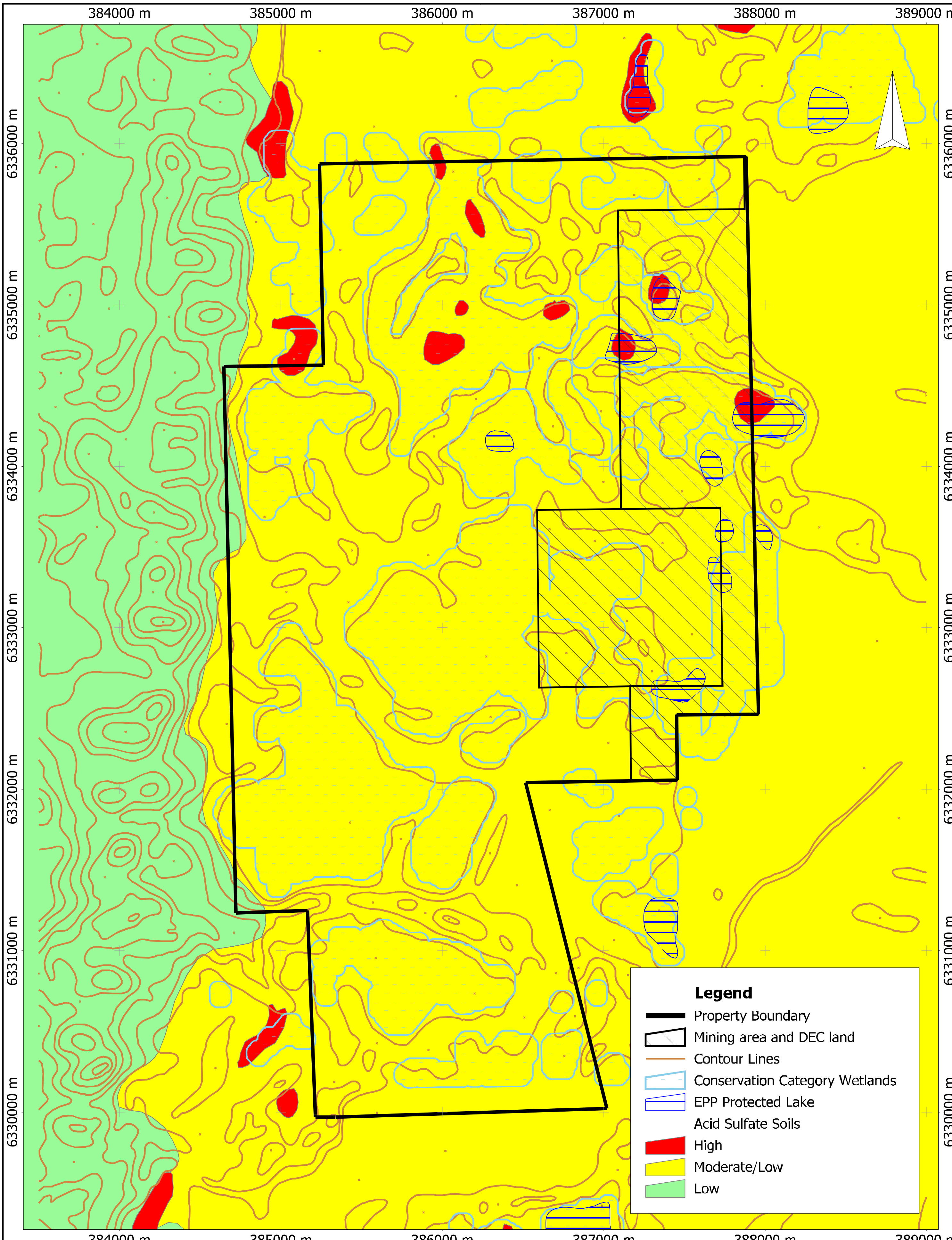
The Department of Environment (DoE) (2003) describes ASS as the common name given to naturally occurring soil or sediment containing iron sulfides over extensive low-lying areas under waterlogged (i.e. anaerobic) conditions. These soils may be found close to the natural ground level but may also be found at depth in the soil profile. When sulfides are exposed to air, oxidation takes place and sulfuric acid is produced where the soil's capacity to neutralise the acidity is exceeded.

In Western Australia, ASS are known to have formed in estuarine areas and coastal lowland areas such as mangroves, tidal flats, salt marshes and swamps, wetland areas, saline inland areas and near mining operations.

Particular areas of concern in Western Australia include:

- Estuarine, floodplain and wetland areas between Perth and Busselton, such as the Peel-Harvey estuarine system and the Vasse River area.
- The northern coastline, including the Pilbara and Kimberley coasts.
- The Scott River Plain, including Toby Inlet.
- Parts of the Wheatbelt where land salinisation has occurred.

The Environmental Protection Authority (EPA) objective is to maintain the integrity, ecological functions and environmental values of the soil and landform.



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Kemerton Silica Sands Pty Ltd

Acid Soils Survey

Figure 1

W:\Itochu_KSS\Maps2006\ASS.map 6/03/2007 Layout A4

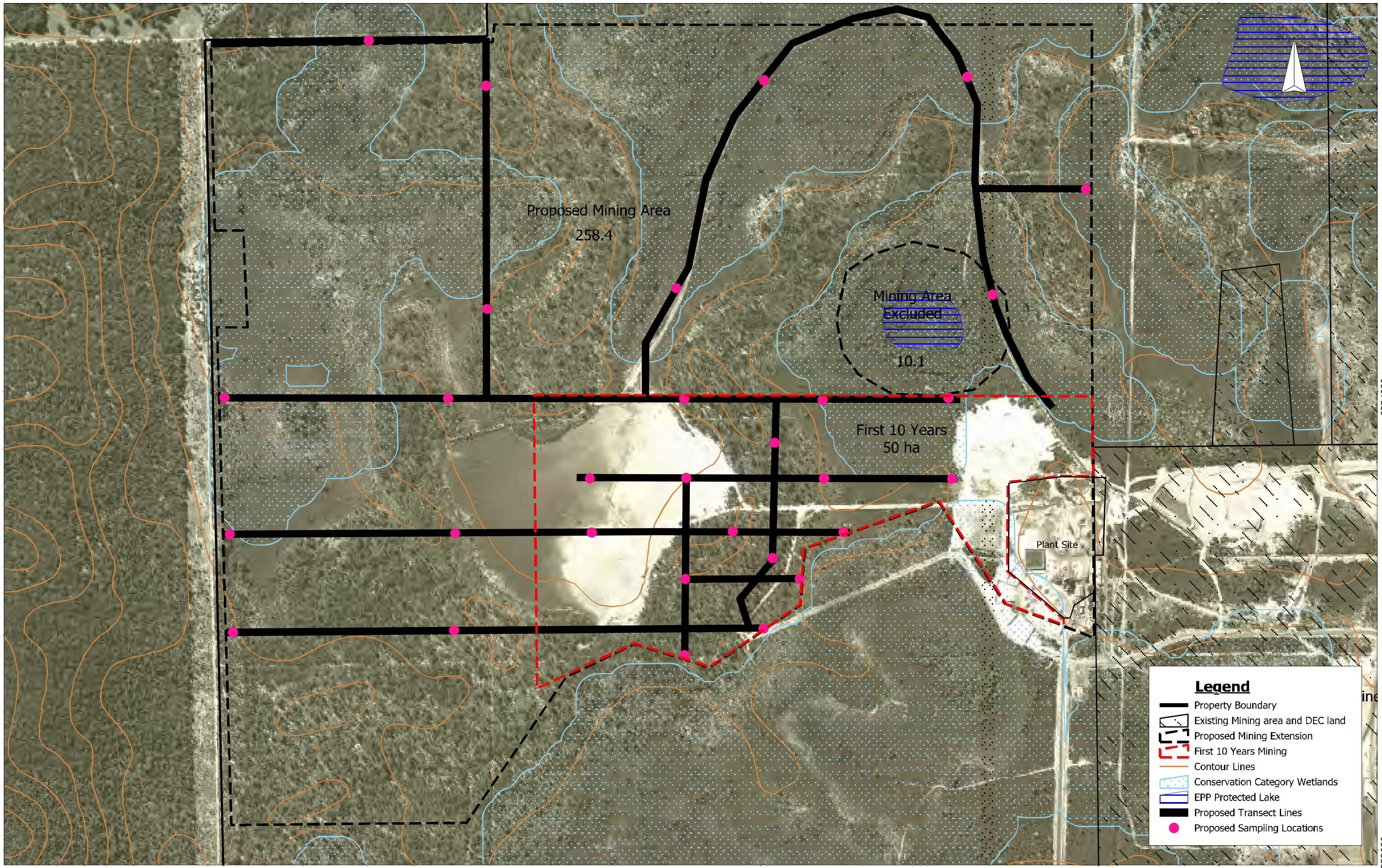
2. BASELINE ACID SOIL ASSESSMENT

Dredge mining operations have occurred for the last ten years on the property, to a depth of approximately 15 metres below the water table. Monitoring undertaken as part of environmental licence conditions has not shown any development of acidity in the dredge pond in the current area of operation, suggesting a very low risk of acid soils development. The dredge pond soils and the returned sand residues which are backfilled below the water table in the dredge pond are exposed to minimal free oxygen, further reducing the rate of any possible acidification. The proposal to expand extraction at the KSS property will continue to use the same dredge mining methods.

MBS liaised with DEC representatives on 3 August 2007, to determine the scope of soil assessment to be conducted over the mine site. Transects proposed for field survey are shown in Figure 2. Initially portions of transects would be sampled as part of the proposal assessment. This would provide an initial indication on the status of potential ASS within the extension areas. Further field survey programs over time would add to this knowledge base.

The field assessment comprised the following elements:

1. Sample from a transect alignment using existing drill lines and access tracks, to minimise the need for further clearing of native vegetation. Drill 30 holes to depths of up to 20 metres. Complete soil descriptions for each location.
2. In line with the low to moderate ASS risk ranking indicated for the mine extension area, sampling is to be undertaken at 250 metre spaced holes in the five to ten year mine area and at 500 metre intervals in future mine areas on transect lines as shown in Figure 2.
3. A reduced level of field assessment at one metre intervals is proposed. The soil profile in the subject area is well known. The existing mining operation dredges white siliceous Bassendean sand to 15 metres below the water table. Exploration drilling undertaken over the area confirms the same soil profile is present over the proposed mine extension area. It is considered the unstratified Bassendean soil profile does not exhibit complexities associated with other soil profiles, where different horizons can have significantly different properties, requiring a more intensive sampling at 0.5 metre layers.
4. The fine sand tailings area shown on Figure 2 is progressively being re-treated through the existing process plant. ASS sampling of this area will commence at approximately three metres below current surface level as the top material will be removed.
5. Conduct field pH (pH_F) and pH after oxidation (pH_{FOX}) testing of all soil samples as this provides an indication of the likelihood of ASS presence. Based on these results, a selection of samples showing the highest ASS field results would be submitted for laboratory analysis using the Suspension Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) analysis method. The SPOCAS method is a standardised set of procedures used in assessing the environmental impact of soils suspected of containing pyrite and other iron sulfides which might lead to an ASS problem if disturbed.



Environmental + Water Resource Consultants 4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale: 1:7500 Original Size: A3 Air Photo 2002 Datum: Australian Geocentric 1994 (GDA94) 0 500 m	Kemerton Silca Sands Pty Ltd	Proposed Acid Sulfate Soil Transects Figure 2

W:\Itochu_KSS\Maps 2007\ASS.map 6/06/2007 A3 mining Area

3. FIELD ASSESSMENT

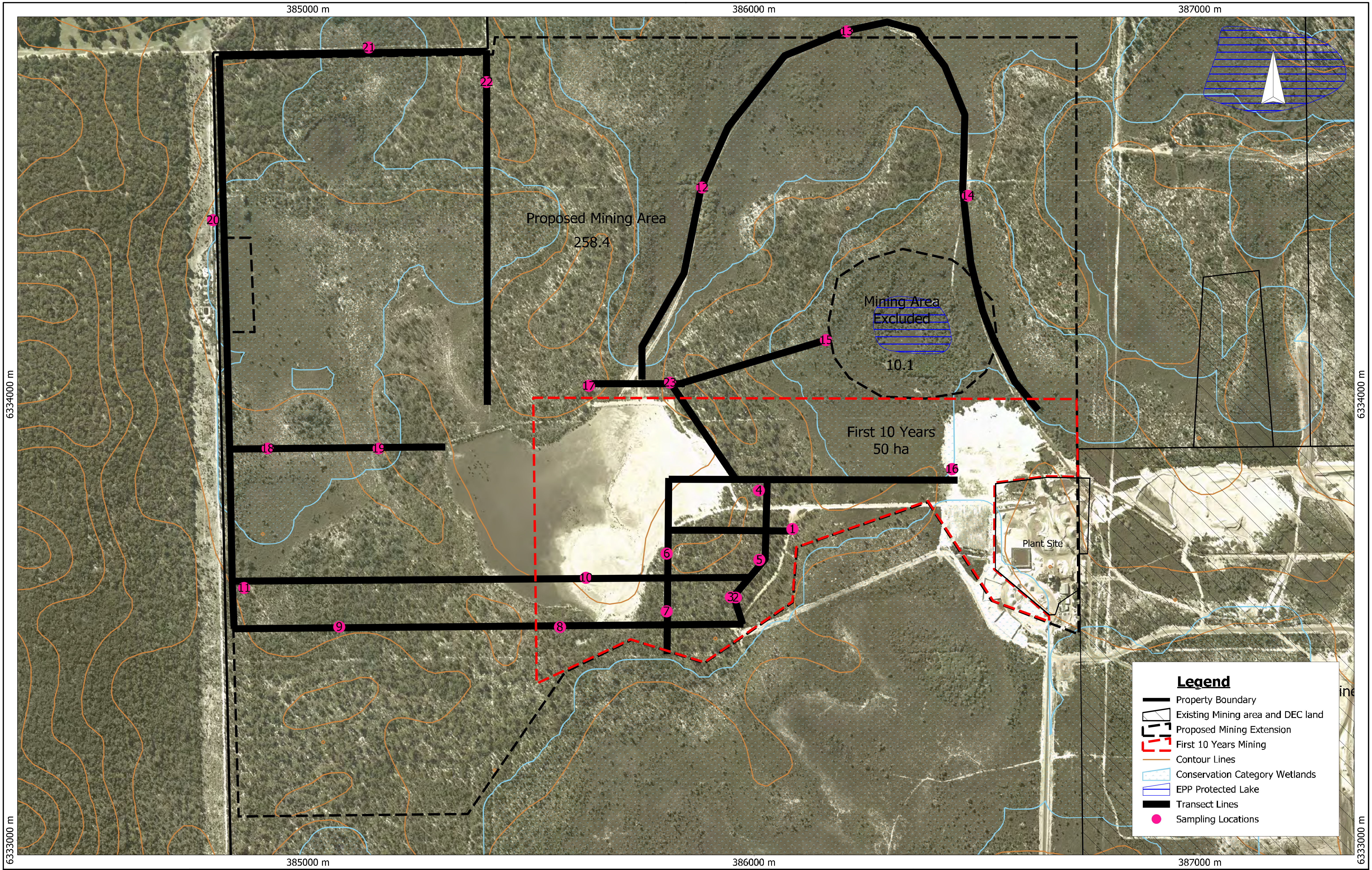
Testing was conducted from the 6 to the 8 August 2007. 23 holes were drilled to depths of up to 30 metres. Samples were taken at one metre intervals. Each one metre sample was placed into a labelled airtight bag, before being placed into a large polyweave bag for each hole. Soil profiles were described for each hole.

Nine holes were drilled within the five to ten year mine area at 250 metre spacing. The remaining holes were sampled at 500 metre intervals in the future mine area. The hole locations are shown in Figure 3. The majority of the fines and tailings area shown on Figure 3 was unable to be sampled as the area was too soft for access by the drill rig.

In the field, samples were stored in eskies in accordance with the DoE Identification and Investigation of ASS (October 2004). The samples were transferred to a deep freezer within four hours of collection and frozen.

Field pH (pH_F) and pH after oxidation (pH_{FOX}) testing of all soil samples was undertaken in the laboratory from the 13 to 15 August 2007. Based on these results, a selection of samples showing the highest ASS field results were submitted for laboratory analysis using the SPOCAS analysis method.

The samples were delivered to the Chemistry Centre (WA) for analysis in a frozen state.



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Kemerton Silca Sand Pty Ltd

Acid Sulfate Soil Sampling Locations

Figure 3

W:\Kemerton Silica Sand\Maps 2007\ASS.map 17/08/2007 A3 mining Area

4. LABORATORY ANALYSIS AND REPORT

4.1 TEST METHODS

The test methods of the Acid Sulfate Soils Laboratory Methods Guidelines (2004) manual were used in this work, specifically Method Code 23 – SPOCAS formed the basis of this work.

The SPOCAS method is a standardised set of procedures useful in assessing the environmental impact of soils suspected of containing pyrite and other iron sulfides which might lead to an ASS problem if disturbed.

After drying at 80°C for a minimum of 48 hours, the dry sample is then sieved through a two millimetre sieve and the greater than two millimetre fraction (which may contain lumps of limestone and shell fragments) is discarded. The sub sample material is then subjected to chemical tests. All results are reported on a dry weight basis.

4.2 SPOCAS METHOD

Step 1: Determination of Potassium Chloride Extractable Sulfur (S_{KCl}), and Total Actual Acidity (TAA)

In this procedure the sample is extracted with potassium chloride solution. The extraction with potassium chloride is used to determine soluble and absorbed sulfur (non-sulfidic sulfur) and the TAA of the sample.

The pH, acidity, and sulfur of the resultant solution are reported as pH_{KCl}, TAA_{KCl}, and S_{KCl} respectively.

Step 2: Determination of the Peroxide Oxidation Sulfur (S_P) and Titratable Peroxide Acidity (TPA)

This step involves oxidation of the sample with hydrogen peroxide to produce maximum acidity from any reduced sulfidic material. The sulfur content (S_P%), the TPA, and pH (pH_{OX}) of the oxidised solution are determined. S_P% will include the soluble, absorbed, and sulfide, sulfur species.

Step 3: Determination of Retained Acidity

Existing acidity in ASS includes 'actual' acidity (TAA) and 'retained' acidity (acidity stored in largely insoluble iron and aluminium sulfate minerals). A dilute hydrochloric acid (HCl) extraction performed on the washed soil residue after peroxide digestion will give S_{HCl}. The net acid soluble sulfur (S_{NAS}) due to sparingly soluble sulfate containing compounds such as jarosite, can be calculated by subtracting S_{KCl} from S_{HCl}. The equivalent acidity is expressed as a-S_{NAS}. For soil samples with pH_{KCl}<4.5 the S_{NAS} must be determined.

Step 4: Determination of the excess Acid Neutralising Capacity (ANC_E)

This determination is optional depending on the peroxide solution pH.

If the solution pH after the peroxide step is >6.5, the material may have an acid neutralization capacity. The fine grinding of the sample for analysis will lead to an over estimation of the effective acid neutralising capacity and an appropriate safety factor must be applied.

Step 5: Peroxide Oxidisable Sulfur (S_{POS})

This step involves calculating the differences between the extracts from Step 2 and Step 1. The peroxide oxidisable sulfur is used to predict the potential acid risk from non-oxidised sulfur compounds:

Peroxide oxidisable sulfur: $S_{POS} = (S_P - S_{KCl})$ %

If it assumed that all the S_{POS} is a result of pyrite oxidation then S_{POS} can be converted to acidity units:

S_{POS} (%S) x 624 = equivalent mol H^+/t

4.3 ACID BASE ACCOUNTING

The acid base accounting approach is used to predict net acidity from the oxidation of sulfidic material. The SPOCAS method is in essence a self contained ABA. The TPA result represents a measure of the net acidity, effectively equivalent to the sum of the soil's potential sulfidic activity and TAA less any neutralising capacity of the sample. Where the pH_{KCl} is <4.5 then the residual acid soluble sulfur (S_{RAS}) component of SPOCAS should be done, since the TPA does not measure retained acidity. In soils that are self neutralising (ie TPA=0), then the HCl titration step in SPOCAS allows calculation of the excess ANC_E.

4.4 INTERPRETATION OF SPOCAS TESTWORK

Interpretation of results from SPOCAS test methods involve comparison of the test results with published action criteria. Table 1 shows the NSW Acid Sulfate Soils Management Advisory Committee (ASSMAC) published Action Criteria.

Table 1: NSW ASSMAC Action Criteria

Type of Material		Action Criteria, <1,000 tonnes		Action Criteria, >1,000 tonnes	
Texture	Approx Clay Content (%<0.002 mm)	Sulfur Trail S_{POS} %	Acid Trail TPA mole H^+/t	Sulfur Trail S_{POS} %	Acid Trail TPA mole H^+/t
Coarse eg sands	5	0.03	18	0.03	18
Medium eg loams/light clays	5 – 40	0.06	36	0.03	18
Fine clays/silts	40	0.1	62	0.03	18

According to the NSW ASSMAC, exceedance of the action criteria indicates risk of an ASS issue and the need for an Acid Sulfate Soil Management Plan (ASSMP) with development approval.

4.5 RESULTS

The rate of the reaction generally indicates the level of sulfides present, but depends also on texture and other soil constituents. A soil containing very little sulfides may only rate a 'X' however a soil containing high levels of sulfides is more likely to rate a 'XXXX' or 'V' although there are exceptions. Other factors including manganese and organic acids may trigger a 'XXXX' or 'V' reaction. Table 2 indicates the reaction scale for PH_{FOX} tests.

Table 2: Soil Reaction Rating Scale from the PH_{FOX} test

Reaction Scale	Rate of Reaction
X	Slight effervescence
XX	Moderate Reaction
XXX	Vigorous Reaction
XXXX OR 'V'	Volcano: very vigorous reaction, gas evolution and heat generation commonly >80°C

Source: Hey *et al.* (2000)

Complete results of the field sampling and the laboratory testing are provided in Appendix 1. Table 3 provides a summary of these results, listing those samples laboratory tested and comparing them with the field assessment results.

The field and laboratory testing undertaken to date indicate the following:

- Field assessment shows the more highly reactive soils, indicated by the difference between the pH_F and pH_{FOX} being greater than four, at generally below 15 metres. This would indicate the soil profile below the base of the dredge pond (which will remain undisturbed and under water) has a greater potential for acid soil generation than the mining profile (the top 15 metres).
- Exceedance of the 'action criteria' for sandy soils is a TPA level greater than 18 Moles H^+/tonne. Table 3 shows that many of the samples selected for laboratory analysis exceed the action criteria. This confirms there are soil locations within the proposed mine profile which are Potentially Acid Forming (PAF). However, they are not universally below 15 metres and are not perfectly correlated with high field measurement results.
- A number of samples recorded extremely high ANC values. Taken in context with other locations which are PAF, the dredge pond may have a significant buffering capacity against acid formation. This is consistent with observation and monitoring results of the existing dredge pond with ten years of active mining showing no appreciable acidification over that time.
- None of the samples tested recorded pH_{KCl} <4.5, indicating that additional testwork is not required to measure retained acidity.

Table 3: Acid Soils Results

Hole Number	Sample Depth (m)	Field Results				Laboratory Results				
		pH_F	Peroxide Reaction	pH_{FOX}	pH_F-pH_{FOX} range >4	pH_{KCl}	pH_{OX}	ANC (Moles H^+/tonne)	TAA (Moles H^+/tonne)	TPA (Moles H^+/tonne)
4	5	8.49	-	5.60		7.7	6.1	<2	<2	<2
	12	8.12	-	5.30		6.3	4	<2	<2	5
	18	7.97	XX	1.53	6.44	6.2	2.8	<2	<2	25
	21	8.15	XXXX	1.62	6.53	5.8	2.6	<2	<2	48
	26	8.52	X	6.14		9.8	8.2	1372	<2	<2
10	3	7.68	-	5.07		9.6	7.1	33	<2	<2
	11	5.93	-	4.53		5.5	3.8	<2	7	27
	16	5.98	-	2.80		5.5	3	<2	5	40
	23	6.20	XXXX	1.47	4.73	5.4	2.3	<2	4	101
	29	6.57	XXXX	1.29	5.28	5.5	2.2	<2	5	369
15	5	6.53	-	5.48		6.4	4	<2	<2	0
	12	6.83	XXX	2.49	4.34	6.8	2.5	<2	<2	59
	17	7.33	XXXX	1.91	5.42	6.7	2.8	<2	<2	43
	22	8.51	-	6.65		9.7	8	2168	<2	<2
	26	8.49	X	6.24		9.5	8.3	2170	<2	<2
20	3	4.99	X	1.91		9.4	5.7	<2	<2	<2
	7	6.82	-	4.94		5.1	3.2	<2	28	142
	12	7.02	-	4.21		6.3	3.9	<2	<2	11
	18	7.28	XXX	1.91	5.37	5.5	2.5	<2	<2	74
	25	7.68	XXXX	1.51	6.17	5.1	2.4	<2	5	148
	27	7.94	X	1.92	6.02	5.4	2.4	<2	3	81

5. CONCLUSION

The results of the initial sampling indicate that most of the potential high acid generating soils are below the base of the final dredge pond depth (15 metres), will not be disturbed and will remain below the water table.

There are some high potential acid generating soils within the mine profile of the proposed mine extension area. There are also high acid neutralising soils, providing a significant in situ buffering capacity for the dredge pond environment.

An ASSMP will be prepared as a component of the project assessment to address possible acid generation issues.

Monitoring is recommended to detect any changes that may occur as the project is implemented.

Sampling of soils in advance of mining to quantify PAF will be incorporated into the ASSMP.

6. REFERENCES

Acid Sulfate Soils Management Advisory Committee (ASSMAC, NSW). 1998. Acid Sulfate Soils Laboratory Methods Guidelines manual.

Acid Sulfate Soils Laboratory Methods Guidelines. 2004. Department of Natural Resources and Mines, Queensland, June 2004.

Hey, K.M., Ahern, C.R. and Watling, K.M. 2000. Using Chemical Field Tests to Identify Acid Sulfate Soils Likelihood. Acid Sulfate Soils: Environmental Issues, Assessment and Management, Technical Papers, Brisbane, June 2000. Department of Natural Resources.

WA Department of Environment. 2003. General Guidance on Managing Acid Sulfate Soils.

WA Department of Environment. 2004. Identification and Investigation of Acid Sulfate Soils. Acid Sulfate Soils Guideline Series.

Western Australian Planning Commission. 2003. Planning Bulletin No. 64: Acid Sulfate Soils.

APPENDICES

APPENDIX 1:
ACID SOIL TEST RESULTS

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
Hole 1												
15/08/2007	1	1	Brown sand	6.83	-	5.33						
15/08/2007	1	2	Brown sand	6.25	-	4.35						
15/08/2007	1	3	Brown sand	4.32	-	3.80						
15/08/2007	1	4	Coffee rock	4.94	-	4.12						
15/08/2007	1	5	Water table, coffey rock	5.09	-	3.88						
15/08/2007	1	6	Coffee rock	5.28	-	4.06						
15/08/2007	1	7	White sand	5.27	-	4.06						
15/08/2007	1	8	White sand	5.45	-	4.57						
15/08/2007	1	9	Light brown fine sand	5.35	-	4.85						
15/08/2007	1	10	Brown sand	5.70	-	4.90						
15/08/2007	1	11	Brown/grey sand	5.82	-	5.11						
15/08/2007	1	12	Brown/grey sand	5.92	-	5.20						
15/08/2007	1	13	Brown/grey sand	5.91	-	5.52						
15/08/2007	1	14	Brown/grey sand	6.13	-	4.24						
15/08/2007	1	15	Grey fine sand	6.52	X	2.64						
15/08/2007	1	16	Grey fine sand	6.68	X	1.80	4.88					
15/08/2007	1	17	Grey fine sand	6.68	XX	1.96	4.72					
15/08/2007	1	18	Grey fine sand	7.76	X	5.82						
15/08/2007	1	19	Grey fine sand	6.98	X	3.96						
15/08/2007	1	20	Dark grey sand	7.63	XX	4.38						
15/08/2007	1	21	Dark grey sand	7.98	-	6.76						
15/08/2007	1	22	Dark grey sand	8.62	-	6.48						
15/08/2007	1	23	Dark grey sand	8.71	-	6.86						
15/08/2007	1	24	Dark grey sand	8.15	-	6.67						
15/08/2007	1	25	Dark grey sand	8.60	-	6.83						
15/08/2007	1	26	Shells	8.37	-	6.81						
15/08/2007	1	27	Dark grey coarse sand	8.30	-	6.20						
15/08/2007	1	28	Dark grey coarse sand	8.57	-	6.24						
15/08/2007	1	29	Dark grey coarse sand	8.54	X	6.44						
Hole 2												
15/08/2007	2	1	Grey sand	6.48	-	5.69						
15/08/2007	2	2	Grey sand	6.79	X	6.26						
15/08/2007	2	3	Dark brown sand	6.64	-	5.45						
15/08/2007	2	4	Dark brown sand	6.67	X	5.51						
15/08/2007	2	5	Dark brown sand	6.62	-	5.38						
15/08/2007	2	6	Dark brown sand	6.26	-	5.41						
15/08/2007	2	7	Dark brown sand, water table	6.36	-	5.81						
15/08/2007	2	8	Brown sand	6.58	-	5.88						
15/08/2007	2	9	Finer, light brown sand	6.74	-	5.99						
15/08/2007	2	10	Finer, light brown sand; lots of wa	6.62	-	6.31						
15/08/2007	2	11	Finer, light brown sand	6.40	-	5.48						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	2	12	Brown/grey sand	6.32	-	5.52						
15/08/2007	2	13	Brown/grey sand	5.95	-	4.93						
15/08/2007	2	14	Brown/grey sand, slightly coarser	6.15	X	3.85						
15/08/2007	2	15	Brown/grey sand, slightly coarser	6.02	-	3.63						
15/08/2007	2	16	Brown/grey sand, slightly coarser	5.96	X	2.10						
15/08/2007	2	17	Fine grey sand	5.94	XXXX	1.40	4.54					
15/08/2007	2	18	Fine grey sand	6.22	XXXX	1.68	4.54					
15/08/2007	2	19	Fine grey sand	6.35	XXX	1.66	4.69					
15/08/2007	2	20	Dark grey sand	6.17	X	1.40	4.77					
15/08/2007	2	21	Dark grey sand	6.65	XX	2.19	4.46					
15/08/2007	2	22	Dark grey sand	6.37	XXXX	1.39	4.98					
15/08/2007	2	23	Fine dark grey sand	6.70	X	5.42						
15/08/2007	2	24	Fine dark grey sand	7.56	-	5.90						
15/08/2007	2	25	Fine dark grey sand	7.73	-	6.13						
15/08/2007	2	26	Fine dark grey sand	7.63	-	5.97						
15/08/2007	2	27	Very coarse dark grey sand	7.71	X	5.77						
15/08/2007	2	28	Very coarse dark grey sand	7.69	X	5.80						
15/08/2007	2	29	Very coarse dark grey sand, shells	7.96	-	6.17						
Hole 3												
15/08/2007	3	1	Red/ brown sand	7.39	X	6.28						
15/08/2007	3	2	Red/ brown sand	5.93	-	5.34						
15/08/2007	3	3	Red/ brown sand	5.38	-	5.04						
15/08/2007	3	4	Coffee rock	5.47	-	4.37						
15/08/2007	3	5	Coffee rock	6.42	-	5.08						
15/08/2007	3	6	Coffee rock	6.27	-	5.04						
15/08/2007	3	7	Water table, coffee rock	6.44	-	5.95						
15/08/2007	3	8	Coffee rock	6.86	-	5.65						
15/08/2007	3	9	Light brown sand	6.55	-	5.68						
15/08/2007	3	10	Light brown sand	6.25	-	3.64						
15/08/2007	3	11	Light brown sand	6.68	-	6.01						
15/08/2007	3	12	Light grey sand	6.81	-	3.72						
15/08/2007	3	13	Light grey sand	7.14	-	6.23						
15/08/2007	3	14	Light grey sand	7.06	-	5.51						
15/08/2007	3	15	Light grey sand	7.33	-	4.23						
15/08/2007	3	16	Fine grey sand	7.30	X	1.83	5.47					
15/08/2007	3	17	Fine grey sand	7.30	XXXX	1.96	5.34					
15/08/2007	3	18	Fine grey sand	8.81	XXX	2.00	6.81					
15/08/2007	3	19	Fine grey sand	9.37	-	6.45						
15/08/2007	3	20	Coarse Grey sand, very wet	9.24	-	7.01						
15/08/2007	3	21	Coarse Grey sand, very wet	9.14	-	6.92						
15/08/2007	3	22	Coarse Grey sand, very wet	9.05	-	7.03						
15/08/2007	3	23	Coarse Grey sand, very wet	8.84	-	7.17						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	3	24	Coarse Grey sand, very wet	9.56	-	7.15						
15/08/2007	3	25	Coarse Grey sand, very wet	9.39	-	6.66						
15/08/2007	3	26	Coarse Grey sand, very wet; some	9.88	X	6.49						
15/08/2007	3	27	Coarse dark grey sand/shells	9.75	X	6.57						
15/08/2007	3	28	Coarse dark grey sand/shells	10.07	X	7.00						
15/08/2007	3	29	Coarse dark grey sand/shells	10.93	X	6.59	4.34					
Hole 4												
15/08/2007	4	1	Dark grey sand	7.64	-	5.80						
15/08/2007	4	2	Dark grey sand	8.09	-	5.67						
15/08/2007	4	3	Ligter grey sand	8.41	-	5.76						
15/08/2007	4	4	Yellow sand	8.47	-	5.66						
15/08/2007	4	5	Yellow sand	8.49	-	5.60		7.7	6.1	<2	<2	<2
15/08/2007	4	6	White sand	8.49	-	5.70						
15/08/2007	4	7	Light yellow sand	8.29	-	6.04						
15/08/2007	4	8	Light yellow sand	8.11	-	6.06						
15/08/2007	4	9	Water table	8.13	-	6.05						
15/08/2007	4	10	Brown sand	8.08	-	5.90						
15/08/2007	4	11	Brown sand	8.20	-	5.85						
15/08/2007	4	12	Brown sand	8.12	-	5.30		6.3	4	<2	<2	5
15/08/2007	4	13	Dark brown sand	8.14	-	5.59						
15/08/2007	4	14	Dark brown sand	7.71	-	3.36	4.35					
15/08/2007	4	15	Dark brown sand	7.81	-	4.23						
15/08/2007	4	16	Coarse dark brown sand	7.70	-	3.36	4.34					
15/08/2007	4	17	Coarse dark brown sand	7.86	-	3.73	4.13					
15/08/2007	4	18	Coarse white/grey sand	7.97	XX	1.53	6.44	6.2	2.8	<2	<2	25
15/08/2007	4	19	Coarse white/grey sand	7.89	X	2.06	5.83					
15/08/2007	4	20	Coarse white/grey sand	7.92	XXX	1.62	6.30					
15/08/2007	4	21	Coarse white/grey sand	8.15	XXXX	1.62	6.53	5.8	2.6	<2	<2	48
15/08/2007	4	22	Coarse white/grey sand	7.73	XXXX	1.53	6.20					
15/08/2007	4	23	Coarse white/grey sand	7.65	X	5.73						
15/08/2007	4	24	Very wet, fine grey sand	7.91	X	6.44						
15/08/2007	4	25	Dark grey coarse sand	8.14	X	5.92						
15/08/2007	4	26	Dark grey coarse sand	8.52	X	6.14		9.8	8.2	1372	<2	<2
15/08/2007	4	27	Dark grey coarse sand	8.32	X	6.55						
15/08/2007	4	28	Dark grey coarse sand	8.21	X	6.22						
15/08/2007	4	29	Dark grey coarse sand	8.36	X	6.36						
15/08/2007	4	30	Rocks/shells, very coarse grey sand	8.65	X	6.07						
15/08/2007	4	31	Rocks/shells, very coarse grey sand	8.64	X	6.07						
15/08/2007	4	32	Rocks/shells, very coarse grey sand	8.84	X	6.01						
Hole 5												
13/08/2007	5	1	Light brown sand	6.88	X	5.34						
13/08/2007	5	2	Light brown sand	6.78	X	5.17						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
13/08/2007	5	3	Light brown sand	6.57	X	5.05						
13/08/2007	5	4	Light brown sand	6.46	-	4.47						
13/08/2007	5	5	Light brown sand	5.59	-	4.37						
13/08/2007	5	6	Dark brown sand	5.58	-	4.13						
13/08/2007	5	7	Dark brown sand	5.47	-	4.20						
13/08/2007	5	8	Dark brown sand; water table	5.54	-	4.10						
13/08/2007	5	9	Dark brown sand	5.89	-	4.56						
13/08/2007	5	10	Dark brown sand	6.16	-	4.54						
13/08/2007	5	11	Light brown sand	6.62	-	4.89						
13/08/2007	5	12	Light brown/grey sand	7.32	-	5.15						
13/08/2007	5	13	Light brown/grey/white sand	7.75	-	5.82						
13/08/2007	5	14	Light brown/grey/white sand	7.34	-	5.05						
13/08/2007	5	15	Brown sand	7.33	-	2.92	4.41					
13/08/2007	5	16	Brown/grey sand	7.96	-	1.99	5.97					
13/08/2007	5	17	Brown/grey sand	7.66	X	1.85	5.81					
13/08/2007	5	18	Dark grey sand	7.85	XXX	2.21	5.64					
13/08/2007	5	19	Dark grey sand	7.62	XX	2.65	4.97					
13/08/2007	5	20	Light grey sand	7.48	X	1.99	5.49					
13/08/2007	5	21	Light grey sand	7.36	XXXX	1.78	5.58					
13/08/2007	5	22	Very wet, dark grey sand	8.20	XXX	6.22						
13/08/2007	5	23	Very wet, dark grey sand	8.76	-	6.19						
13/08/2007	5	24	Very wet, dark grey sand; few shel	8.84	-	6.32						
13/08/2007	5	25	Coarse dark grey sand/shells	8.45	X	6.26						
13/08/2007	5	26	Fine grey sand	8.73	X	6.47						
13/08/2007	5	27	Fine grey sand	8.50	-	6.58						
13/08/2007	5	28	Coarse dark grey sand/shells	8.54	X	6.08						
13/08/2007	5	29	Grey clay	8.34	XX	6.29						
Hole 6												
13/08/2007	6	1	Fine grey sand	6.71	-	5.70						
13/08/2007	6	2	Fine yellow sand	6.85	-	5.60						
13/08/2007	6	3	Fine yellow sand	6.00	-	4.81						
13/08/2007	6	4	Fine dark yellow sand	5.57	-	4.08						
13/08/2007	6	5	Fine dark yellow sand	5.77	-	5.16						
13/08/2007	6	6	Fine lighter yellow sand	5.69	-	5.47						
13/08/2007	6	7	Fine pale brown snad	5.51	-	4.13						
13/08/2007	6	8	Rfine brown sand	5.49	-	4.20						
13/08/2007	6	9	Fine dark brown sand	5.67	-	4.75						
13/08/2007	6	10	Water table	5.69	-	5.20						
13/08/2007	6	11	Fine dark brown sand	5.40	-	4.86						
13/08/2007	6	12	Fine dark brown sand	5.63	-	4.80						
13/08/2007	6	13	Fine dark brown sand	5.56	-	4.74						
13/08/2007	6	14	Fine dark brown sand	5.58	-	3.21						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
13/08/2007	6	15	Fine dark brown sand	5.50	-	3.27						
13/08/2007	6	16	Fine dark brown sand	5.81	-	4.52						
13/08/2007	6	17	Fine light brown sand	4.76	-	4.76						
13/08/2007	6	18	Fine light brown sand	5.93	-	5.31						
13/08/2007	6	19	Fine light brown sand	6.07	-	5.20						
13/08/2007	6	20	Fine light brown sand	5.85	-	3.54						
13/08/2007	6	21	Fine light brown sand	5.86	-	3.74						
13/08/2007	6	22	Fine light grey sand	5.70	-	2.49						
13/08/2007	6	23	Coarse grey sand	5.58	-	1.93						
13/08/2007	6	24	Coarse grey sand	5.92	XXXX	1.36	4.56					
13/08/2007	6	25	Light grey coarse sand	6.47	XX	1.70	4.77					
13/08/2007	6	26	Light grey coarse sand	6.70	XX	1.80	4.90					
13/08/2007	6	27	Some shells	7.16	X	5.39						
13/08/2007	6	28	Light grey coarse sand	7.31	X	6.01						
13/08/2007	6	29	Light grey coarse sand	8.03	X	6.19						
13/08/2007	6	30	Light grey coarse sand	8.62	X	6.13						
13/08/2007	6	31	Very coarse grey sand/shells	8.89	X	5.80						
13/08/2007	6	32	Limestone	8.84	X	5.98						
Hole 7												
13/08/2007	7	1	Brown sand	7.27	X	4.93						
13/08/2007	7	2	Fine light brown sand	7.03	X	5.02						
13/08/2007	7	3	Fine light brown sand	5.28	X	4.31						
13/08/2007	7	4	Fine brwon sand	4.89	X	3.75						
13/08/2007	7	5	Fine brwon sand	5.10	-	3.82						
13/08/2007	7	6	Fine yellow/brown sand	5.28	-	3.53						
13/08/2007	7	7	water table	5.40	-	3.88						
13/08/2007	7	8	Fine yellow/brown sand	5.63	-	4.57						
13/08/2007	7	9	Fine yellow/brown sand	5.49	-	4.38						
13/08/2007	7	10	Fine yellow/brown sand	5.78	-	4.86						
13/08/2007	7	11	Fine yellow/brown sand	5.66	-	4.59						
13/08/2007	7	12	Fine yellow/brown sand	5.78	-	3.97						
13/08/2007	7	13	Fine yellow/brown sand	5.53	-	3.63						
13/08/2007	7	14	Fine yellow/brown sand	5.68	-	3.24						
13/08/2007	7	15	Fine yellow/brown sand	5.75	X	2.70						
13/08/2007	7	16	Fine light brown/grey sand	5.99	X	4.63						
13/08/2007	7	17	Fine light brown/grey sand	6.08	X	2.07	4.01					
13/08/2007	7	18	Fine light brown/grey sand	6.15	X	1.88	4.27					
13/08/2007	7	19	Slightly darker fine brown/grey sa	6.36	X	1.85	4.51					
13/08/2007	7	20	Slightly darker fine brown/grey sa	6.42	X	1.55	4.87					
13/08/2007	7	21	Fine grey sand	6.59	X	1.64	4.95					
13/08/2007	7	22	Fine dark grey sand	6.64	X	1.70	4.94					
13/08/2007	7	23	Fine dark grey sand	6.57	XXXX	1.49	5.08					

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
13/08/2007	7	24	Fine dark grey sand	6.45	XXXX	1.41	5.04					
13/08/2007	7	25	Fine dark grey sand	6.70	XXX	1.73	4.97					
13/08/2007	7	26	Fine dark grey sand	6.74	XXX	1.70	5.04					
13/08/2007	7	27	Slightly coarse dark grey sand	6.64	XXX	1.64	5.00					
13/08/2007	7	28	Few shells	6.54	XXX	1.60	4.94					
13/08/2007	7	29	Lots of shells/coarse sand	7.26	XXX	5.71						
Hole 8												
15/08/2007	8	1	Fine yellow sand	6.84	X	5.45						
15/08/2007	8	2	Fine yellow sand	6.83	X	5.18						
15/08/2007	8	3	Fine yellow sand	6.86	X	5.65						
15/08/2007	8	4	Fine yellow sand	6.85	X	5.58						
15/08/2007	8	5	Light yellow sand	6.94	X	5.46						
15/08/2007	8	6	Light brown sand	6.56	-	4.26						
15/08/2007	8	7	Light brown sand	6.79	-	4.72						
15/08/2007	8	8	Light brown sand	6.68	-	4.47						
15/08/2007	8	9	Water table	6.50	-	5.18						
15/08/2007	8	10	Light brown sand	6.72	-	4.48						
15/08/2007	8	11	Fine brown sand	6.29	-	4.54						
15/08/2007	8	12	Fine brown sand	6.43	-	5.16						
15/08/2007	8	13	Fine brown sand	6.56	-	5.07						
15/08/2007	8	14	Fine brown sand	6.61	-	2.53	4.08					
15/08/2007	8	15	Fine brown sand	6.61	-	4.80						
15/08/2007	8	16	Fine brown sand	6.92	-	4.72						
15/08/2007	8	17	Fine brown sand	6.44	-	2.90						
15/08/2007	8	18	Fine brown sand	6.31	-	4.41						
15/08/2007	8	19	Fine brown sand	6.74	-	4.78						
15/08/2007	8	20	Fine brown sand	6.17	X	2.74						
15/08/2007	8	21	Fine brown sand	6.80	X	5.58						
15/08/2007	8	22	Fine brown sand	6.77	XX	1.77	5.00					
15/08/2007	8	23	Slightly coarse borwn sand	6.92	X	2.70	4.22					
15/08/2007	8	24	Slightly coarse borwn sand	7.06	X	3.48						
15/08/2007	8	25	Slightly coarse borwn sand	7.48	X	4.73						
15/08/2007	8	26	Slightly coarse borwn sand	8.83	X	6.37						
15/08/2007	8	27	Coarse grey sand some shells	8.58	X	5.97						
15/08/2007	8	28	Dark grey coarse sand	9.04	XX	6.26						
15/08/2007	8	29	Dark grey coarse sand	8.35	X	5.85						
15/08/2007	8	30	Shells	8.85	X	6.36						
Hole 9												
15/08/2007	9	1	Fine white sand	5.54	X	5.19						
15/08/2007	9	2	Fine brown snad	6.03	-	5.70						
15/08/2007	9	3	Fine light brown/grey sand	6.73	-	5.26						
15/08/2007	9	4	Fine light brown/grey sand	5.24	-	5.55						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	9	5	Fine brown sand	5.88	-	4.61						
15/08/2007	9	6	Fine darker brown sand	5.48	X	5.07						
15/08/2007	9	7	Water table	5.77	-	5.04						
15/08/2007	9	8	Fine darker brown sand	-	-	-						
15/08/2007	9	9	Fine darker brown sand	-	-	-						
15/08/2007	9	10	Fine darker brown sand	5.22	-	5.44						
15/08/2007	9	11	Fine darker brown sand	5.84	-	5.01						
15/08/2007	9	12	Fine brown sand	5.80	-	5.88						
15/08/2007	9	13	Fine brown sand	6.32	-	5.66						
15/08/2007	9	14	Fine brown sand	6.39	-	5.67						
15/08/2007	9	15	Fine brown sand	6.32	-	5.86						
15/08/2007	9	16	Fine brown sand	6.81	-	6.56						
15/08/2007	9	17	Fine brown sand	6.82	-	6.45						
15/08/2007	9	18	Fine brown/grey sand	6.93	-	6.60						
15/08/2007	9	19	Fine brown/grey sand	6.77	-	5.80						
15/08/2007	9	20	Fine brown/grey sand	6.89	-	5.80						
15/08/2007	9	21	Fine brown/grey sand	6.96	-	5.52						
15/08/2007	9	22	Fine brown/grey sand	7.07	-	5.85						
15/08/2007	9	23	Fine grey sand	7.41	-	6.23						
15/08/2007	9	24	Fine grey sand	6.86	-	5.22						
15/08/2007	9	25	Fine grey sand	6.87	-	6.02						
15/08/2007	9	26	Fine grey sand	7.18	XX	2.32	4.86					
15/08/2007	9	27	Coarse grey sand	7.32	X	3.51						
15/08/2007	9	28	Coarse grey sand	7.71	-	6.21						
15/08/2007	9	29	Coarse grey sand, shells	8.00	-	6.37						
15/08/2007	9	30	Clay	8.33	X	6.87						
Hole 10												
14/08/2007	10	1	Fine grey sand	7.14	-	4.75						
14/08/2007	10	2	Fine grey sand	7.68	-	4.98						
14/08/2007	10	3	Fine grey sand	7.68	-	5.07		9.6	7.1	33	<2	<2
14/08/2007	10	4	Fine dark brown sand	4.94	-	3.48						
14/08/2007	10	5	Fine dark brown sand	5.51	-	4.19						
14/08/2007	10	6	Fine dark brown sand	5.78	-	4.19						
14/08/2007	10	7	water table	5.56	-	3.79						
14/08/2007	10	8	Fine brown sand	5.81	-	4.60						
14/08/2007	10	9	Fine brown sand	6.01	-	4.35						
14/08/2007	10	10	Fine brown sand	5.92	-	4.53						
14/08/2007	10	11	Fine brown sand	5.93	-	4.53		5.5	3.8	<2	7	27
14/08/2007	10	12	Fine brown sand	6.08	-	4.04						
14/08/2007	10	13	Fine brown sand	5.95	-	5.28						
14/08/2007	10	14	Fine brown sand	6.20	-	3.68						
14/08/2007	10	15	Lighter brown sand	6.13	-	3.89						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	10	16	Lighter brown sand	5.98	-	2.80		5.5	3	<2	5	40
14/08/2007	10	17	Lighter brown sand	6.07	XXX	2.05	4.02					
14/08/2007	10	18	Lighter brown sand	6.14	X	2.22						
14/08/2007	10	19	Lighter brown sand	6.09	X	2.29						
14/08/2007	10	20	Lighter brown sand	6.11	X	2.03	4.08					
14/08/2007	10	21	Lighter brown sand	5.92	X	1.65	4.27					
14/08/2007	10	22	Fine brown/grey sand	6.11	XX	1.44	4.67					
14/08/2007	10	23	Fine brown/grey sand	6.20	XXXX	1.47	4.73	5.4	2.3	<2	4	101
14/08/2007	10	24	Fine brown/grey sand	6.15	XX	3.66						
14/08/2007	10	25	Fine grey sand	6.20	XX	1.56	4.64					
14/08/2007	10	26	Fine grey sand	6.22	XX	1.52	4.70					
14/08/2007	10	27	Coarse grey sand	6.44	XX	1.61	4.83					
14/08/2007	10	28	Coarse grey sand	6.72	XXX	1.54	5.18					
14/08/2007	10	29	Coarse grey sand	6.57	XXXX	1.29	5.28	5.5	2.2	<2	5	369
14/08/2007	10	30	Very dark brown/black rocky sand	7.19	XXX	2.60	4.59					
14/08/2007	10	31	Shells, rocky, grey sand	8.10	X	6.17						
Hole 11												
14/08/2007	11	1	Fine light brown sand	6.66	-	4.93						
14/08/2007	11	2	Fine light brown sand	6.65	-	5.38						
14/08/2007	11	3	Fine dark brown sand	4.78	-	4.74						
14/08/2007	11	4	Fine dark brown sand	4.62	-	3.93						
14/08/2007	11	5	Fine dark brown sand	5.26	-	4.28						
14/08/2007	11	6	Water table	4.84	-	4.23						
14/08/2007	11	7	Sludgy	4.77	-	4.31						
14/08/2007	11	8	Fine dark brown sand	4.63	-	4.07						
14/08/2007	11	9	Fine dark brown sand	4.72	-	4.21						
14/08/2007	11	10	Fine dark brown sand	5.30	-	4.95						
14/08/2007	11	11	Fine light brown sand	5.38	-	4.79						
14/08/2007	11	12	Fine grey/brown sand	5.58	-	4.38						
14/08/2007	11	13	Fine light grey/brown sand	5.99	-	5.38						
14/08/2007	11	14	Fine light grey/brown sand	5.75	-	4.18						
14/08/2007	11	15	Fine light grey/brown sand	5.53	-	5.71						
14/08/2007	11	16	Fine light grey/brown sand	5.72	X	3.25						
14/08/2007	11	17	Fine light grey/brown sand	5.99	-	4.14						
14/08/2007	11	18	Fine light grey/brown sand	6.00	X	1.98	4.02					
14/08/2007	11	19	Fine light grey/brown sand	5.98	-	2.37						
14/08/2007	11	20	Fine grey sand	5.71	-	2.08						
14/08/2007	11	21	Fine grey sand	6.80	XXX	1.84	4.96					
14/08/2007	11	22	Fine grey sand	7.89	-	5.75						
14/08/2007	11	23	Fine grey sludge	7.94	-	5.82						
14/08/2007	11	24	Fine grey sludge	8.43	-	5.84						
14/08/2007	11	25	Rocky coarse sand	8.53	X	5.96						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	11	26	Coarse sand/shells	8.62	-	6.35						
14/08/2007	11	27	Coarse sand/shells	8.69	X	5.98						
Hole 12												
15/08/2007	12	1	Fine dark brown sand	4.29	X	2.73						
15/08/2007	12	2	Fine dark brown sand	7.19	X	5.73						
15/08/2007	12	3	Fine dark brown sand	6.17	X	6.06						
15/08/2007	12	4	Water table	7.57	-	5.94						
15/08/2007	12	5	Fine dark brown sand	6.73	X	5.68						
15/08/2007	12	6	Fine dark brown sand	7.80	-	5.05						
15/08/2007	12	7	Fine dark brown sand	6.59	X	5.97						
15/08/2007	12	8	Fine brown sand	7.12	-	4.86						
15/08/2007	12	9	Fine brown sand	6.72	-	5.37						
15/08/2007	12	10	Light brown sand	7.13	-	5.79						
15/08/2007	12	11	Light brown sand	6.56	-	3.73						
15/08/2007	12	12	Light brown sand	7.48	-	2.82	4.66					
15/08/2007	12	13	Light brown sand	6.55	-	5.77						
15/08/2007	12	14	Light brown sand	7.04	X	2.53	4.51					
15/08/2007	12	15	Light brown sand	6.60	-	4.86						
15/08/2007	12	16	Light brown sand	6.94	-	5.80						
15/08/2007	12	17	Light grey sand	6.72	-	2.32	4.40					
15/08/2007	12	18	Light grey sand	7.35	X	2.28	5.07					
15/08/2007	12	19	Grey sand	6.90	X	2.96						
15/08/2007	12	20	Grey sand	7.55	XX	1.90	5.65					
15/08/2007	12	21	Dark grey sand	7.04	XX	1.83	5.21					
15/08/2007	12	22	Dark grey sand	7.25	XX	1.89	5.36					
15/08/2007	12	23	Very wet, fine dark grey sand	6.86	X	5.45						
15/08/2007	12	24	Very wet, fine dark grey sand	7.36	-	6.03						
15/08/2007	12	25	Slightly coarser dark grey sand	7.27	X	5.63						
15/08/2007	12	26	Slightly coarser dark grey sand	7.88	X	4.67						
15/08/2007	12	27	Slightly coarser dark grey sand	7.40	X	5.51						
15/08/2007	12	28	Coarse shelly grey sand	8.53	X	6.10						
Hole 13												
15/08/2007	13	1	Fine brown sand	6.61	X	4.31						
15/08/2007	13	2	Fine brown sand	6.47	X	4.28						
15/08/2007	13	3	Fine brown sand	6.75	-	4.64						
15/08/2007	13	4	Fine brown sand	6.53	-	5.52						
15/08/2007	13	5	Water table	6.48	-	5.49						
15/08/2007	13	6	Lighter brown sand	6.09	-	4.31						
15/08/2007	13	7	Lighter brown sand	6.64	-	5.02						
15/08/2007	13	8	Lighter brown sand	6.76	-	5.20						
15/08/2007	13	9	Lighter brown sand	6.71	-	5.65						
15/08/2007	13	10	Lighter brown sand	6.65	XX	2.67						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	13	11	Light brown coarser sand	6.96	XXX	1.86	5.10					
15/08/2007	13	12	Light brown coarser sand	6.89	XXX	1.64	5.25					
15/08/2007	13	13	Light brown coarser sand	6.55	XXX	1.56	4.99					
15/08/2007	13	14	Light brown coarser sand	6.41	XXX	1.52	4.89					
15/08/2007	13	15	Light brown coarser sand	7.02	XXX	1.55	5.47					
15/08/2007	13	16	Light brown coarser sand	7.08	XXX	1.59	5.49					
15/08/2007	13	17	Light brown coarser sand	6.56	XXXX	1.40	5.16					
15/08/2007	13	18	Fine dark brown sand	6.48	XXXX	1.40	5.08					
15/08/2007	13	19	Fine dark brown sand	6.94	XXXX	1.21	5.73					
15/08/2007	13	20	Light brown/grey sand	7.76	X	5.74						
15/08/2007	13	21	Light brown/grey sand	7.85	X	6.10						
15/08/2007	13	22	Light brown/grey sand	8.15	X	6.23						
15/08/2007	13	23	Light brown/grey sand	8.29	-	6.70						
15/08/2007	13	24	Very wet fine brown/grey sand	8.48	X	6.13						
15/08/2007	13	25	Very wet fine brown/grey sand	7.95	X	6.00						
15/08/2007	13	26	Rocks, shells grey coarse sand	8.93	X	6.10						
15/08/2007	13	27	Rocks, shells grey coarse sand	8.97	X	6.10						
Hole 14												
15/08/2007	14	1	Very fine grey/brown snad	6.59	X	6.19						
15/08/2007	14	2	Fine dark brown sand	6.37	X	4.83						
15/08/2007	14	3	Fine dark brown sand	6.40	-	4.81						
15/08/2007	14	4	Water table	5.90	-	4.34						
15/08/2007	14	5	Fine dark brown sand	5.28	-	4.05						
15/08/2007	14	6	Fine dark brown sand	5.27	-	4.16						
15/08/2007	14	7	Fine dark brown sand	5.65	X	3.85						
15/08/2007	14	8	Fine dark brown sand	5.98	-	4.72						
15/08/2007	14	9	Fine dark brown sand	6.21	X	4.01						
15/08/2007	14	10	Fine light brown sand	5.83	X	3.48						
15/08/2007	14	11	Fine light brown sand	6.25	X	4.64						
15/08/2007	14	12	Fine light brown sand	6.44	X	2.64						
15/08/2007	14	13	Fine light brown sand	6.05	X	2.53						
15/08/2007	14	14	Slightly coarser brown sand	6.59	X	2.56	4.03					
15/08/2007	14	15	Slightly coarser brown sand	6.52	XX	1.80	4.72					
15/08/2007	14	16	Slightly coarser brown sand	6.80	XXX	1.73	5.07					
15/08/2007	14	17	Slightly coarser brown sand	6.71	XX	1.51	5.20					
15/08/2007	14	18	Very fine, slightly clayey dark bro	6.35	XXX	1.57	4.78					
15/08/2007	14	19	Coarse grey sand	7.68	X	5.74						
15/08/2007	14	20	Coarse grey sand	8.09	-	5.98						
15/08/2007	14	21	Coarse grey sand	8.16	X	5.84						
15/08/2007	14	22	Coarse grey sand	7.95	-	6.09						
15/08/2007	14	23	Coarse grey sand	8.29	-	6.06						
15/08/2007	14	24	Coarse grey sand	8.16	X	5.91						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	14	25	Coarse grey sand	8.34	X	5.84						
15/08/2007	14	26	Very coarse grey , rocky sand	8.68	X	5.90						
15/08/2007	14	27	Very coarse grey , rocky sand	8.98	X	5.98						
Hole 15												
14/08/2007	15	1	Fine dark brown sand	6.54	-	5.01						
14/08/2007	15	2	Fine dark brown sand	5.77	-	4.48						
14/08/2007	15	3	Fine dark brown sand	5.61	X	4.85						
14/08/2007	15	4	Fine dark brown sand	5.78	-	4.99						
14/08/2007	15	5	Fine light brown/white sand	6.53	-	5.48		6.4	4	<2	<2	0
14/08/2007	15	6	Fine light brown/white sand	6.70	-	5.54						
14/08/2007	15	7	Fine light brown sand	6.91	X	5.57						
14/08/2007	15	8	Water table	6.39	X	5.08						
14/08/2007	15	9	Fine light brown sand	6.22	X	4.94						
14/08/2007	15	10	Fine light brown sand	6.62	X	1.96	4.66					
14/08/2007	15	11	Fine light brown sand	6.57	XXXX	1.69	4.88					
14/08/2007	15	12	Slightly coarser light brown sand	6.83	XXX	2.49	4.34	6.8	2.5	<2	<2	59
14/08/2007	15	13	Slightly coarser light brown sand	7.05	XX	2.85	4.20					
14/08/2007	15	14	Finer brown sand	6.85	XX	2.26	4.59					
14/08/2007	15	15	Finer brown sand	7.09	X	2.24	4.85					
14/08/2007	15	16	Finer brown sand	6.74	XXX	1.86	4.88					
14/08/2007	15	17	Finer brown sand	7.33	XXXX	1.91	5.42	6.7	2.8	<2	<2	43
14/08/2007	15	18	Finer brown sand	7.68	XXX	1.81	5.87					
14/08/2007	15	19	Finer brown sand	8.11	-	6.21						
14/08/2007	15	20	Fine beige/grey sand	8.40	-	6.74						
14/08/2007	15	21	Fine beige/grey sand	8.28	-	6.56						
14/08/2007	15	22	Very fine grey sand	8.51	-	6.65		9.7	8	2168	<2	<2
14/08/2007	15	23	Very fine grey sand	8.26	-	6.87						
14/08/2007	15	24	Very fine grey sand	8.02	-	6.66						
14/08/2007	15	25	Coarse grey sand	8.45	X	6.27						
14/08/2007	15	26	Coarse grey sand	8.49	X	6.24		9.5	8.3	2170	<2	<2
14/08/2007	15	27	Shells	8.32	X	6.12						
Hole 16												
14/08/2007	16	1	Fine grey/brown sand	6.25	-	6.00						
14/08/2007	16	2	Fine grey/brown sand	7.99	-	6.04						
14/08/2007	16	3	Fine dark brown sand	7.44	-	5.57						
14/08/2007	16	4	Coffee rock	6.96	-	5.66						
14/08/2007	16	5	Coffee rock	6.85	-	5.37						
14/08/2007	16	6	Coffee rock	6.45	-	4.96						
14/08/2007	16	7	Coffee rock	6.25	-	4.86						
14/08/2007	16	8	Water table	6.27	-	5.30						
14/08/2007	16	9	Coffee rock	6.15	-	4.92						
14/08/2007	16	10	Coffee rock	6.45	-	5.50						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	16	11	Fine light brown sand	6.26	-	5.48						
14/08/2007	16	12	Fine light brown sand	6.48	-	5.68						
14/08/2007	16	13	Fine light brown sand	6.71	-	4.40						
14/08/2007	16	14	Fine light brown sand	6.81	X	2.06	4.75					
14/08/2007	16	15	Fine light brown sand	6.75	XXX	1.80	4.95					
14/08/2007	16	16	Fine light brown sand	7.04	XX	1.84	5.20					
14/08/2007	16	17	Fine light brown sand	7.34	XXX	2.33	5.01					
14/08/2007	16	18	Fine light brown sand	7.73	XX	5.49						
14/08/2007	16	19	Very wet, fine grey sand	7.78	X	6.35						
14/08/2007	16	20	Very wet, fine grey sand	8.14	X	6.48						
14/08/2007	16	21	Very wet, fine grey sand	8.34	X	6.14						
14/08/2007	16	22	Slightly coarse grey sand	8.72	X	6.21						
14/08/2007	16	23	Slightly coarse grey sand	8.80	X	6.33						
14/08/2007	16	24	Slightly coarse grey sand	8.66	X	6.41						
14/08/2007	16	25	Slightly coarse grey sand	8.78	X	6.43						
14/08/2007	16	26	Coarse grey/shelly sand	8.99	X	6.05						
14/08/2007	16	27	Very shelly	8.90	X	6.12						
Hole 17												
14/08/2007	17	1	Fine dark grey sand	7.14	-	5.44						
14/08/2007	17	2	Fine dark grey sand	7.58	-	5.66						
14/08/2007	17	3	Fine light grey sand	7.63	-	5.69						
14/08/2007	17	4	Fine grey/brown sand	5.80	-	4.06						
14/08/2007	17	5	Fine grey/brown sand	4.35	-	3.42						
14/08/2007	17	6	Fine grey/brown sand	4.65	-	3.71						
14/08/2007	17	7	Water table, brown coffee rock	4.75	-	3.94						
14/08/2007	17	8	Brown coffee rock	4.86	-	4.24						
14/08/2007	17	9	Brown coffee rock	4.85	-	4.36						
14/08/2007	17	10	Brown coffee rock	5.28	-	5.32						
14/08/2007	17	11	Fine light grey sand	6.11	-	5.80						
14/08/2007	17	12	Fine light grey sand	6.31	-	5.88						
14/08/2007	17	13	Fine light grey sand	6.56	-	5.86						
14/08/2007	17	14	Fine light grey sand	6.58	-	5.90						
14/08/2007	17	15	Fine light grey sand	6.48	-	5.97						
14/08/2007	17	16	Fine grey/white sand	6.50	-	6.02						
14/08/2007	17	17	Fine grey/white sand	6.48	XXX	5.30						
14/08/2007	17	18	Fine grey/brown sand	5.86	XX	1.93						
14/08/2007	17	19	Fine grey/brown sand	6.56	XXX	1.97	4.59					
14/08/2007	17	20	Fine grey/brown sand	7.18	XX	4.60						
14/08/2007	17	21	Fine grey/brown sand	7.02	XXX	2.05	4.97					
14/08/2007	17	22	Coarse grey sand	7.29	XXX	2.00	5.29					
14/08/2007	17	23	Coarse grey sand	7.81	XXX	2.01	5.80					
14/08/2007	17	24	Coarse dark grey sand some shells	7.96	XXX	2.13	5.83					

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	17	25	Coarse sand	8.21	X	6.02						
14/08/2007	17	26	Coarse sand	8.27	X	6.13						
14/08/2007	17	27	Coarse dark grey sand some shells	8.25	X	6.22						
14/08/2007	17	28	Clayey sand	8.25	X	6.38						
14/08/2007	17	29	Clayey sand	8.49	X	6.04						
Hole 18												
14/08/2007	18	1	Fine grey/brown sand	5.30	-	5.91						
14/08/2007	18	2	Fine grey/brown sand	6.07	-	5.94						
14/08/2007	18	3	Fine grey/brown sand	6.11	-	5.18						
14/08/2007	18	4	Water table	6.78	-	5.92						
14/08/2007	18	5	Brown coffee rock	6.67	-	5.81						
14/08/2007	18	6	Brown coffee rock	6.59	-	5.51						
14/08/2007	18	7	Brown coffee rock	6.88	-	6.30						
14/08/2007	18	8	Brown coffee rock	6.88	-	6.28						
14/08/2007	18	9	Fine yellow/grey sand	6.65	-	6.03						
14/08/2007	18	10	Fine yellow/grey sand	6.91	-	6.03						
14/08/2007	18	11	Fine grey/biege sand	6.98	-	5.99						
14/08/2007	18	12	Fine grey/biege sand	6.81	-	6.02						
14/08/2007	18	13	Fine grey/biege sand	6.94	-	5.83						
14/08/2007	18	14	Coarse grey/brown sand	6.65	-	4.95						
14/08/2007	18	15	Coarse grey/brown sand	6.85	-	5.78						
14/08/2007	18	16	Coarse grey/brown sand	6.33	-	4.26						
14/08/2007	18	17	Coarse grey/brown sand	6.26	-	2.36						
14/08/2007	18	18	Very wet coarse grey/brown sand	6.52	X	5.21						
14/08/2007	18	19	Very wet coarse grey/brown sand	6.83	X	2.76	4.07					
14/08/2007	18	20	Very wet coarse grey/brown sand	6.75	X	6.05						
14/08/2007	18	21	Fine grey sand	6.89	X	4.88						
14/08/2007	18	22	Fine grey sand	6.76	XX	1.53	5.23					
14/08/2007	18	23	Fine dark grey sand	6.72	XXX	1.59	5.13					
14/08/2007	18	24	Fine dark grey sand	6.62	XX	1.46	5.16					
14/08/2007	18	25	Coarse grey/brown sand	6.64	XX	1.48	5.16					
14/08/2007	18	26	Coarse grey/brown sand	6.87	XX	1.65	5.22					
14/08/2007	18	27	Coarse grey/brown sand	7.07	XX	1.39	5.68					
14/08/2007	18	28	Fine light grey/brown sand few she	7.66	X	4.16						
14/08/2007	18	29	Fine white sand/clay/shells	8.63	X	6.00						
Hole 19												
15/08/2007	19	1	Fine light brown sand	7.03	-	4.23						
15/08/2007	19	2	Fine light brown sand	6.70	-	5.29						
15/08/2007	19	3	Fine light brown sand	6.30	-	5.04						
15/08/2007	19	4	Fine dark brown sand	6.39	-	4.61						
15/08/2007	19	5	Fine dark brown sand	5.76	-	4.83						
15/08/2007	19	6	Fine dark brown sand	6.29	-	5.25						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	19	7	Water table	6.05	-	5.93						
15/08/2007	19	8	Fine brown sand	6.46	-	6.58						
15/08/2007	19	9	Fine brown sand	6.67	-	6.54						
15/08/2007	19	10	Fine brown sand	6.58	-	5.80						
15/08/2007	19	11	Fine brown sand	6.47	-	5.77						
15/08/2007	19	12	Fine brown sand	6.22	-	5.21						
15/08/2007	19	13	Fine brown sand	6.48	-	6.38						
15/08/2007	19	14	Fine brown sand	6.50	-	5.02						
15/08/2007	19	15	Fine beige sand	6.43	X	4.17						
15/08/2007	19	16	Fine beige sand	6.38	-	5.30						
15/08/2007	19	17	Fine beige sand	6.41	-	2.55						
15/08/2007	19	18	Fine beige/grey sand	6.46	X	2.93						
15/08/2007	19	19	Fine beige/grey sand	6.48	X	2.70						
15/08/2007	19	20	Fine beige/grey sand	6.73	X	2.52	4.21					
15/08/2007	19	21	Fine grey sand	6.67	-	3.15						
15/08/2007	19	22	Very wet, fine grey/brown sand	6.78	XXX	1.96	4.82					
15/08/2007	19	23	Very wet, fine grey/brown sand	6.78	XX	2.02	4.76					
15/08/2007	19	24	Very wet, fine grey/brown sand	7.05	XXX	1.84	5.21					
15/08/2007	19	25	Very wet, fine grey/brown sand	7.02	X	2.17	4.85					
15/08/2007	19	26	Very wet, fine grey/brown sand	6.94	XX	1.87	5.07					
15/08/2007	19	27	Dark brown/black sandy/clay	7.38	X	2.04	5.34					
15/08/2007	19	28	Dark brown/black sandy/clay	7.74	X	5.71						
Hole 20												
15/08/2007	20	1	Fine light brown sand	5.38	X	2.23						
15/08/2007	20	2	Fine light brown sand	5.39	X	2.06						
15/08/2007	20	3	Fine light brown sand	4.99	X	1.91		9.4	5.7	<2	<2	<2
15/08/2007	20	4	Fine dark brown sand	5.03	-	4.44						
15/08/2007	20	5	Fine dark brown sand	6.34	-	4.35						
15/08/2007	20	6	Fine dark brown sand	6.41	-	4.98						
15/08/2007	20	7	Water table	6.82	-	4.94		5.1	3.2	<2	28	142
15/08/2007	20	8	Fine brown sand	6.45	-	4.84						
15/08/2007	20	9	Fine light brown sand	6.51	-	5.48						
15/08/2007	20	10	Fine light brown sand	6.54	-	5.24						
15/08/2007	20	11	Fine light brown sand	6.74	-	6.44						
15/08/2007	20	12	Fine beige sand	7.02	-	4.21		6.3	3.9	<2	<2	11
15/08/2007	20	13	Fine beige sand	7.23	-	5.46						
15/08/2007	20	14	Fine beige sand	7.19	-	5.34						
15/08/2007	20	15	Fine beige sand	7.23	-	5.55						
15/08/2007	20	16	Fine beige/grey sand	7.32	-	5.35						
15/08/2007	20	17	Fine beige/grey sand	7.36	X	2.16	5.20					
15/08/2007	20	18	Slightly coarse grey sand	7.28	XXX	1.91	5.37	5.5	2.5	<2	<2	74
15/08/2007	20	19	Slightly coarse grey sand	7.31	X	1.92	5.39					

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	20	20	Slightly coarse grey sand	7.11	XX	1.59	5.52					
15/08/2007	20	21	Slightly coarse grey sand	7.23	XXX	1.66	5.57					
15/08/2007	20	22	Fine grey/brown sand	7.01	XX	1.56	5.45					
15/08/2007	20	23	Very wet	7.26	XXXX	1.53	5.73					
15/08/2007	20	24	Very wet	7.38	X	2.01	5.37					
15/08/2007	20	25	Very wet	7.68	XXXX	1.51	6.17	5.1	2.4	<2	5	148
15/08/2007	20	26	Coarse grey sand	7.88	XXX	1.72	6.16					
15/08/2007	20	27	Coarse grey sand	7.94	X	1.92	6.02	5.4	2.4	<2	3	81
15/08/2007	20	28	Coarse grey sand, rocks	8.68	X	6.20						
15/08/2007	20	29	Clay, rocks	8.95	X	6.57						
Hole 21												
14/08/2007	21	1	Fine light brown sand	4.39	-	4.43						
14/08/2007	21	2	Fine light brown sand	4.64	-	4.86						
14/08/2007	21	3	Fine dark brown sand	5.30	-	4.82						
14/08/2007	21	4	Fine dark brown sand	6.27	-	5.30						
14/08/2007	21	5	Fine dark brown sand	6.33	-	5.22						
14/08/2007	21	6	Fine dark brown sand	5.98	-	5.12						
14/08/2007	21	7	Water table	6.60	-	6.19						
14/08/2007	21	8	Fine brown sand	6.63	-	5.65						
14/08/2007	21	9	Fine brown sand	6.24	-	5.04						
14/08/2007	21	10	Fine brown sand	6.17	-	5.76						
14/08/2007	21	11	Fine brown sand	6.15	-	4.20						
14/08/2007	21	12	Fine beige sand	6.20	-	5.60						
14/08/2007	21	13	Fine beige sand	6.66	-	5.28						
14/08/2007	21	14	Fine beige sand	6.55	-	5.36						
14/08/2007	21	15	Fine beige sand	6.30	-	3.35						
14/08/2007	21	16	Fine beige/grey sand	6.81	X	6.34						
14/08/2007	21	17	Fine beige/grey sand	9.78	XX	2.44	7.34					
14/08/2007	21	18	Fine beige/grey sand	6.63	XX	2.04	4.59					
14/08/2007	21	19	Fine beige/grey sand	7.38	X	5.89						
14/08/2007	21	20	Slightly coarse grey/brown sand	7.54	X	2.55	4.99					
14/08/2007	21	21	Slightly coarse grey/brown sand	6.89	XXX	1.89	5.00					
14/08/2007	21	22	Grey sand	6.95	XXX	1.77	5.18					
14/08/2007	21	23	Grey sand	6.85	X	1.69	5.16					
14/08/2007	21	24	Very wet	6.99	X	4.38						
14/08/2007	21	25	Very wet	7.27	X	2.34	4.93					
14/08/2007	21	26	Slightly coarse grey/brown sand	7.45	XXX	1.82	5.63					
14/08/2007	21	27	Slightly coarse grey/brown sand	7.35	XXXX	1.52	5.83					
14/08/2007	21	28	Coarse dark brown/grey sandey/sla	7.77	XX	4.25						
14/08/2007	21	29	Rocks/clay	8.63	X	5.95						
Hole 22												
14/08/2007	22	1	Fine grey sand	8.32	-	5.77						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
14/08/2007	22	2	Fine yellow sand	8.32	-	5.94						
14/08/2007	22	3	Fine yellow sand	8.10	-	5.78						
14/08/2007	22	4	Fine yellow sand	8.28	-	5.78						
14/08/2007	22	5	Very fine light yellow sand	8.50	-	5.76						
14/08/2007	22	6	Very fine light yellow sand	8.54	-	5.71						
14/08/2007	22	7	Very fine light yellow sand	8.45	-	5.81						
14/08/2007	22	8	Very fine light yellow sand	8.60	-	5.83						
14/08/2007	22	9	Very fine white sand	8.42	-	5.76						
14/08/2007	22	10	Moist fine grey sand	8.62	-	6.16						
14/08/2007	22	11	Moist fine grey sand	8.70	-	5.81						
14/08/2007	22	12	Moist fine grey sand	8.36	-	5.93						
14/08/2007	22	13	Water table, beige sand	7.53	-	6.30						
14/08/2007	22	14	Fine beige sand	7.73	-	6.02						
14/08/2007	22	15	Fine beige sand	7.64	-	5.82						
14/08/2007	22	16	Fine beige sand	7.61	-	5.89						
14/08/2007	22	17	Fine beige sand	7.37	-	5.80						
14/08/2007	22	18	Fine light grey/beige sand	7.39	-	6.26						
14/08/2007	22	19	Fine light grey/beige sand	7.43	-	5.24						
14/08/2007	22	20	Fine light grey/beige sand	7.59	-	6.30						
14/08/2007	22	21	Fine light grey/beige sand	7.70	-	4.40						
14/08/2007	22	22	Fine light grey/beige sand	7.67	XX	1.96	5.71					
14/08/2007	22	23	Fine light grey/beige sand	7.47	XXX	2.26	5.21					
14/08/2007	22	24	Fine grey/beige sand	7.38	XX	1.85	5.53					
14/08/2007	22	25	Fine grey/beige sand	7.56	XX	1.70	5.86					
14/08/2007	22	26	Slightly coarse grey/brown sand	7.54	XXX	1.84	5.70					
14/08/2007	22	27	Slightly coarse grey/brown sand	7.39	X	1.77	5.62					
14/08/2007	22	28	Slightly coarse grey/brown sand	7.40	X	2.61	4.79					
14/08/2007	22	29	Slightly coarse grey/brown sand	7.34	XX	1.80	5.54					
14/08/2007	22	30	Coarse grey sand	7.28	XXX	1.85	5.43					
14/08/2007	22	31	Coarse grey sand	7.30	X	1.77	5.53					
14/08/2007	22	32	Coarse grey/brown sand	7.88	X	2.15	5.73					
14/08/2007	22	33	Coarse grey sand	7.92	XXXX	1.78	6.14					
14/08/2007	22	34	Shells	8.18	X	5.56						
Hole 23												
15/08/2007	23	1	Fine dark grey sand	8.83	-	7.07						
15/08/2007	23	2	Fine light grey sand	9.06	-	7.03						
15/08/2007	23	3	Fine dark grey sand	9.05	-	7.24						
15/08/2007	23	4	Fine brown sand rocks	8.78	-	6.75						
15/08/2007	23	5	Fine dark brown sand	8.04	-	6.68						
15/08/2007	23	6	Fine dark brown sand	7.77	-	6.06						
15/08/2007	23	7	Water table	7.33	-	6.64						
15/08/2007	23	8	Fine dark brown sand	7.64	-	6.42						

Date	Hole Number	Sample Depth (m)	Texture and colour	Field Results				Laboratory Results				
				pH (F)	Peroxide Reaction	pH(FOX)	pH pFox range >4	pH(KCl)	pH(FOX)	ANC	TAA	TPA
15/08/2007	23	9	Fine dark brown sand	7.28	-	6.57						
15/08/2007	23	10	Fine dark brown sand	6.98	-	6.40						
15/08/2007	23	11	Fine light brown sand	6.58	-	6.38						
15/08/2007	23	12	Fine light brown sand	6.80	-	6.56						
15/08/2007	23	13	Fine light brown sand	7.16	-	7.14						
15/08/2007	23	14	Fine light brown sand	7.12	-	6.63						
15/08/2007	23	15	Fine light brown sand	7.10	X	6.80						
15/08/2007	23	16	Fine light brown sand	6.94	-	8.51						
15/08/2007	23	17	Fine light brown sand	6.92	X	7.98						
15/08/2007	23	18	Fine light brown sand	6.98	X	8.52						
15/08/2007	23	19	Fine light brown sand	7.19	-	8.11						
15/08/2007	23	20	Fine light brown sand	7.32	-	8.96						
15/08/2007	23	21	Fine light brown sand	7.40	-	7.78						
15/08/2007	23	22	Fine grey sand	7.52	-	8.47						
15/08/2007	23	23	Slightly coarse grey sand	7.62	-	8.00						
15/08/2007	23	24	Slightly coarse dark grey sand	7.54	-	8.61						
15/08/2007	23	25	Slightly coarse dark grey/brown sa	7.61	-	7.77						
15/08/2007	23	26	Slightly coarse dark grey/brown sa	7.47	X	8.55						
15/08/2007	23	27	Coarse grey sand	7.54	-	7.77						
15/08/2007	23	28	Coarse dark grey sand	7.40	XXX	2.66	4.74					
15/08/2007	23	29	Coarse dark grey sand	7.99	X	6.35						
15/08/2007	23	30	Shells	8.20	X	6.65						

APPENDIX 2:
ACID SULFATE SOIL FIELD TESTING PROCEDURES

OVERVIEW

When performing field tests, the soil samples must not be left in the open air in the test tubes or beakers for an extended period of time before conducting the tests. If sulphides are present, there is a risk that they will oxidise, and this will substantially affect the end pH result by lowering the pH_F.

When conducting the pH_{FOX} test, it is important to allow enough time for the reaction to occur, especially if low strength (i.e. <30%) hydrogen peroxide is used.

SAMPLING PROCEDURE

pH_F Measurement

1. Calibrate pH meter.
2. Wash the cell with deionised water, gently pat dry with a tissue.
3. Collect approximately 10 grams (one teaspoon) of the soils ample into a plastic container (if soil sample is a solid lump, will need to be broken down into smaller fragments).
4. Measure and add 50 millilitres deionised water to the soil sample.
5. Stir the soil/water mixture until a slurry has been generated.
6. Measure the pH of the soil/water slurry using the pH electrode and record on the ASS Field Test Form.

pH_{FOX} Measurement

7. Calibrate pH meter.
8. Wash the cell with deionised water, gently pat dry with a tissue.
9. Collect approximately 10 grams (one teaspoon) of the soils ample into a plastic container (if soil sample is a solid lump, will need to be broken down into smaller fragments).
10. Measure and add three millilitres Hydrogen Peroxide (30%) to the soil sample.
11. Allow the reaction to occur for 15 minutes or until the peroxide stops fizzing. Note the degree of he reaction on the ASS Field Test Form.
12. Add 40 millilitres deionised water to the soil sample.
13. Gently stir the soil/water mixture until a slurry has been generated.
14. Measure the pH of the soil/water slurry using the pH electrode and record on the ASS Field Test Form.

APPENDIX 17:
POTENTIAL IMPACTS, RISK ASSESSMENT AND MANAGEMENT AND MITIGATION MEASURES

Aspect	Potential Impacts	Risk No Management Measures			Management and Mitigation Measures	Residual Environmental Risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
Soils	Wind and water erosion.	Almost Certain	Minor	Moderate	• Strip and stockpile topsoil (where required) in dry and preferably still wind conditions, to minimise dust generation and assist rapid revegetation **(Commitment 7.2.1.4a).** • Control slope gradients to minimise erosion and soil loss. Finished slopes will include a zone of shallow beach approximately 30 to 40 metres wide before sloping at a stable angle of repose (approximately one in four) to the base of the rehabilitated lake. **(Commitment 7.2.1.4b).** • Routinely inspect rehabilitated and disturbed surfaces for erosion, particularly after significant rainfal**l (Commitment 7.2.1.4c).** • Implement appropriate remediation measures if soil erosion is observed during routine inspections **(Commitment 7.2.1.4d).**	Moderate	Minor	Low
	Loss of soil resources (volume, contained seed, micro-organisms).	Moderate	Severe	Moderate	• Place stockpiled topsoil in windrows less than three metres high to minimise loss of seed viability and soil biota **(Commitment 7.2.1.4e)**.	Unlikely	Severe	Low
	Incorrect topsoil placement.	Moderate	Severe	Moderate	• Strip and replace topsoil fresh and dry (known as the autumn direct return) to a maximum depth of about 100 millimetres where practicable and place directly onto rehabilitation areas or stockpiles **(Commitment 7.2.1.4f)**. • Complete direct replacement wherever practicable **(Commitment 7.2.1.4g)**. • Undertake progressive rehabilitation where practicable. All rehabilitation will be performed in accordance with contemporary accepted industry best practice **(Commitment 7.2.1.4h)**.	Unlikely	Severe	Low
	Compaction.	Unlikely	Negligible	Low	• Rip rehabilitation areas on the contour to remove compaction, improve soil structure and improve infiltration capacity if required **(Commitment 7.2.1.4i)**. • Vehicles and mining equipment will keep to the designated roads. Very little vehicle use is needed as the mining process is dredge operated **(Commitment 7.2.1.4j)**.	Unlikely	Negligible	Low
	Contamination (salinity, hydrocarbons).	Moderate	Minor	Low	• Refuelling and servicing is carried out at the existing plant **(Commitment 7.2.1.4k)**. • Heavy mineral concentrate is recovered and not placed back into the dredge pond **(Commitment 7.2.1.4l)**.	Unlikely	Negligible	Low
Acid Sulfate Soils	Contamination of groundwater.	Unlikely	Major	Moderate	• If ASS sampling identifies significantly sized high Potentially Acid Forming locations within the proposed pond area, KSS will alter mine plans to reduce the dredge depth to avoid these areas **(Commitment 7.2.2.4a)**. • Where Potentially Acid Forming materials are small in volume, the material will be dredged, however residues will be returned to permanent lakes and will remain below the water in the long term **(Commitment 7.2.2.4b)**. • KSS will implement a monitoring program to detect any changes attributable to the generation of acid. Ongoing monitoring will continue to record water quality in the dredge pond, rehabilitated cells and surrounding groundwater **(Commitment 7.2.2.4c)**. • Should any acid generation occur due to mining, the ASSMP will be implemented to address any acidity generated **(Commitment 7.2.2.4d)**.	Rare	Major	Low
	Contamination of pond.	Unlikely	Major	Moderate		Rare	Major	Low
	Acidification of beaches.	Unlikely	Major	Moderate		Rare	Major	Low
	Death/retardation of plant growth.	Unlikely	Major	Moderate		Rare	Major	Low
	Fauna deaths.	Rare	Major	Low		Rare	Major	Low
Surface Hydrology	Surface water contamination (acid, hydrocarbons, sediment).	Likely	Severe	Moderate	• Pipelines between the dredge and processing plant will be located in the infrastructure corridor. They will be fully bunded with purpose built sumps located along the infrastructure corridor with sufficient capacity to hold the pipeline volume in the event of a pipe failure **(Commitment 7.3.4a)**. • Regular dredge maintenance to minimise risk of spills and leaks **(Commitment 7.3.4b)**. • Any spills of contaminants such as oil or fuel will be immediately cleaned up **(Commitment 7.3.4c)**. • Place spill kits in easily accessible locations and provide operator training for hydrocarbon spill response **(Commitment 7.3.4d)**.	Moderate	Minor	Low
	Changing landform and catchment characteristics.	Almost Certain	Major	High	• Altered design of mine extension area boundary to reduce the impact on EPP4 and conservation category wetlands. • Regular monitoring of EPP wetlands for water levels and water quality **(Commitment 7.3.4e)**. • Monitor surface water quality around the active mine area **(Commitment 7.3.4f)**. • Natural surface water flows in the mine extension areas will be maintained. Diversion of	Almost Certain	Severe	High

Aspect	Potential Impacts	Risk No Management Measures			Management and Mitigation Measures	Residual Environmental Risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
					surface water will not be required during operation or rehabilitation. Surface water flows of adjoining areas will not be affected by dredging operations **(Commitment 7.3.4g)**.			
Groundwater	Contamination (salinity).	Likely	Major	High	• Monitor the dredge pond and rehabilitated cells. Implement measures to balance pH if monitoring results show an increase in acid generation **(Commitment 7.4.4a)**.	Moderate	Minor	Low
	Contamination (acidification).	Unlikely	Major	Moderate		Rare	Major	Low
	Contamination (hydrocarbons).	Moderate	Severe	Moderate	• Any spills of contaminants such as oil or fuel will be immediately cleaned up **(Commitment 7.4.4b)**. • Place spill kits in easily accessible locations and provide operator training for hydrocarbon spill response **(Commitment 7.4.4c)**.	Unlikely	Negligible	Low
	Depletion of resource.	Almost Certain	Severe	High	• Maintain current water usage and continue to implement water saving initiatives (**Commitment 7.4.4d)**. • Measure abstraction volumes **(Commitment 7.4.4e)**. • Install additional monitoring bores to allow continued water quality monitoring of aquifer water levels in response to dredge mining and production bore abstraction to ensure no adverse impacts occur to the region's groundwater quantity. KMB1 is located about 400 metres up the hydraulic gradient from EPP4. Two monitoring bores will be installed along the western boundary of the property **(Commitment 7.4.4f)**. • Two production bores will be installed, one located 200 metres north of KMB6 and the other 200 metres west of KMB6 **(Commitment 7.4.4g)**.	Likely	Minor	Moderate
	Altered wetland hydrology outside of the mine extension area.	Likely	Major	High		Moderate	Severe	Moderate
	Altered wetland hydrology within the mine extension area.	Almost Certain	Major	High	• Create north to south designed dredge ponds and rehabilitated lakes to reduce water loss by evaporation and impacts associated with easterly and westerly winds **(Commitment 7.4.4h)**.	Almost Certain	Severe	High
Vegetation and Flora	**Impact on Vegetation Communities:**							
	Loss of vegetation as a result of land clearing. Loss will be permanent in some locations and temporary in others.	Almost Certain	Severe	High	• Progressive clearing of an average of five hectares per year **(Commitment 7.5.4a)**. • Delineate areas to be cleared with survey pegs and flagging tape before clearing starts. Company supervisors will oversee clearing works **(Commitment 7.5.4b)**. • Undertake surveys of areas planned to be cleared in the short term to identify plants suitable for translocation, seed collection or collection of propagating material for use in the annual rehabilitation program **(Commitment 7.5.4c)**.	Almost Certain	Severe	High
	Altered vegetation distribution patterns post rehabilitation. Rehabilitated landforms will differ in total area compared to the pre-existing condition.	Almost Certain	Severe	High	• Progressive rehabilitation to encourage colonisation from surrounding vegetative areas **(Commitment 7.5.4d)**.	Almost Certain	Severe	High
	Impact on Muchea Limestone TEC.	Unlikely	Major	Moderate	No direct impact.	Rare	Major	Low
	Impact on Declared Rare and Priority Flora:							
	Removal of individual plants of conservation significance within the mine extension area.	Unlikely	Major	Moderate	• Seed collection and cuttings of Priority Species **(Commitment 7.5.4e)**.	Unlikely	Severe	Low
	Outside of mine extension area.	Rare	Major	Low	• KSS has carefully chosen a proposed mine extension area where there will be the least effect on species of conservation significance and fauna habitat. The proponent considers this fulfils the principle of avoidance outlined in EPA Guidance Statements 55 and 19.	Rare	Major	Low

Aspect	Potential Impacts	Risk No Management Measures			Management and Mitigation Measures	Residual Environmental Risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
	Indirect Impacts from Mining:							
	Impact on groundwater dependent species due to drawdown.	Unlikely	Severe	Low	• Continue to undertake detailed monitoring of rehabilitated areas to ensure short, medium and long term rehabilitation objectives are achieved. Monitoring to be carried out on a regular basis to assess **(Commitment 7.5.4f)**: - Physical stability of the landform of rehabilitated areas. - Success of vegetation and fauna re-colonisation in rehabilitated areas. - Water quality and ecology of lakes. - Monitoring should also be conducted within 200 metres of groundwater abstraction bores and dredge ponds to target susceptible species, particularly Banksia ilicifolia, and other Banksia and Melaleuca species.	Unlikely	Minor	Low
	Weeds.	Almost Certain	Severe	Moderate	Weed and dieback hygiene will be implemented during all operations and will include the following provisions **(Commitment 7.5.4g)**: • All vehicles and machinery will arrive at the proposed mine extension area clean and free from soil, mud, soil slurry and vegetation material, in accordance with the Weed Inspection List. • Soil and vegetation stripped from the mine area will be stored in marked areas. • No soil or vegetation material will be transported around the proposed mine extension area. • Movement of vehicles into non-production areas of the property is restricted, with permission required from the General Manager.	Almost Certain	Minor	Moderate
	Dieback.	Almost Certain	Major	High		Almost Certain	Major	High
Wetlands	Loss of Conservation Category wetlands.	Almost Certain	Major	High	• KSS has carefully chosen a proposed mine extension area that reduces impacts on EPP4 and adjoining Conservation Category wetlands. EPP4 appears to be a perched wetland, primarily receiving water inflows from the surrounding Conservation Category wetland which effectively acts as a catchment to EPP4. The proposed mine extension area should therefore not impact Conservation Category wetland UFI 13254 or EPP4. Monitoring will ensure that any adverse impacts are managed accordingly.	Almost Certain	Major	High
	Indirect impacts on adjoining wetlands.	Likely	Major	High	• A regular annual monitoring program for reference wetlands and rehabilitated wetlands and lakes will be established, to include the wetlands sampled in the 2007 and 2008 study (McCullough and Lund, 2008). Annual monitoring will include vegetation and flora, fish, macroinvertebrates and physico-chemical parameters **(Commitment 7.6.4a)**.	Almost Certain	Major	Moderate
	Change in wetland type post mining.	Almost Certain	Major	High	• KSS will create north to south designed dredge ponds and rehabilitated lakes to reduce water loss by evaporation and impacts associated with easterly and westerly winds **(Commitment 7.4.4h)**.	Almost Certain	Major	High
Fauna	**Conservation Significance 1 Species:**							
	Impact on Baudin's Black-Cockatoo.	Unlikely	Severe	Low	• Conduct surveys to identify potential Cockatoo tree hollows prior to annual land clearing and to determine whether any hollows are actually in use by Cockatoos. Tree hollows suitable for Cockatoos that are not being actively used at the time, will be relocated to other areas, preferably within newly rehabilitated areas or remounted on trees outside the mine extension area. If this is not practical, hollows will be replaced with similar sized nest boxes **(Commitment 7.7.4a)**. Tree hollows suitable for Cockatoos may be used by Carnaby's Black-Cockatoo, but Baudin's Black-Cockatoo is not expected to nest in the Kemerton region. • Planting of tree species likely to develop hollows and provide Cockatoo habitat in the long term **(Commitment 7.7.4b)**.	Unlikely	Severe	Low
	Impact on Carnaby's Black-Cockatoo foraging habitat.	Likely	Major	High		Likely	Severe	Moderate
	Impact on Carnaby's Black-Cockatoo breeding habitat.	Unlikely	Major	Moderate		Unlikely	Severe	Low
	Impact on Forest Red-tailed Black-Cockatoo.	Unlikely	Severe	Low		Unlikely	Severe	Low
	Impact on Australasian Bittern.	Unlikely	Negligible	Low	• No specific management measures are considered necessary to protect the biodiversity of wetland species as there is no permanent water in the mine extension area.	Unlikely	Negligible	Low
	Impact on Common Greenshank.	Unlikely	Negligible	Low		Unlikely	Severe	Low
	Impact on Common Sandpiper.	Unlikely	Negligible	Low		Unlikely	Severe	Low
	Impact on Rainbow Bee-eater.	Almost Certain	Major	High	• No specific management measures are considered necessary to protect the biodiversity of the Rainbow Bee-eater or Peregrine Falcon as they should be able to move out of the way of	Likely	Severe	Moderate

Aspect	Potential Impacts	Risk No Management Measures			Management and Mitigation Measures	Residual Environmental Risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
	Impact on Peregrine Falcon.	Unlikely	Negligible	Low	clearing. • Minimising the amount of vegetation that will be cleared at any one time. Progressive clearing of an average of five hectares per year will be carried out in Autumn when species are less likely to be breeding **(Commitment 7.7.4d)**. This will enable any Threatened or Migratory Fauna species to migrate to other areas of the KSS property. • Progressive rehabilitation mining with local provenance seed to encourage colonisation from surrounding vegetative areas, to re-establish vegetation and hence fauna **(Commitment 7.7.4e)**. Rehabilitation will provide restored habitat for recolonisation over time.	Unlikely	Negligible	Low
	Impact on Western Ringtail Possum.	Unlikely	Major	Moderate	• Conduct targeted survey for Chuditch, Western Ringtail Possum and Quokka prior to annual land clearing to ensure that populations of these Vulnerable species will not be affected by the planned clearing. If evidence of their presence is found, trapping will be undertaken and captured individuals relocated to suitable alternative sites on the property **(Commitment 7.7.4f)**. • Erecting nest boxes suitable for use by Western Ringtail Possums where annual surveys show Possums are present in areas planned to be cleared in the short term. Nest boxes will be placed in adjacent undisturbed areas where suitable foraging habitat is present **(Commitment 7.7.4g)**. • Planting areas of peppermint (Agonis flexuosa) within upland woodland areas to be rehabilitated post mining. Peppermint trees will be planted in clumps to encourage interlocking branches **(Commitment 7.7.4h)**.	Unlikely	Negligible	Low
	Impact on Chuditch.	Unlikely	Severe	Low	• Conduct targeted survey for Chuditch, Western Ringtail Possum and Quokka prior to annual land clearing to ensure that populations of these Vulnerable species will not be affected by the planned clearing. If evidence of their presence is found, trapping will be undertaken and captured individuals relocated to suitable alternative sites on the property **(Commitment 7.7.4f)**.	Unlikely	Severe	Low
	Impact on Quokka.	Unlikely	Severe	Low		Unlikely	Severe	Low
	Impact on Brush-tailed Phascogale.	Almost Certain	Major	High	• Pre-clearance surveys will be undertaken within suitable habitat to determine the presence/absence of targeted vertebrate conservation significance species will not be affected by the planned clearing. If evidence of their presence is found, trapping will be undertaken and captured individuals relocated to suitable alternative sites on the property (**Commitment 7.7.4i)**.	Moderate	Severe	Moderate
	Impact on Southern Brown Bandicoot.	Almost Certain	Major	High	• Much of the KSS property supports low, dense vegetation favoured by the Southern Brown Bandicoot, progressive rehabilitation will encourage colonisation from surrounding vegetative areas.	Unlikely	Severe	Low
	Impact on South-west Carpet Python.	Unlikely	Severe	Low	• No specific management measures are considered necessary to protect the biodiversity of the South-west Carpet Python as has not been found on the KSS property. • Minimising the amount of vegetation that will be cleared at any one time. Progressive clearing of an average of five hectares per year will be carried out in Autumn when species are less likely to be breeding **(Commitment 7.7.4d)**. This will enable any Threatened or Migratory Fauna species to migrate to other areas of the KSS property. • Progressive rehabilitation mining with local provenance seed to encourage colonisation from surrounding vegetative areas, to re-establish vegetation and hence fauna **(Commitment 7.7.4e)**. Rehabilitation will provide restored habitat for recolonisation over time.	Unlikely	Severe	Low
	Iconic species:							
	Impact on Black-striped Jollytail.	Rare	Severe	Low	• The pest species Gambusia negatively impacts frog and possibly Black-striped Jollytail populations. Therefore quarantine of the mine extension dredge ponds to prevent the pest species Gambusia being transferred from the existing mine area will be achieved by **(Commitment 7.7.4j)**: - Cleaning all dredging equipment and pipes prior to relocation to the mine extension area. - Preventing direct pumping of water from existing dredge ponds to the proposed mine extension area ponds. • Funding a two year masters research program for the Black-striped Jollytail **(Commitment 7.7.4k)**. Findings are intended to assist with identification of habitat requirements to assist Jollytail introductions as part of rehabilitation activities.	Rare	Severe	Low

Aspect	Potential Impacts	Risk No Management Measures			Management and Mitigation Measures	Residual Environmental Risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
	Impact on Water Rat.	Rare	Severe	Low	• On-going research by ECU into establishing dense understorey, returning habitat logs and rocks, return of aquatic vertebrate and invertebrate species to the dredge ponds will provide preferred habitat for this native mammal (McCullough et al. 2007; McCullough and Lund, 2008).	Rare	Severe	Low
	Impact on Honey Possum and Western Pygmy Possum.	Likely	Severe	Moderate	• Selection of appropriate species in rehabilitated areas to provide food resource for target Possum species.	Unlikely	Severe	Low
	Other Fauna Species:							
	Impact on CS2 and CS3 species.	Almost Certain	Severe	High	• Relocate habitat logs and brush for ground dwelling fauna. Habitat logs and brush are re-spread in areas undergoing rehabilitation as part of current operations **(Commitment 7.7.4l)**. This practice will continue.	Unlikely	Severe	Low
	Impact on other Migratory Birds.	Unlikely	Severe	Low	• No specific management measures are considered necessary to protect the biodiversity of migratory wetland birds as there is no permanent water in the mine extension area.	Unlikely	Severe	Low
	Impact on EPP4 macroinvertebrates.	Almost Certain	Major	High	• Altered design of mine extension area boundary to reduce the impact on EPP4 and conservation category wetlands. • Further macroinvertebrate and wetland research funded through Edith Cowan University to establish baseline conditions as analogues for future rehabilitation **(Commitment 7.7.4m)**.	Rare	Severe	Low
	Impacts on SRE population.	Almost Certain	Severe	High	• No specific management measures are considered necessary to protect the biodiversity of terrestrial invertebrate species as no species of significance were found.	Unlikely	Severe	Low
	Removal of tree hollows.	Almost Certain	Severe	High	• Relocation of nest hollows in undisturbed areas on the property for use by other bird and mammal species will offset habitat lost through the development **(Commitment 7.7.4n)**.	Unlikely	Severe	Low
	Feral animal introduction/population increase.	Almost Certain	Severe	High	• Foxes, feral cats, rabbits and wild pigs are all present on the KSS property. KSS will continue to undertake feral animal control to minimise impacts from feral animals on native species **(Commitment 7.7.4o)**.	Unlikely	Severe	Low
Heritage Values	Mining may disturb a site of Aboriginal significance.	Rare	Minor	Low	• In the event that an archaeological site or a site of cultural importance to Aboriginal people is discovered, the proponent will immediately inform the DIA **(Commitment 7.8.4a)**.	Rare	Negligible	Low
Noise	Impact on residents.	Unlikely	Minor	Low	• Noise levels will not be increased from that already generated by the existing operation. Noise is not considered to be a key environmental issue for the following reasons: - There will be no net increase in noise from current levels. - There are large distances from the mine extension are to residences. - Low noise levels are emitted from equipment used. • Occupational noise management measures will continue to be applied to operational areas of the mine.	Rare	Negligible	Low
	Impact on fauna.	Unlikely	Negligible	Low		Rare	Negligible	Low
Emissions and Dust	Offsite aesthetics.	Unlikely	Minor	Low	• Disturbance of vegetation will be kept to a minimum **(Commitment 7.10.4a)**. • As the resource is pumped to and from the dredge pond rather than transported in conventional 'haul trucks', the majority of vehicle movement on unsealed internal access roads are 4WD light vehicles **(Commitment 7.10.4b)**. • A water cart is used to suppress dust on all unsealed access roads when required **(Commitment 7.10.4c)**. • A road sweeper periodically sweeps the main apron where loading of vehicles is carried out **(Commitment 7.10.4d)**. • Auto-reticulation is used in stockpile and permanent road areas **(Commitment 7.10.4e)**. • Site personnel will visually monitor dust levels during earth moving activities and dredging operations **(Commitment 7.10.4f)**.	Rare	Minor	Low
	Decrease in vegetation condition.	Moderate	Minor	Low		Unlikely	Minor	Low
	Increase in greenhouse gas emissions.	Moderate	Minor	Low	• Earth moving equipment and the dredge will be regularly maintained and serviced to manufacturer's specifications to ensure efficient running and optimum fuel consumption, thereby minimising exhaust emissions **(Commitment 7.10.4g)**.	Moderate	Minor	Low

Aspect	Potential Impacts	Risk No Management Measures			Management and Mitigation Measures	Residual Environmental Risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
Visual Amenity	Offsite aesthetics.	Unlikely	Minor	Low	• The large distances to residences and main roads from the mine extension area. There are no dwellings on properties to the west of the KSS property boundary. • A 20 metre vegetated setback will be maintained along the property boundary. This has been provided to allow firebreak construction and perimeter access around the property and as a visual screen for adjacent properties.	Rare	Negligible	Low
	Light pollution.	Unlikely	Minor	Low		Rare	Negligible	Low
Road Transportation/Traffic	Noise.	Almost Certain	Minor	Moderate	• Road train transport has not been an issue with the public in the past. • A 12 kilometre private haul road has been constructed to minimise disturbance to local residents. All trucks are well maintained and operated by licensed operators.	Likely	Negligible	Low
	Product spillage.	Unlikely	Minor	Low	• If product is spilled it will be remediated immediately **(Commitment 7.12.3a)**.	Rare	Negligible	Low
	Fauna deaths.	Moderate	Minor	Low	• KSS employees are committed to driving to the designating speed limits to reduce potential for fauna deaths **(Commitment 7.12.3b)**.	Moderate	Minor	Low
	Increase in dust emissions.	Likely	Minor	Moderate	• Transport is not considered a key environmental factor as it occurs on sealed roads.	Unlikely	Negligible	Low
	Increase in greenhouse gas emissions.	Almost Certain	Minor	Moderate	• All trucks are well maintained and operated by licensed operators. • The mine extension will not increase silica sand truck traffic above existing approved levels, but will extend the number of years that trucks will be travelling this route.	Almost Certain	Minor	Low

APPENDIX 18:
KEMERTON SILICA SAND
REPORT FOR PROPOSED WESTERN EXTENSION
IMPACT ASSESSMENT OF MINING ON GROUNDWATER
MAY 2008
GHD

Kemerton Silica Sand

Report for Proposed Western Extension

Impact Assessment of Mining on Groundwater

May 2008

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Executive Summary

Kemerton Silica Sand Pty Ltd (KSS) is currently extracting silica sand from surface pits and it is proposing to extend its operations to a proposed new Western Extension Area.

As part of the review of environmental assessment and potential environmental impacts of the proposed western extension site, Kemerton Silica Sand was requested to develop an investigation of the groundwater patterns and the interface need to be extended to cover the proposed new mine areas. Also a conservative Excel based geochemical modelling approach of post-mining salinity evolution in the flow-through pit-lake was proposed.

Main objectives of this investigation included a groundwater modelling of the impact of current mining on local groundwater levels and post-mining salinity evolution and impacts of the proposed New Western Extension on the wetlands.

The results of the modelling show that a maximum rise in groundwater level in wetland 4 area due to expansion of proposed mine is in the order of 0.1m. This rise in groundwater level is unlikely to cause adverse impact in the surrounding environment as the natural variations in the groundwater level is in the order of 1.5m.

The post-mining groundwater salinity is expected to rise from an initial value of 300 mg/L to reach a near equilibrium concentration of about 1000 mg/L after 85 years. This, if remediation measures are in place, would represent lower risk of contamination to the surrounding environment and groundwater.

1. Introduction

Kemerton Silica Sand Pty Ltd (KSS) is curretnly silica sand from surface pits at a site in the Kemerton Industrial Park approximately 27 km north-northeast of Bunbury. The mine has been operating for more than 10 years and it is proposing to extract silica sand from the new Western Extension Area (Figure 1).

Previous modelling of the groundwater for the existing mine areas at KSS was completed by GHD in 2002. In addition to 2002, GHD developed a groundwater model for the KSS and undertook modelling for the proposed Western extension. Three-dimensional MODFLOW based modelling was also completed as part of the design of the bunds for the southern expansion of the main dredge pond.

As part of the review of environmental assessment and potential environmental impacts of the proposed western extension site, Kemerton Silica Sand requested GHD to complete an assessment of the local and regional hydrogeology. This investigation purposed that existing model set up using the MODFLOW modelling package with the GMS (Groundwater Modelling System) interface need to be extended to encompass the proposed new mine areas, thereby reducing costs to the client. Also a conservative Excel based geochemical modelling approach of the salinity evolution in the flow-through pit-lake was proposed.

Overall objectives of this investigation are:

- Task 1: Groundwater Modelling of the Impact of current mining on local groundwater levels and salinity during and post mining
- Task 2: Groundwater Modelling of the Impact of proposed Western Extension on Local Groundwater Levels and salinity during and post mining.
- Task 3: Impact Assessment of Bore groundwater abstraction, reuse of dredge pond water, removal of coffee rock, and
- Task 4: Impacts of New Western Extension on the wetlands.

2. Climate

The Kemerton area has a Mediterranean-type climate with cool wet winters and hot dry summers. Climatic data, including rainfall, are collected at three sites these being Parkfield, Wokalup Agricultural Research Station (Bureau of Meteorology Station Number 9642) and at the mine site itself. Evaporation data are available only for Wokalup (Table 1).

Although average annual rainfall generally increases towards the east, across the coastal plain, average rainfall records for the 2006-2007 at all stations is well below the long-term average values. Rainfall at the mine site during July 2006 to June 2007 was 669.0 mm (Rockwater 2007) which is about 23% lower that the long-term average value of 863.4 mm. Data in Table 1 also illustrates seasonality of rainfall with an approximate 78% of the rain occurring during the five months from May to September inclusive. Long-term average monthly rainfall at Wokalup exceeds average monthly evaporation only during the four months May to August (Table 1) and higher evaporation correspond with the periods of lower rainfall.

Table 1 Rainfall and Evaporation

	Wokalup Agricultural Research Station			Parkfield		Kemerton Mine site	
	Long-Term Average Rainfall	Rainfall 2006/2007	Average Evaporation	Long-Term Average Rainfall	Rainfall 2006/ 2007	Long-Term Average Rainfall	Rainfall 2006/2007
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
January	**14.7**	**24.8**	**280.4**	**11.6**	**28.8**	**17.1**	**13.8**
February	**6.9**	**7.1**	**242.3**	**12.8**	**3.0**	**7.7**	**29.3**
March	**21.5**	**14.3**	**209.6**	**21.8**	**11.8**	**13.2**	**5.0**
April	**37.4**	**35.3**	**129.9**	**38.3**	**35.4**	**39.3**	**13.3**
May	**108.0**	**57.55**	**83.9**	**116.8**	**34.6**	**127.6**	**41.3**
Jun	**144.7**	**61**	**63.9**	**173.8**	**98.0**	**149.7**	**54.0**
Jul	**151.4**	**139.7**	**64.0**	**164.3**	**122.8**	**156.6**	**26.5**
August	**146.7**	**168.2**	**76.3**	**114.7**	**137.8**	**150.2**	**169.5**
September	**100.9**	**60**	**96.2**	**81.3**	**43.8**	**101.9**	**180.0**
October	**49.1**	**23.9**	**137.5**	**50.5**	**19.2**	**57.6**	**63.0**
November	**35.1**	**21.9**	**179.0**	**26.5**	**24.7**	**31.6**	**45.0**
December	**12.3**	**nr**	**246.7**	**12**	**nr**	**10.9**	**28.5**
Annual	**828.7**	**613.8**	**1809.7**	**824.4**	**559.8**	**863.4**	**669.0**

3. Hydrogeology

3.1 Physiography

Kemerton Silica Sand Pty Ltd is located on the Swan Coastal Plain within the geomorphological unit known as the Bassendean Dune System. The mine area has a low irregular topography and the dune system in the area forms a north trending strip approximately three kilometres wide between the Pinjarra Plain to the east and the Spearwood Dune system to the west. Dune crests have an elevation up to 25 mAHD whereas the inter-dunes have elevations of approximately 10 mAHD. Dune crests in the Spearwood Dune System reach elevations of approximately 50 mAHD immediately west of the property.

The Wellesley River flows towards the southwest on the Pinjarra Plain just east of the mine site.

3.2 Geology

The mine-site is located within the Perth Basin and is underlain by superficial sediments of Quaternary-Tertiary age which rest unconformably on the Leederville Formation at approximately 30 metres depth. The Leederville Formation (Cretaceous age) is approximately 120 metres thick beneath the site and rests unconformably on the Cockleshell Gully Formation (Jurassic age). The superficial sediments comprise fine to medium grained quartz sand, with minor clay, silt and peat layers (Bassendean Sand), overlying a basal approximately 5 to 10 metres of silty sand and limestone (Ascot Formation). The Leederville Formation comprises siltstone, shale and sandstone.

3.3 Hydrogeology

The superficial sediments contain an unconfined to confined aquifer system, termed the superficial aquifer (Davidson, 1995), which extends between the Darling Scarp and the coast. This aquifer has variable hydraulic conductivity with the underlying Leederville aquifer depending on the permeability of the juxtaposed sediments. Deeney (1989b) suggests there is leakage of groundwater from the superficial aquifer to the Leederville aquifer.

The mine area is within the Serpentine groundwater flow system near the crest of the Mialla mound (Deeney, 1989a). Recharge to the aquifer system is mostly by direct infiltration of rainfall with particular response to more intense or prolonged events. The watertable fluctuates seasonally and occurs at depths of more than 10 metres under topographically higher areas and it intersects the surface in several topographically lower areas where wetlands occur. Groundwater flows South-easterly from the top of the Mialla mound towards the Wellesley River/Magosteen Drain, within the Myalup groundwater flow system (Deeney, 1989a). Groundwater losses occurs via discharges into the river, evapotranpiration mainly from wetlands, leakage into the underlying

Leederville Aquifer and potential south-westwards movement into the superficial aquifer.

3.4 Groundwater Hydrogeochemistry

Groundwater chemical characteristics within the vicinity of the proposed site are highly variable. Whilst average pH ranges from a minimum of 4.25 (KMB1 bore) to a maximum of 7.05 (KMB4 bore), average TDS (total dissolved solids) varies from less than 100 mg/L to approximately 750 mg/L. Higher salinity groundwater occurs near the Plant site, namely KMB7 and KMB14 bores. Chloride with an average 101 mg/L is relatively high and sulphate is relatively low with an average 44.88 mg/L. Proposed flow-through-pit up-gradient groundwater are characterised by water quality from KMB1, KMB2 and KMB14 bores. These are of low salinity with relatively weak acid pH. KMB1 bore presented the lowest pH values of 3.4 and 5.1 respectively.

4. Groundwater-Flow Model

4.1 Numerical Model and Model Grid

The numerical model was constructed using the GMS (Groundwater Modelling System) interface to MODFLOW (McDonald and Harbaugh, 1988).

The model domain is bounded to the east by the Wellesley River, to the north by the Harvey River Diversion Drain and to the west by a north-trending line that includes the eastern shoreline of Myalup Swamp, Mialla Lagoon and associated wetlands. It covers some 74 km^2. The model domain has been descretised into a regular grid of 9516 cells with dimensions 100 metres x 100 metres. Model set up and calibration has been described in detail in the report (GHD 2002). A brief summary of the model set up is given below.

4.2 Model Layers

The numerical model represents the conceptual model vertically as four layers:

Layer 1 – extends from the ground surface and includes the upper approximately 10 metres of the Bassendean Sand. Layer 1 contains the watertable, the wetlands and the Wellesley River along the eastern boundary.

Layer 2 – includes the remaining section of the Bassendean Sand and is approximately 10 metres thick. The active mine areas (dredge ponds) and the lakes that remain after mining is completed extend over model layers 1 and 2.

Layer 3 – includes the Ascot Formation at the base of the superficial aquifer and is approximately 10 metres thick. The base of layer 3 is defined by the base of the superficial formations as mapped by Deeney (1989a). Production bores KMB7 and KMB14 are screened over layers 2 and 3 in the model.

Layer 4 – includes the upper 120 metres of the Leederville Formation.

The four layers of the model include 38,064 three-dimensional cells.

4.3 Boundary Conditions

No-flow boundaries in the model are aligned with the Harvey River Diversion Drain at the north and along an arbitrary boundary at the south at sufficient distance to have no effect on the model simulations in the area of interest. The west boundary of the model is a constant-head boundary in all model layers where the groundwater heads are based on lake and ground-surface elevations, and data contained in Deeney (1989a) ranging from 5.0 mAHD at the north to 7.0 mAHD at the south. The east model boundary is a constant-head boundary in Layer 1, with groundwater heads derived from river and ground-surface elevations, and data contained in Deeney (1989a), and no-flow boundaries in Layers 2, 3 and 4.

4.4 Rainfall, Evapotranspiration and Runoff

Average monthly rainfall was used for the predictive runs. Evaporation from open water surface was set as 75% of the pan evaporation rate (after applying a correction of –7% to the pan evaporation data to allow for a bird guard). Evapotranspiration was varied linearly in the model according to the depth to the watertable with the rate being reduced as watertable depth increased.

An assessment of runoff for the Kemerton area was derived from a gauged catchment located 12kms directly north of the minesite within the Bassendean Dune System. A yield analysis, using monthly stream gauging data for Merredith Drain at Johnston Road and monthly rainfall data for a meteorological station within the catchment, determined average runoff to be 12.2% of rainfall. Net rainfall recharge in the model is about 20% of rainfall, which is within the range of values (7% to 36%) estimated by Davidson (1995) for Bassendean Sand areas of the superficial aquifer. Average evapotranspiration over the model domain was 560 mm/year.

Drainage from the wetland areas after water levels attain the maximum elevations is simulated by including drain cells to remove water from the model and thereby maintain constant model-predicted maximum water levels.

4.5 Hydraulic Parameters

Aquifer properties were obtained from ranges for regional values provided for the superficial and Leederville aquifers in Deeney (1989a) and Davidson (1995). An anisotropy ratio of 10 between horizontal and vertical hydraulic conductivities was applied to account for lithological and grain-size layering within the aquifers. The adopted values were optimised during the model calibration and are listed in Table 2. Void has been modelled as having hydraulic conductivity of 1000m/d and specific yield of 1.0.

4.6 Model Calibration

Calibration of the numerical model involved undertaking simulations to obtain modelled groundwater levels and comparing the modelled groundwater levels with measured groundwater levels in the monitoring sites. Monthly water level monitoring data are available for the superficial aquifer only from Kemerton Silica Sand Pty Ltd bores and wetlands on the Kemerton Silica Sand Pty Ltd property. The current model calibration period is from 2002 to 2007. Current calibration is an extension of the previous calibration from 1996 to 2002 (GHD 2002). Hydrographs of groundwater levels generated from the calibrated model indicate satisfactory agreements at most monitor bores and wetlands (Figure 1a and 1b). The model data show acceptable fluctuations in response to seasonal variations of rainfall and evapotranspiration. Relatively poorer agreements between model-predicted and measured water levels can be seen for wetland monitoring site WL3, WL4, WL6 and WL7. The reason for this is due to the fact, measured water level are the surface water levels in the pond and modelled are for the groundwater.

Table 2 Model used hydraulic parameters

Model Layer	K_x (m/d)	K_z (m/d)	S_y (dimensionless)	S_s (1/m)
Layer 1 – unconfined superficial aquifer (Bassendean Sand)	15	1.5	0.25	–
Layer 2 – confined superficial aquifer (Bassendean Sand)	15	1.5	–	0.001
Layer 3 – confined superficial aquifer (Ascot Formation)	8.5	0.85	–	0.001
Layer 4 – confined Leederville aquifer	0.05	0.0005	–	0.0001

Notes: K_x = horizontal hydraulic conductivity

K_x = vertical hydraulic conductivity

S_y = specific yield

S_s = specific storage

– = not required

5. Predictive Simulations

5.1 Modelled Scenarios

The period of predictive simulations is from 2008 to 2057. To allow more accurate modelling of the gradual increase in area of each new dredge pond as mining proceeds, the whole simulation period is represented by a number of models. Individual model timeframes were restricted to approximately 5 years and the sizes of the dredge ponds were increased incrementally in zones for each subsequent model up to the final pond size. Consequently, the 50 years that are estimated for the completion of mining of the Western Extension has been divided into 10 blocks according to mine plans provided by KSS.

Groundwater flow occurs into the ponds and lakes from the up-hydraulic-gradient side and discharge occurs on the down-hydraulic gradient side so that the ponds and lakes are simulated in the model as 'flow-through lakes' as defined by Davidson (1995).

The modelling scenarios and the estimated mining schedule are illustrated in Figure 3.

5.1.1 Base Case

Predictive model runs were undertaken to provide an indication of the effects of changes in the locations of the dredge pond and the inclusion of areas of open water after completion of mining in each proposed area. Changes in the watertable were assessed by comparing model-predicted watertable with a 'base case' watertable. Watertable at the end of December for each block were used for the comparisons.

5.1.2 Western Extension

Mining of the Western Extension is estimated to be completed at the end of 2057 (50 years after the beginning). The model-predicted watertable for the end of December 2057 is illustrated in Figure 4. Model predicted change in water levels after the completion of each five yearly block are presented in Figures 5a to Figure 5j.

The modelling results show that:

» At the end of block 1 mining the maximum predicted drop in water level at the pit lake is about 0.5m and change in water level in wetland 4 is negligible (less than 0.1m).

» At the end of block 2 mining the maximum predicted drop in water level at the pit lake is about 1.8m and change in water level in wetland 4 is negligible (less than 0.1m).

» At the end of block 3 mining the maximum predicted drop in water level at the pit lake is about 1.6m and change in water level in wetland 4 is negligible (less than 0.1m).

» At the end of block 4 mining the maximum predicted drop in water level at the pit lake is about 1.5m and change in water level in wetland 4 is negligible (less than 0.1m).

- At the end of block 5 mining the maximum predicted drop in water level at the pit lake is about 1.3m and change in water level in wetland 4 is negligible (less than 0.1m).
- At the end of block 6 mining the maximum predicted drop in water level at the pit lake is about 1.3m and change in water level in wetland 4 is negligible (less than 0.1m).
- At the end of block 7 mining the maximum predicted drop in water level at the pit lake is about 1.3m and change in water level in wetland 4 is negligible (less than 0.1m).
- At the end of block 8 mining the maximum predicted drop in water level at the pit lake is about 1.2m and change in water level in wetland 4 is negligible (less than 0.1m).
- At the end of block 9 mining the maximum predicted drop in water level at the pit lake is about 1.2m and change in water level in wetland 4 is negligible (less than 0.1m).
- At the end of block 10 mining the maximum predicted drop in water level at the pit lake is about 1.2m and change in water level in wetland 4 is negligible (in the order of 0.1m increase).

The data indicate the following changes from the 'base case' watertable and the model-predicted watertable for the end of December 2057.

- The affected area at the end of mining compared to the 'base case' (reductions of more than 0.2 metres) extends northwest, southwest and west for approximately 1500 metres from the shoreline. A maximum reduction of approximately 1.2m is expected to occur along the western end of predicted pond.
- The water level towards the east of the mining area is predicted to rise (a maximum rise of 0.8m is expected)
- The lake level in West Pond is about 14 mAHD.
- The water level at the wetland 4 is expected to rise by less than 0.1m at the end of 50 year (end of block 10 mining).

5.1.3 Post-mining Modelling (ten years following mine completion)

The model was run for an additional 10 years following mine completion. The model predicted watertable up to the end of December 2067 (Figure 6), when groundwater dynamic equilibrium after the mining is re-established. The water level in Western Extension Pond is approximately 14 mAHD. Water level in the pond is expected to decrease by a maximum value of 1.2m towards the western end of the pond and increase by a maximum value of 1.0m towards to eastern end of the pond at the end 10 years (Figure 7) after the completion of mining as compared pre-mining conditions. Near wetland 4, water levels are expected to rise by about 0.1m.

Water levels in the lakes that are established as a result of the mining are constant with seasonal fluctuations over a smaller range of elevations than the predicted 'base case’ watertable for the same areas in the model. Lake water levels have an overriding effect on watertable levels in adjacent areas. There is a net discharge of water from the model in the lake areas due to increased water losses by evaporation from the open water compared to water losses by evapotranspiration from the same areas in the ‘base case’, which have below-ground watertables.

6. Groundwater Salinity

The proposed flow-through-pit would contain water body with continuous flow direction, preferentially south-south-easterly. The system would principally allow direct input from groundwaters and rainfall and water losses through evaporation and seepages into the groundwater system. Although this water body system would experience water column mixing through various environmental forces such as wind and thermal gradients, water chemistry is assumed to remain in a more conservative state and experience seasonal changes due to chemical load in input water sources only.

6.1 Assumption made

Considering the above observation, it is assumed the flow-through-pit-lake water composition and quality will result from simple mixing processes. Accordingly the model used to predict the long term “pit-lake” water quality and their potential effects on the surrounding environment is a simple Excel based mixing interpretation. Although the theoretical approach is applied to qualitatively interpret the chemistry of a solution resulting from mixing of different waters with different concentrations, uncertainty generated by water velocities and physical-chemical processes (e.g., no reaction sources, sink terms such as precipitation, etc) occurring within the flow-through-system still remains for consideration.

6.2 Data input

Initial background water composition and quality of the flow-through-pit-lake is assumed to be a mixture of up-gradient and down-gradient groundwaters and rainfall. Groundwaters are characterised by relatively low pH and low salinity levels. However, a previous study by Rockwater (2007) indicated that down-gradient zones contain relatively brackish groundwaters. The brackish water zones were reported to be caused by evaporative concentration of salts in the wetlands and the subsequent seepage of more saline water to the groundwater on the down-hydraulic-gradient side.

Groundwater infiltration into the flow-through-pit-lake is assumed to only derive from up-gradient zones.

6.3 Results and discussion

Input flow-through-pit-lake background water quality is relatively good with an average pH of 6.0 and an average salinity value of 248.9 mg/L. Predicted groundwater quality indicates that salinity and selected conservative ions in the proposed flow-through-pit-lake (Figure 8) will increase with time. Whilst increasing pattern of salinity especially following year 60 would decrease to become almost in equilibrium after 85 years, chloride and sulphate will continue to steadily increase with time. pH value is also relatively increasing with time but this, depending on the groundwater recharge and new freshwater input, may remain in equilibrium with values slightly above circumneutrality.

7. Conclusions and recommendations

- An existing groundwater flow model of Kemerton Study Area set up by GHD in 2002 has been used for the prediction of the potential impact on the surrounding aquifer and wetlands. The existing model has been extended in calibration for the period of 2002 to 2007. The results of the modelling show that a maximum rise in groundwater level in wetland 4 area due to proposed mining presented in Figure 2 is in the order of 0.1m. This rise in groundwater level is unlikely to cause adverse impact in the environment surrounding the wetland as the natural variations in the groundwater level is in the order of 1.5m.
- The post-mining groundwater salinity (in terms of TDS) is expected to rise from an initial value of 300 mg/L to reach a near equilibrium concentration of about 1000 mg/L after 85 years. However as results are derived from a very conservative a simple mixing approach, pit-lake quality will need to be interpreted using a more dynamic hydro-geochemical modelling approach. This should consider to interpret before-, during- and post-mining water quality evolution.
- Although it is not expected substantial changes on groundwater patterns and quality, it is recommended to develop a more focused (e.g., monthly water levels and quarterly water quality) groundwater monitoring program around the pit and wetland systems.
- Modelling is based on information supplied by Kemerton Silica Sands. The hydrogeological information has not been independently verified. Ongoing long term monitoring, updating and recalibration of the groundwater model during the life of mine will be necessary to increase the confidence and accuracy of the predictions.

8. References

DAVIDSON, W.A., 1995, Hydrogeology and groundwater resources of the Perth Region Western Australia: Western Australia Geological Survey, Bulletin 132, 257 p.

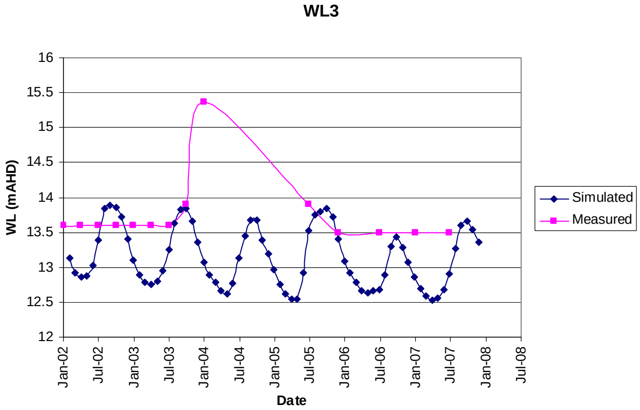
DEENEY, A.C., 1989a, Geology and groundwater resources of the superficial formations between Pinjarra and Bunbury, Perth Basin: Western Australia Geological Survey, Report 26, Professional Papers, p. 31-57.

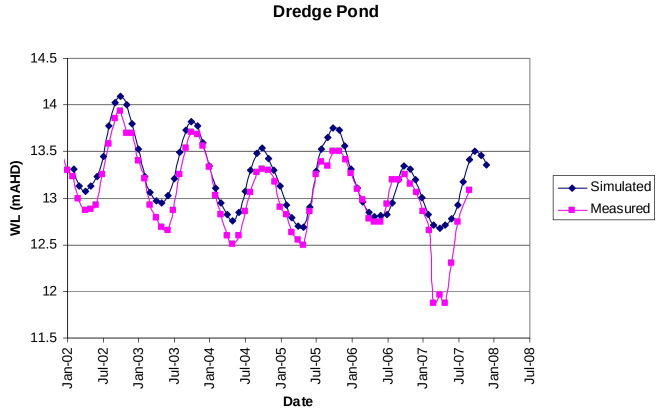
DEENEY, A.C. 1989b, Hydrogeology of the Binningup borehole line, Perth Basin: Western Australia Geological Survey, Report 26, Professional Papers, p. 58-68.

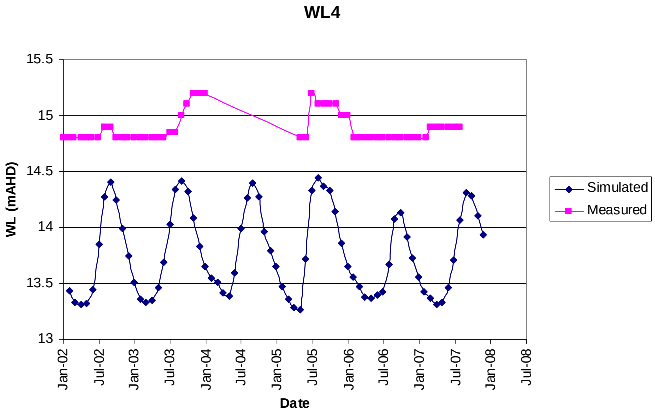
MCDONALD, M.G. and HARBAUGH, A.W., 1988, A modular three-dimensional finite-difference ground-water flow model: USGS Techniques of Water Resources Investigations, Book 6, Chapter A1, Washington DC.

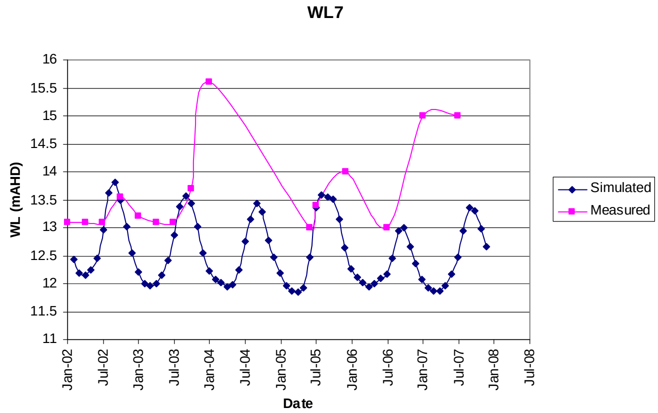
ROCKWATER, 2007, Groundwater monitoring review for July 2006 to June 2007 (GWL No. 60367): Draft report prepared for Kemerton Silica Sand Pty Ltd (unpublished).

Figure 1 Exiting pond and proposed western extension









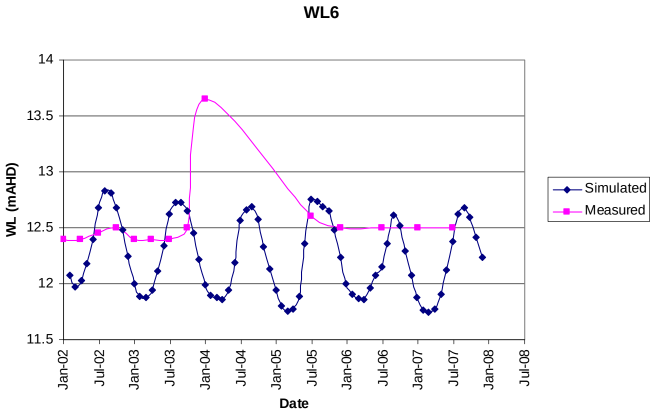


Figure 2A Calibration: groundwater levels

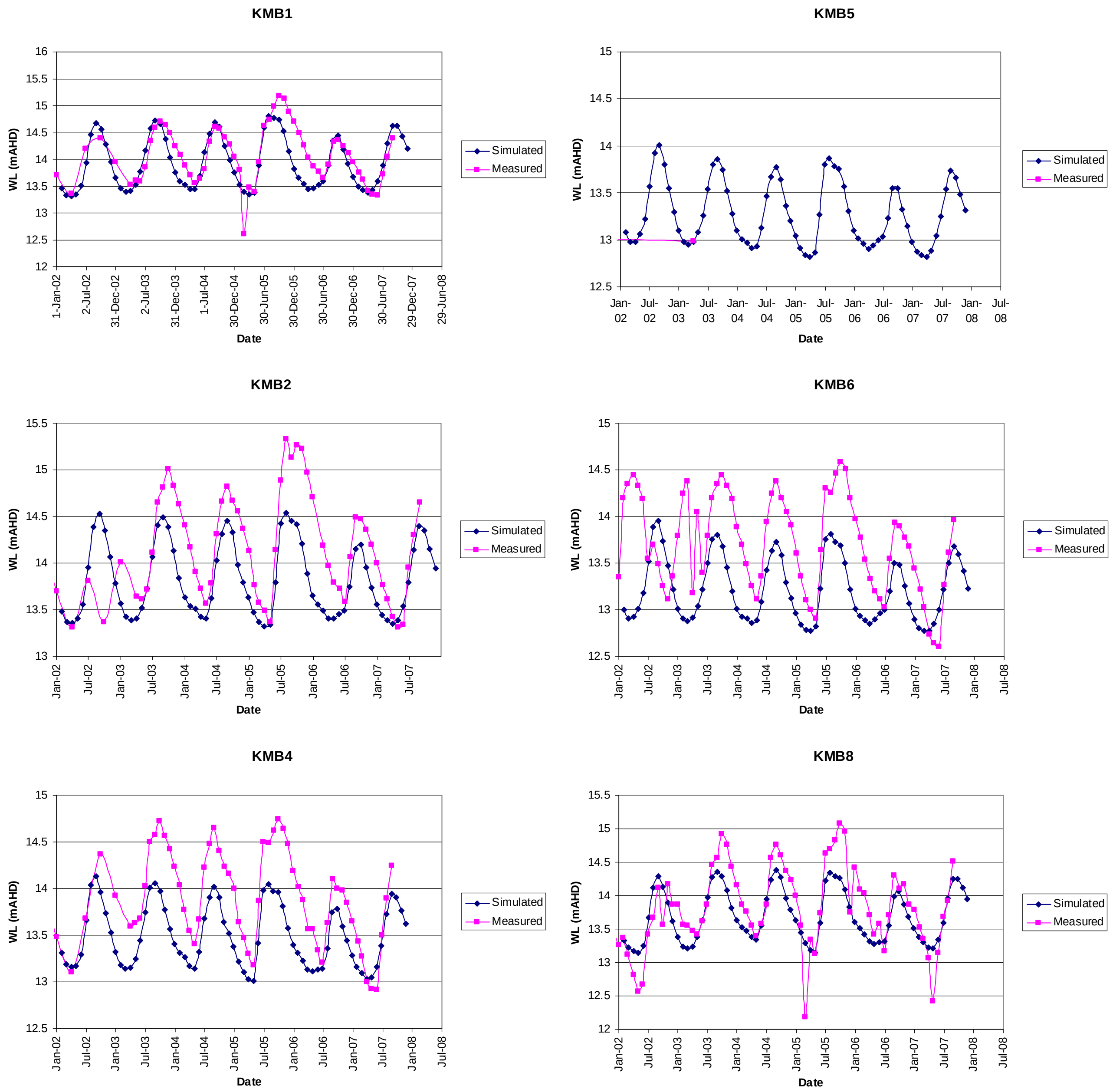


Figure 2B Calibration: groundwater levels

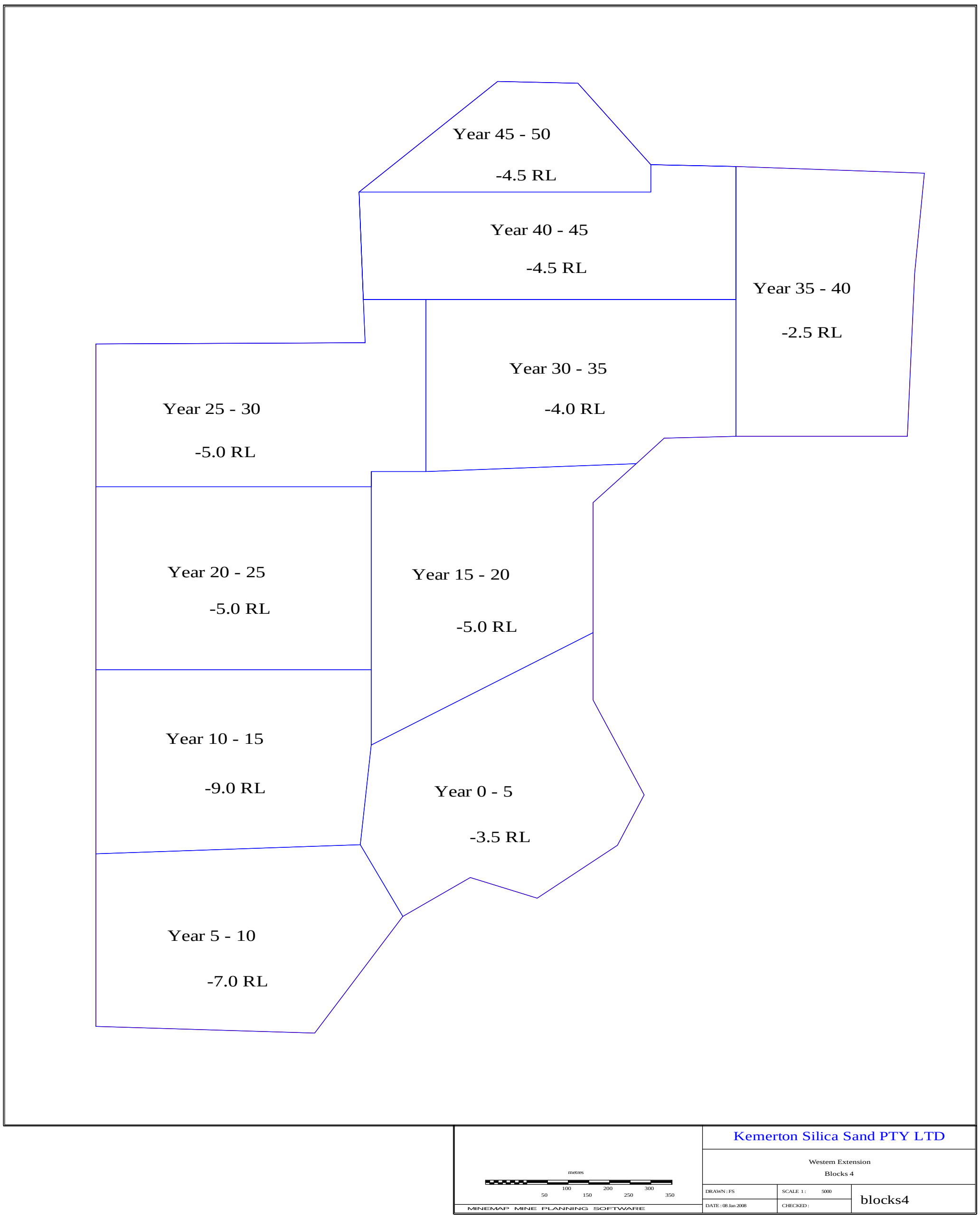


Figure 3 Proposed Mine Plan supplied by KSS

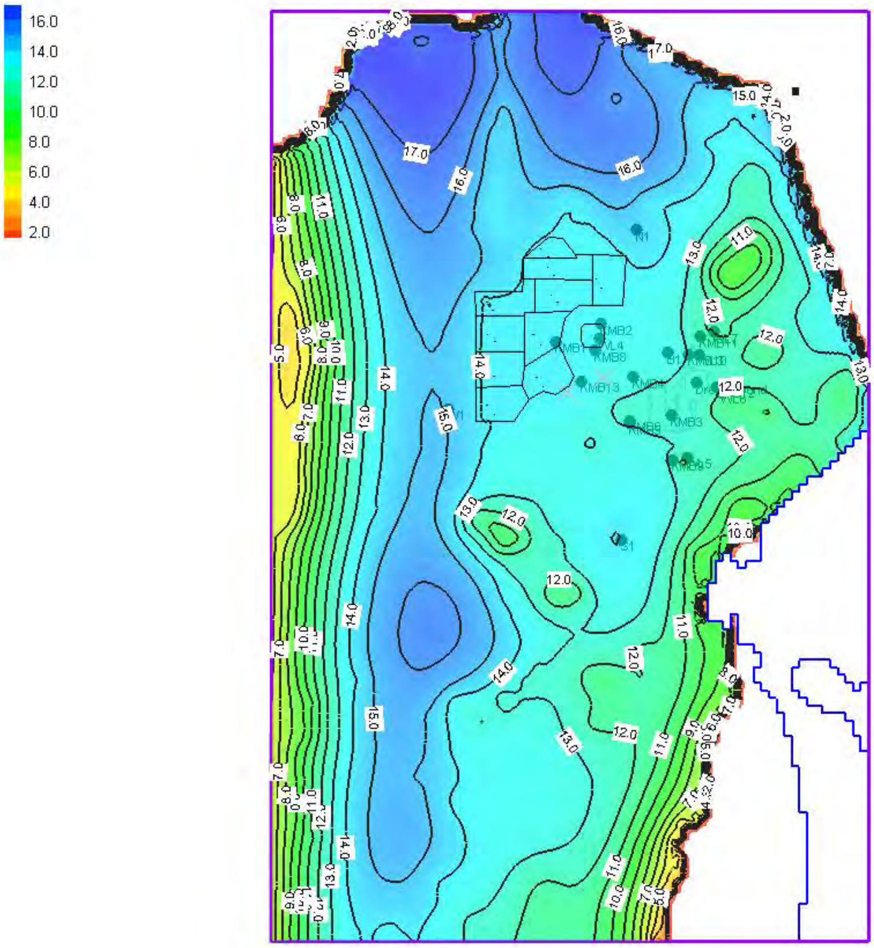


Figure 4 Model predicted groundwater levels at the end of block 10 mining (head values in mAHD)

Figure 5A: Block 1 impact: Model predicted change in groundwater levels at the end of block 1 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels)

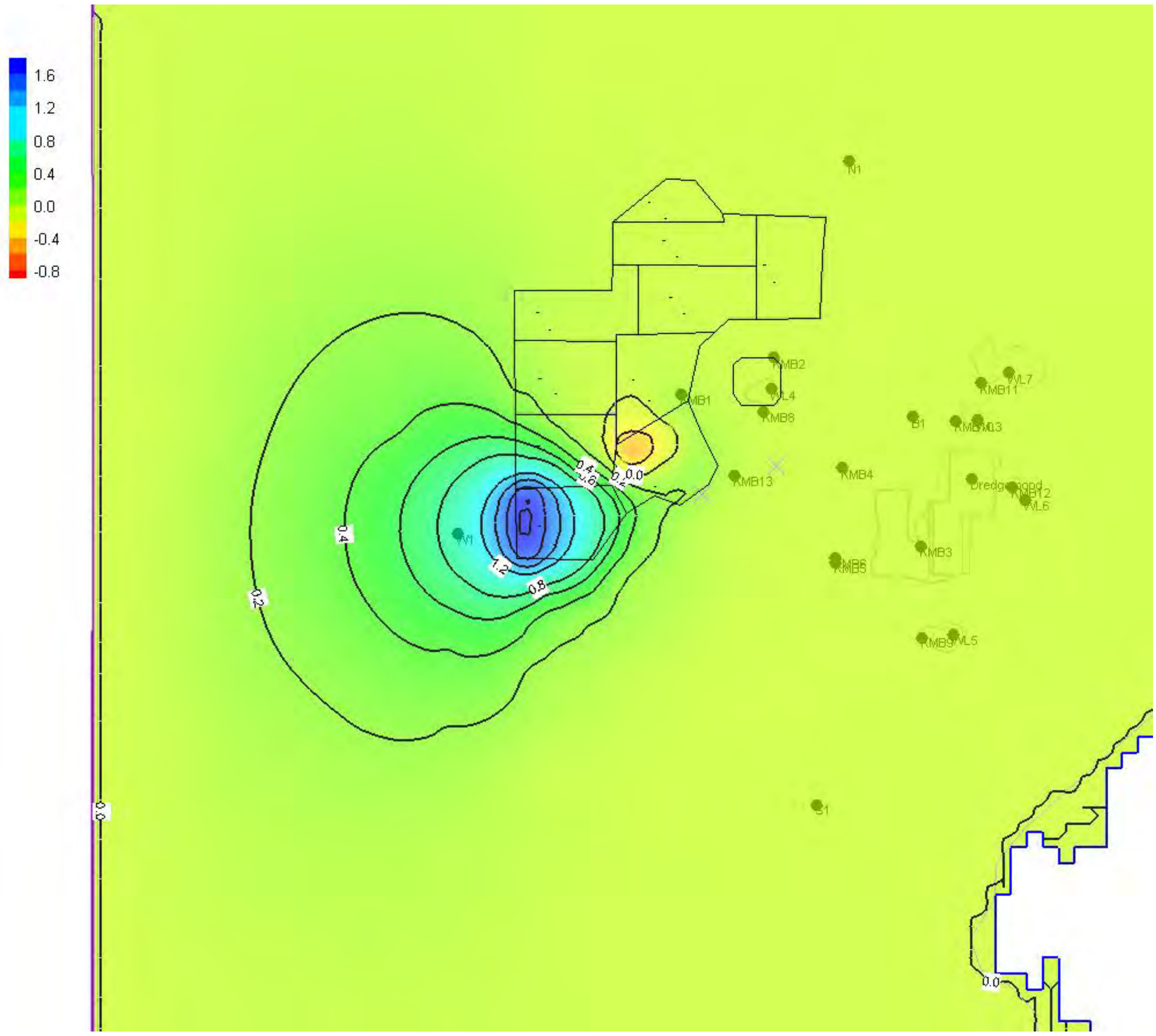


Figure 5B Block 2 impact: Model predicted change in groundwater levels at the end of block 2 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels)

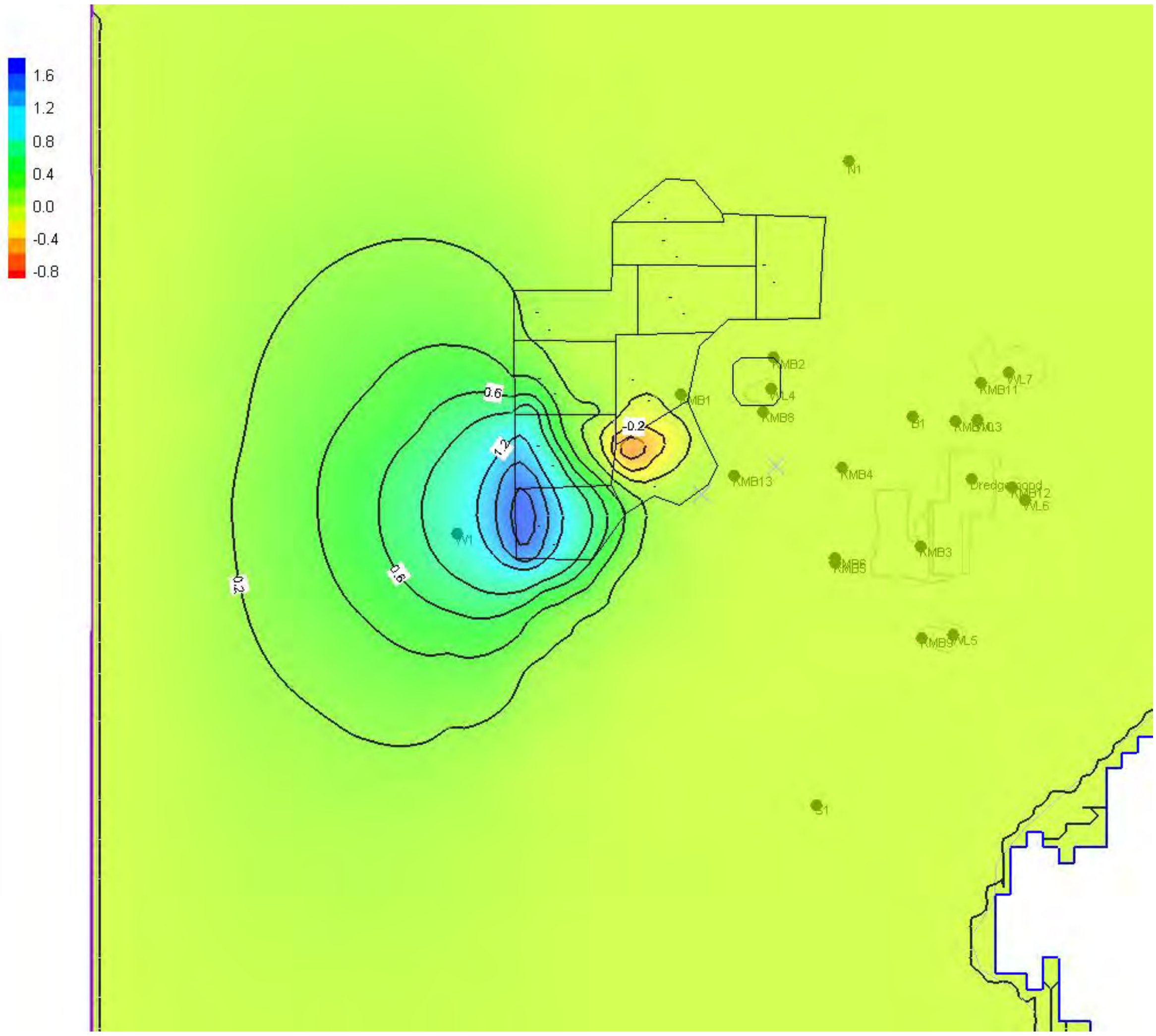


Figure 5C Block 3 impact: Model predicted change in groundwater levels at the end of block 3 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels).

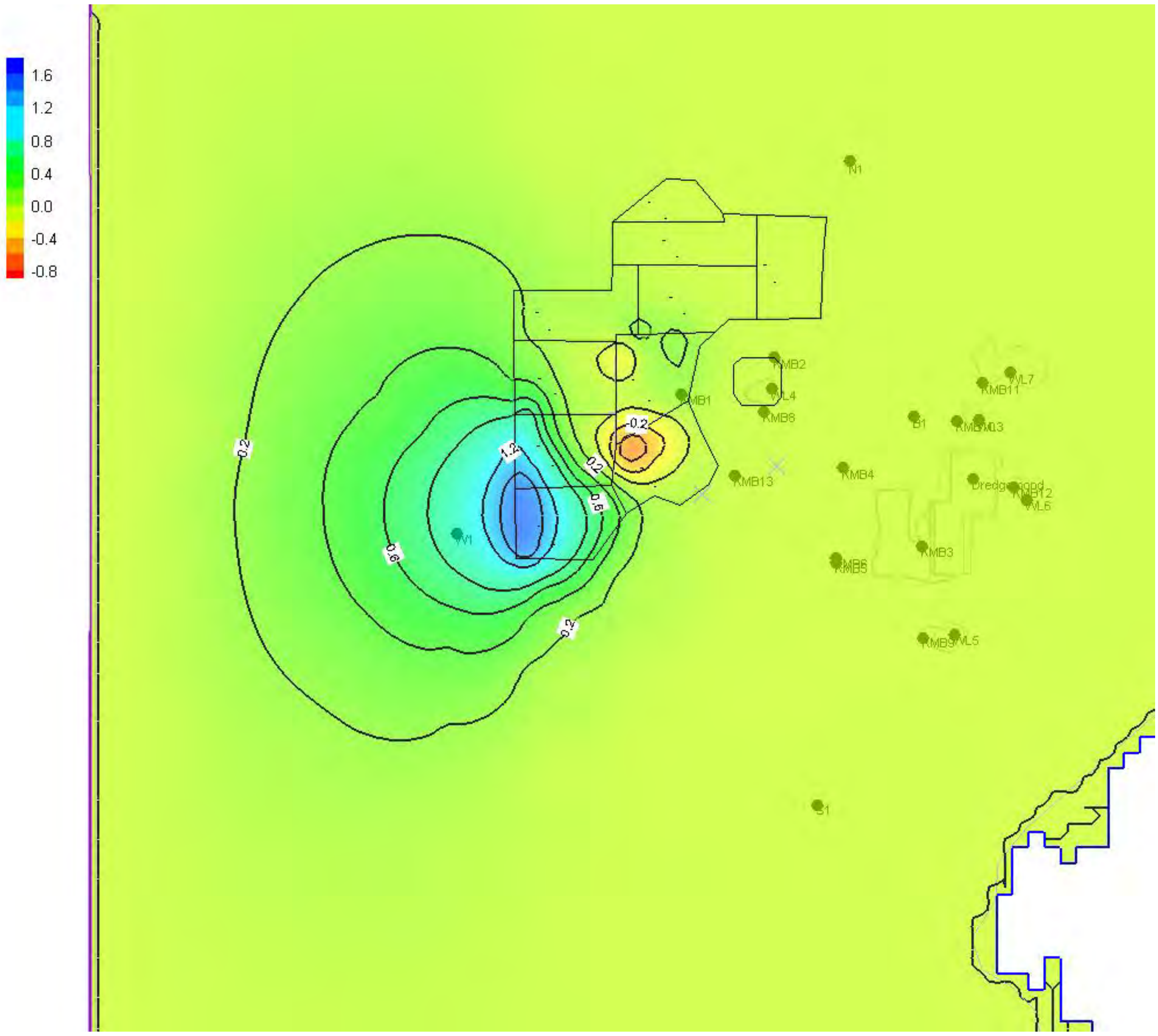


Figure 5D Block 4 Impact: Model predicted change in groundwater levels at the end of block 4 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels).

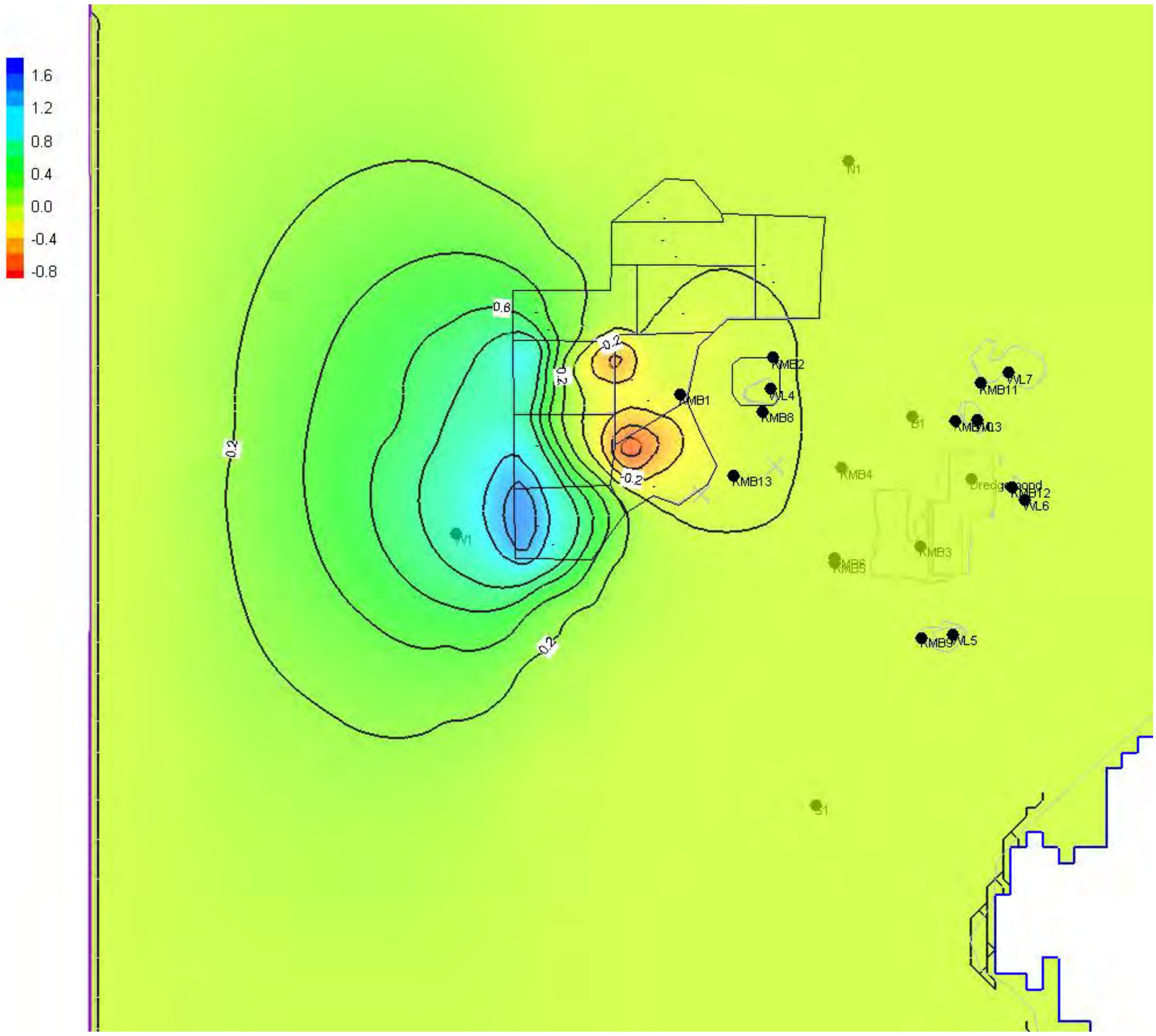


Figure 5E Block 5 Impact: Model predicted change in groundwater levels at the end of block 5 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels).

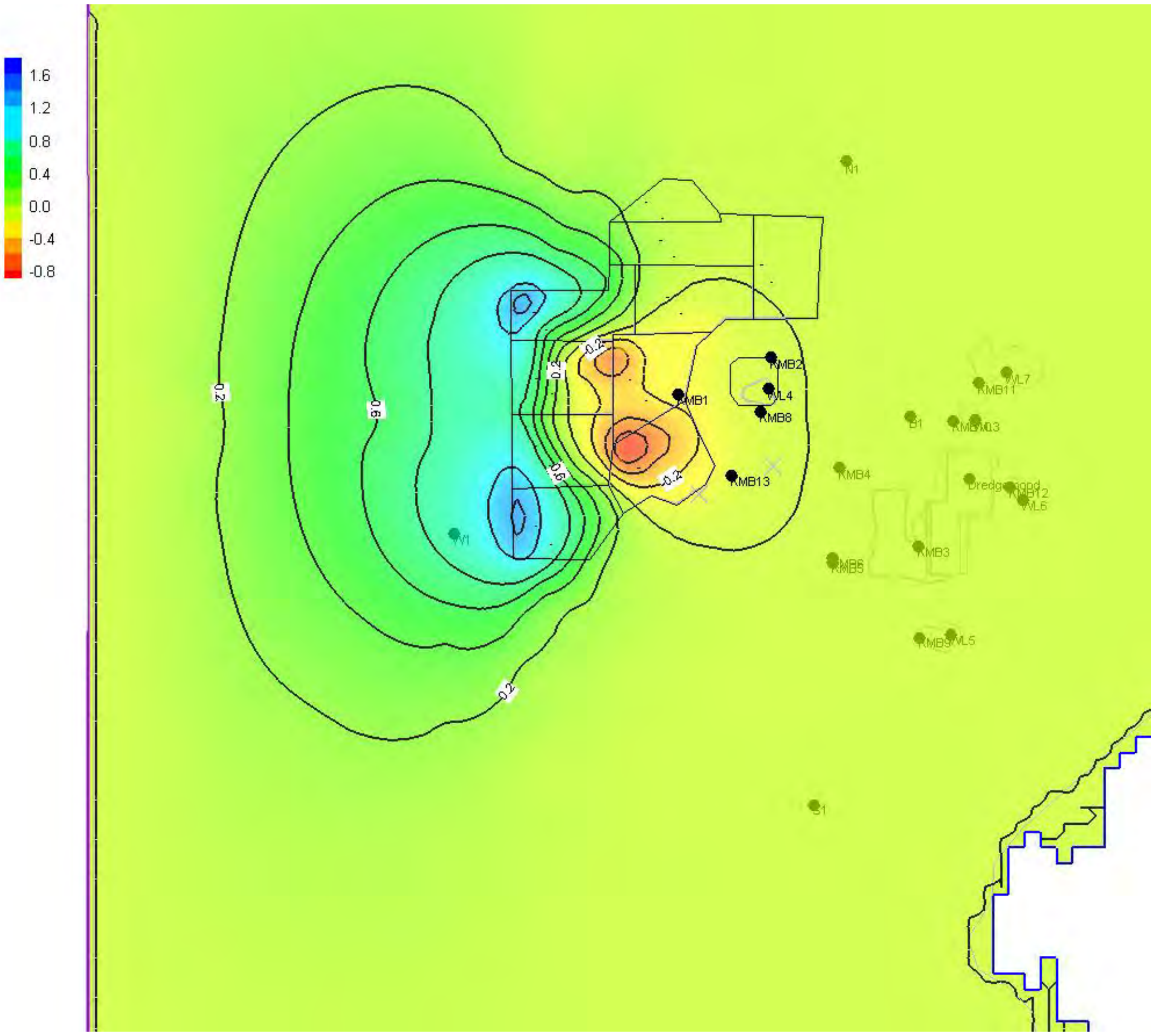


Figure 5 F Block 6 Impact: Model predicted change in groundwater levels at the end of block 6 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels).

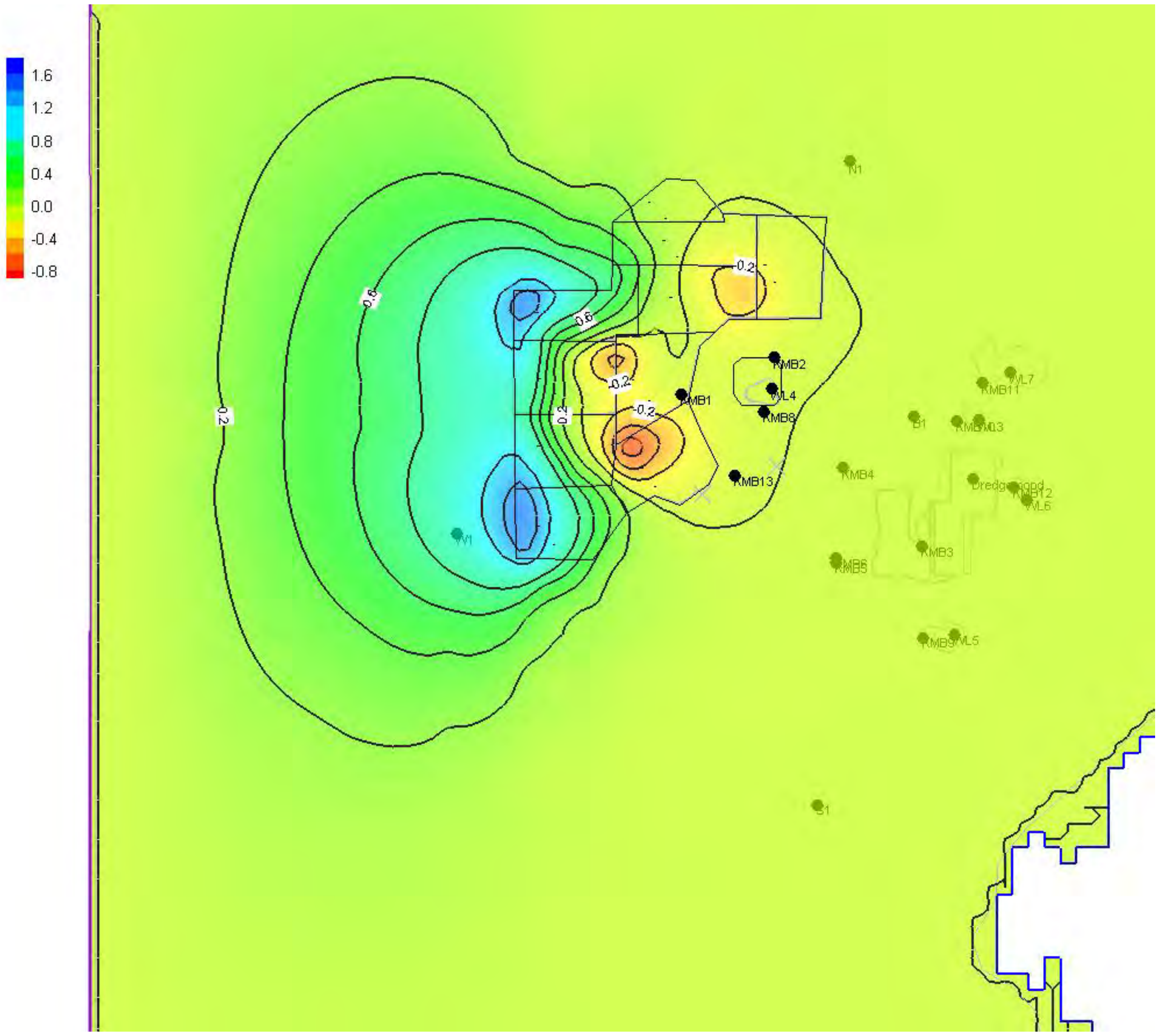


Figure 5G Block 7 Impact: Model predicted change in groundwater levels at the end of block 7 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels).

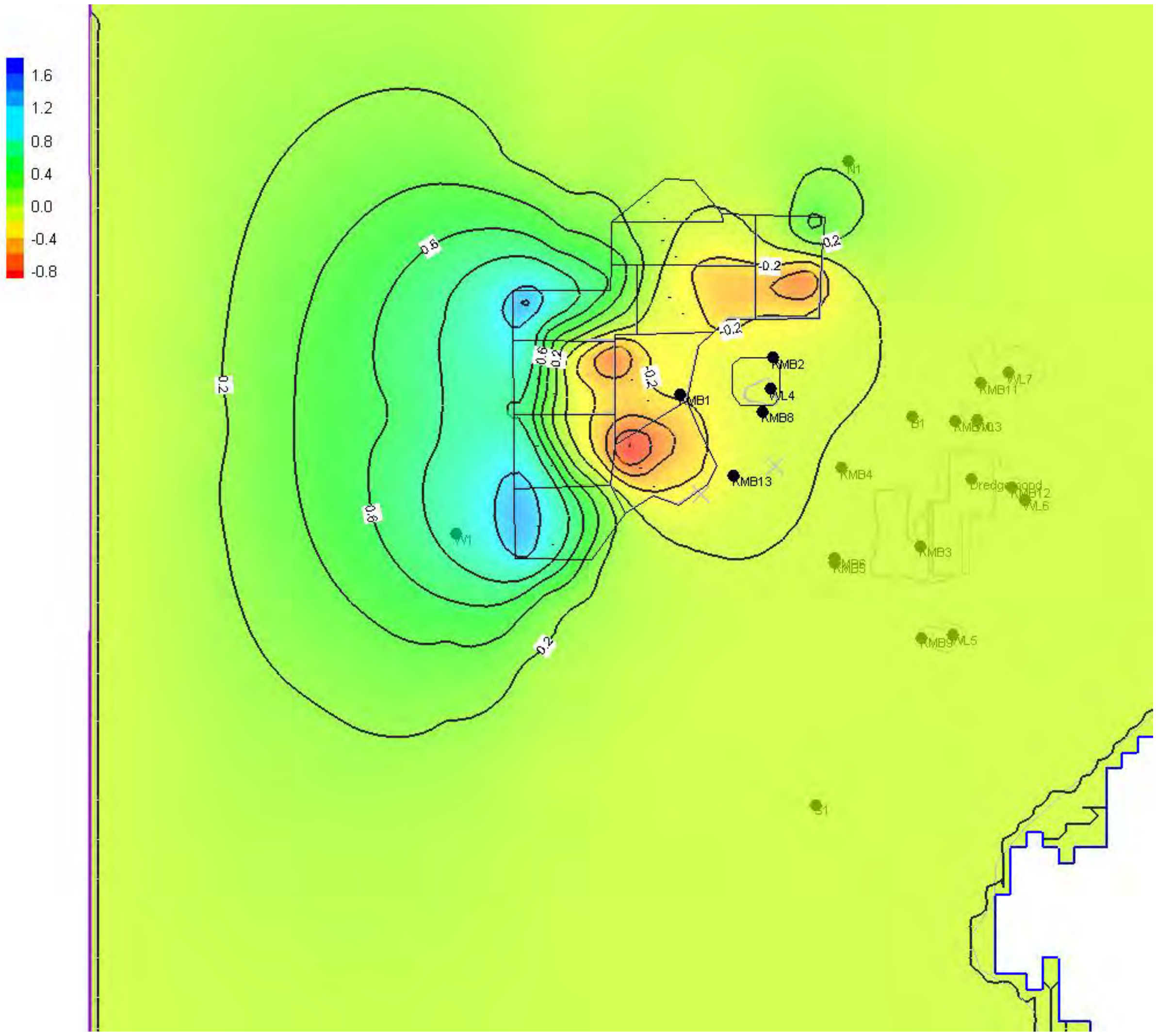


Figure 5H Block 8 Impact: Model predicted change in groundwater levels at the end of block 8 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels).

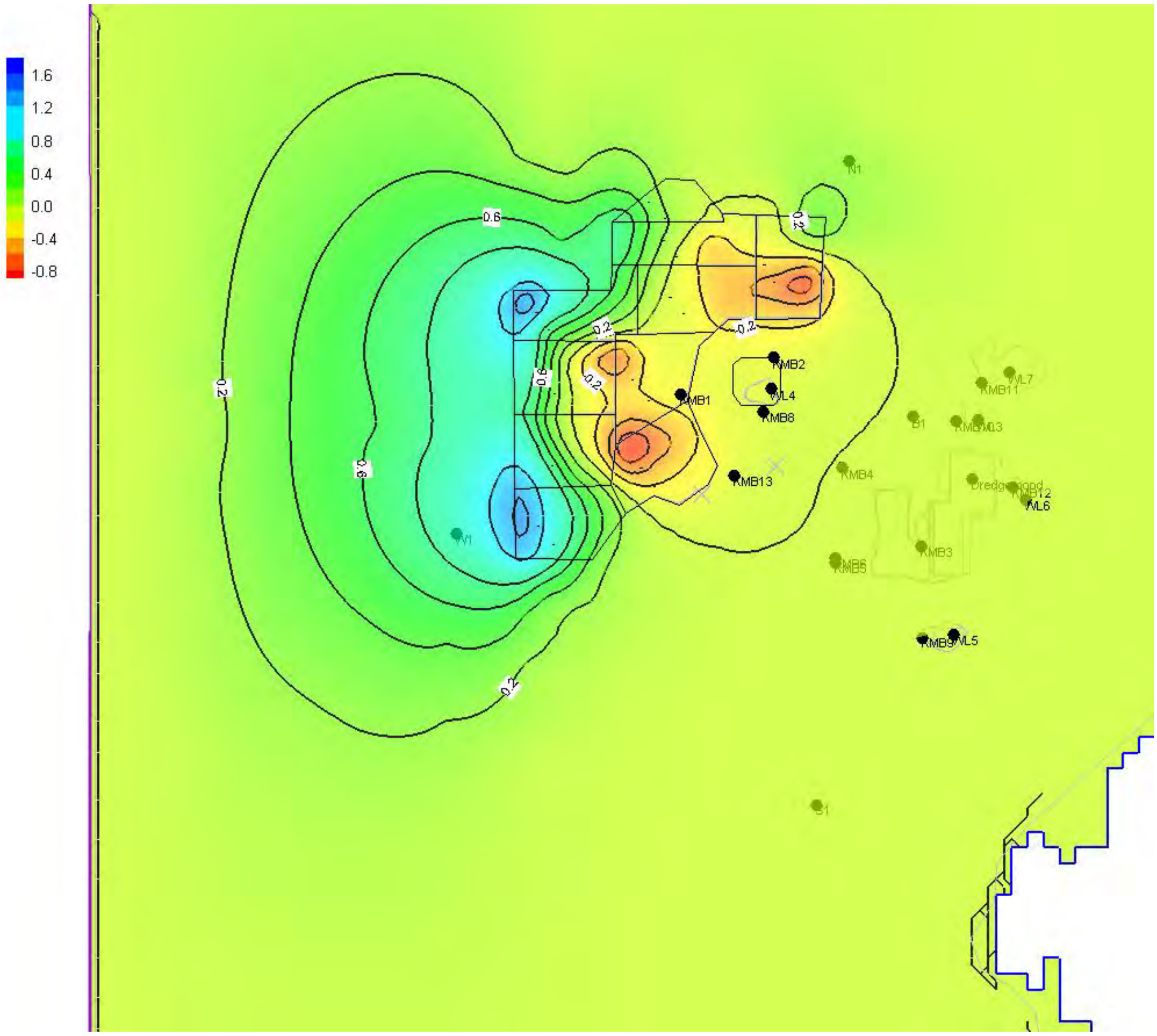


Figure 5I Block 9 Impact: Model predicted change in groundwater levels at the end of block 9 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels).

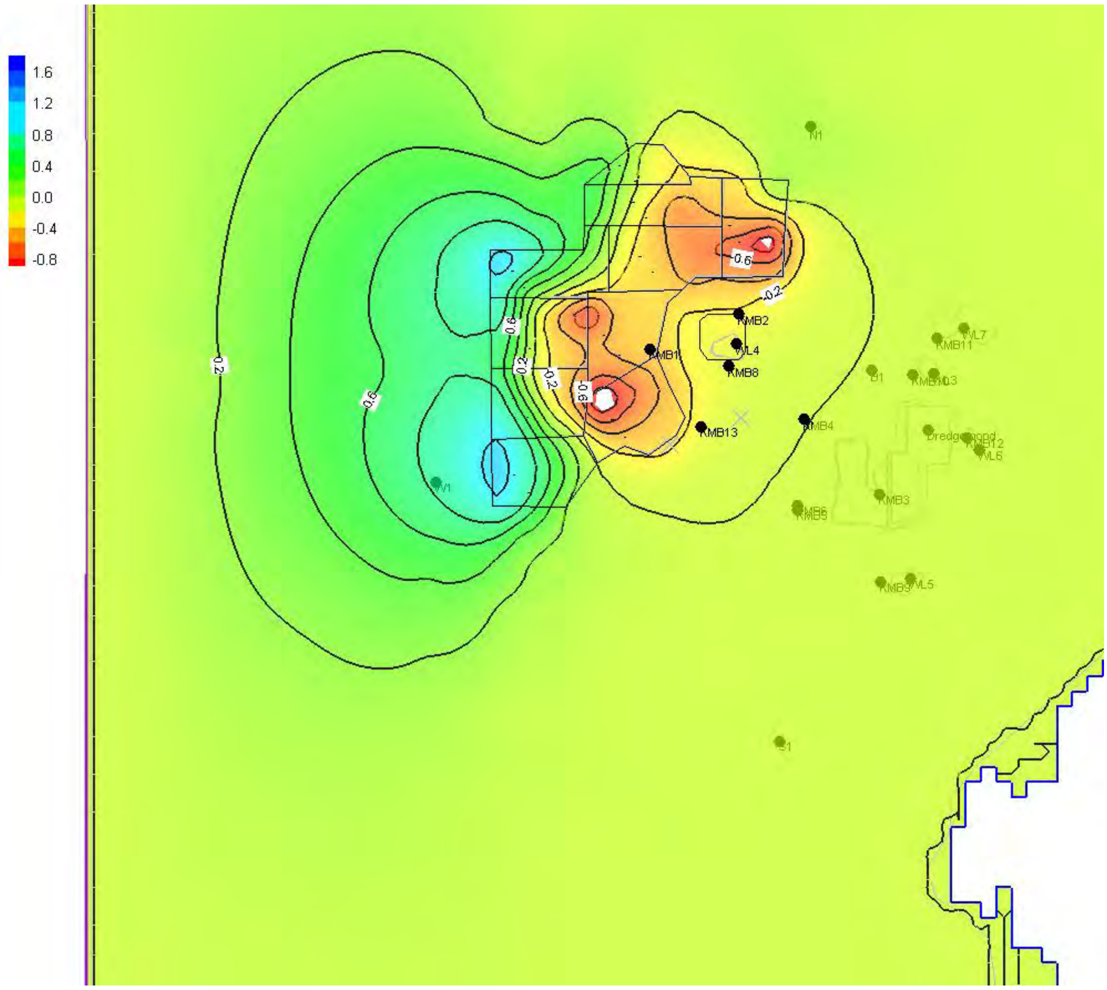


Figure 5J: Block 10 Impact: Model predicted change in groundwater levels at the end of block 10 mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels).

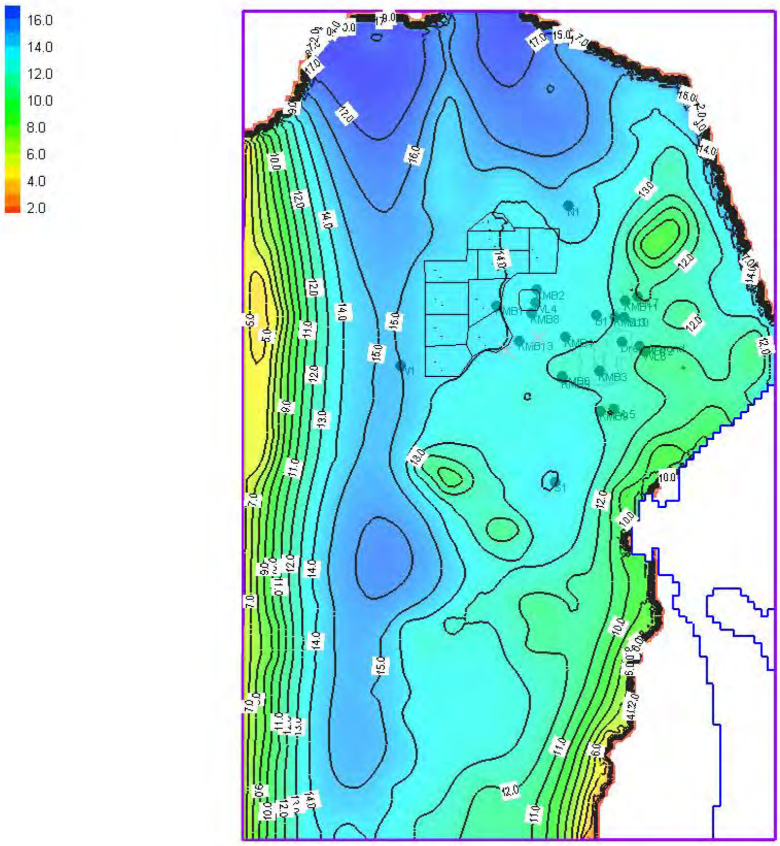


Figure 6 Model predicted groundwater levels at the end of 10 year after the completion of mining.

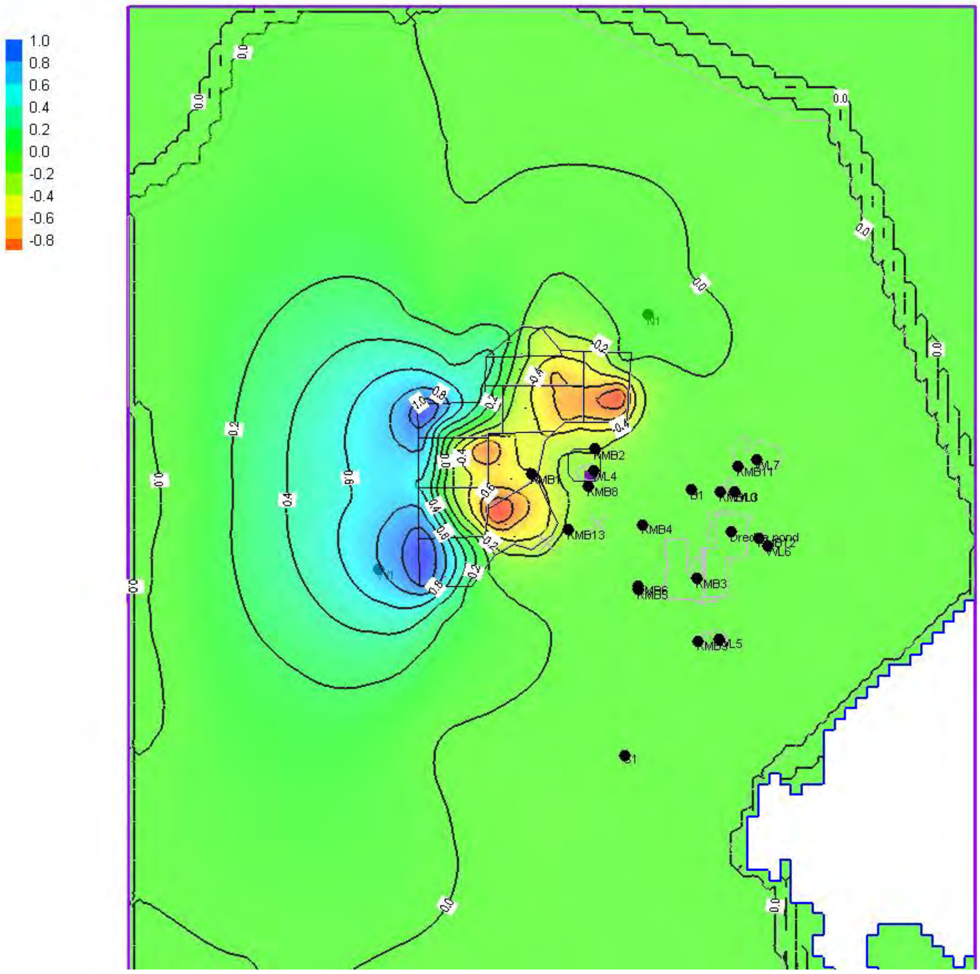


Figure 7 Model predicted change in groundwater levels 10 years after the completion of mining (head values in meters; positive values indicate drop in water levels and negative values indicate rise in water levels).

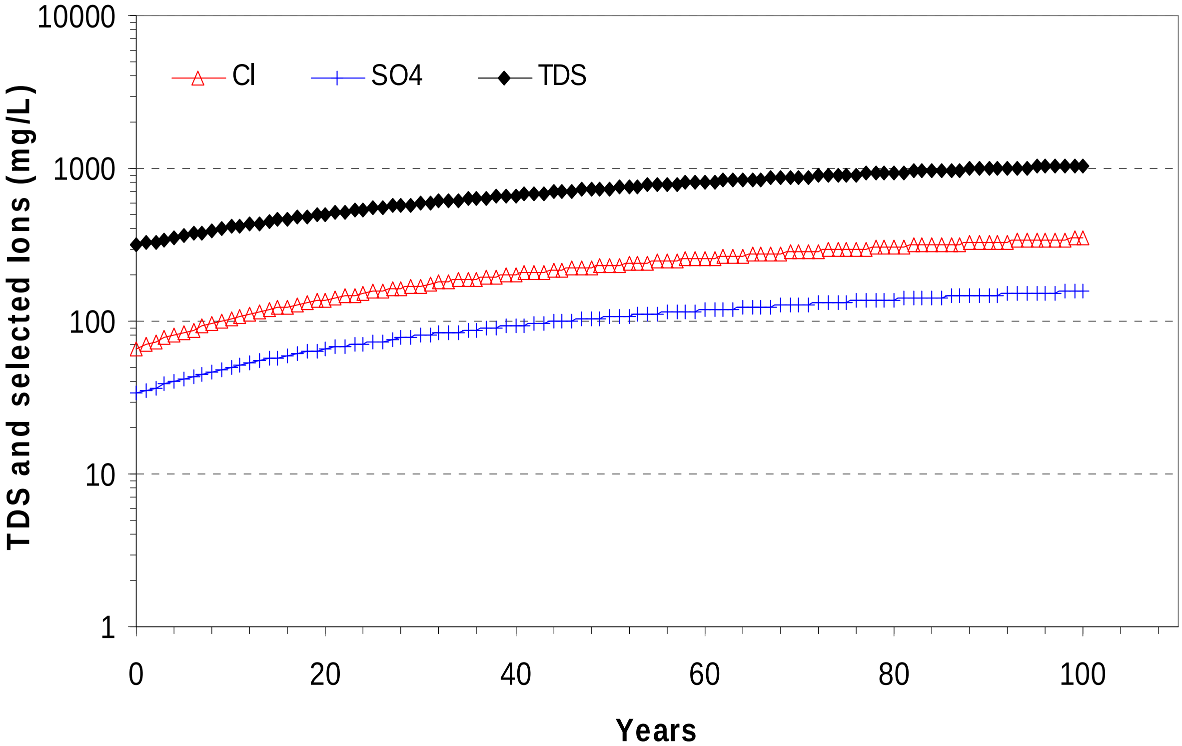


Figure 8: Salinity evolution in post-mining flow-through Pit Lake.

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
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	Edgardo Alarcon Leon	Bradley Van Blomestein		Bradley van Blomestein		1 May 08
	Bishnu Gautam					

APPENDIX 19:
KEMERTON SILICA SAND REHABILITATION MANAGEMENT PLAN
FEBRUARY 2009
MBS ENVIRONMENTAL

KEMERTON SILICA SAND REHABILITATION MANAGEMENT PLAN

FEBRUARY 2009

PREPARED FOR

KEMERTON SILICA SAND PTY LTD

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1. INTRODUCTION

Kemerton Silica Sand (KSS) is a sand dredging operation located 35 kilometres north of the Port of Bunbury and approximately 150 kilometres south of Perth. The project is situated on a property originally of 1,520 hectares of which 60 hectares is currently disturbed by the current operations. The current operation was approved by the Western Australian Environment Minister in 1994 and has been undertaken since 1995. Feldspathic silica sands are extracted from below the water table using a dredge. The resource generally lies beneath one to seven metres of overburden (depending on local topography), with the dredge mining to 15 metres below the water table.

Although Silica sand resources exist across the entire site. KSS has identified an area containing sufficient silica sand resources to allow mining for approximately 50 years. Access to this area will enable secure long term resource extraction and provide sufficient overburden to implement rehabilitation of dredge ponds in mined areas to create functioning wetland environments. This will also allow long-term management of the site and consequently long-term environmental management and rehabilitation plans. Environmental approvals to access this resource are being sought.

The slopes of North Lake in the existing mine area have been progressively rehabilitated between 2001 and 2007. In 2007 KSS commissioned the Centre for Ecosystem Management at Edith Cowan University as rehabilitation consultants, to conduct ongoing research and development on the rehabilitation with the goal of identifying realistic and achievable outcomes for completed mine areas that are sustainable and of environmental value.

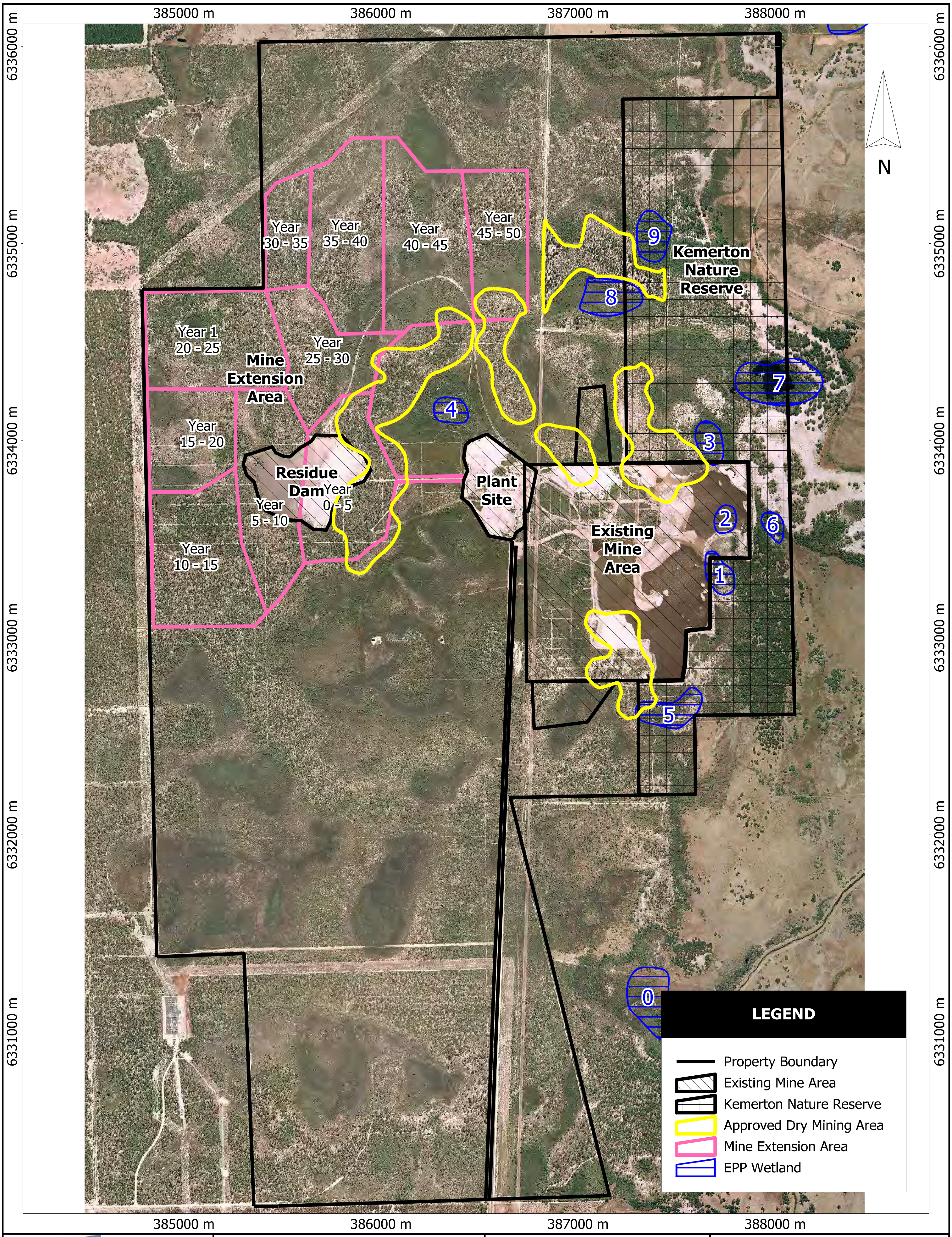
1.1 LOCATION

KSS is located in the Shire of Harvey, 2.5 kilometres north of the Kemerton Industrial Park and 12 kilometres south west of Harvey, on the Swan Coastal Plain in the south west of Western Australia. The KSS property consists of approximately 1,517 hectares of pre 1899 grant freehold land owned by the proponent (Figure 1). Mineral rights for this area are to the landowner.

1.2 PREVIOUS STUDIES

Periodic assessment of rehabilitation undertaken in the existing mine area has occurred. The following reports have been prepared:

1. Arbortech Pty Ltd, 1997. Kemerton Silica Sand Environmental Monitoring Report 1997. Annual report outlining quarterly flora monitoring conducted within the project area during 1997.
2. Ecos Consulting (Aust) Pty Ltd, 1998. Kemerton Silica Sand Environmental Monitoring Report 1998. Annual report outlining quarterly flora monitoring conducted within the project area during 1998.



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Scale: 1:24000
Original Size: A4
Air Photo: 2006
Grid: Australia MGA94 (50)
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Kemerton
Silica Sand Pty Ltd

Site Layout

Figure 1

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3. Bamford, M.J. and Bamford, A.R. 1998. Kemerton Silica Sands Mine. Annual report on fauna monitoring programme; 1997. Unpublished report by Bamford Consulting Ecologists for Arbotech, Perth.

4. Bamford, M.J. and Bamford, A.R., 1999. Kemerton Silica Sand Mine. Annual Report on Fauna Monitoring Programme, 1998. Unpublished report by Bamford Consulting Ecologists for Ecos Consulting, Perth.

5. Ecos Consulting (Aust) Pty Ltd, 2000a. Rehabilitation Trials Final Assessment Report. May 2000. Kemerton Silica Sand Pty Ltd.

6. Ecos Consulting (Aust) Pty Ltd, 2000b. Assessment of Impacts on Sedimentation on Wetland Four. Unpublished report prepared for Sons of Gwalia, June 2000.

7. Ecos Consulting (Aust) Pty Ltd, 2000c. Establishing of Monitoring Quadrats at Kemerton Silica Sand. Unpublished report prepared for Sons of Gwalia, August 2000.

8. Mattiske Consulting Pty Ltd, 2001a. Vegetation Monitoring of Wetlands at Kemerton. April 2001. Unpublished report prepared for GHD Pty Ltd and Sons of Gwalia Ltd.

9. Mattiske Consulting Pty Ltd, 2001b. Vegetation Monitoring of Wetlands at Kemerton. July 2001. Unpublished report prepared for GHD Pty Ltd and Sons of Gwalia Ltd.

10. Mattiske Consulting Pty Ltd, 2002a. Vegetation Monitoring of Wetlands at Kemerton. February 2002. Unpublished report prepared for GHD Pty Ltd and Sons of Gwalia Ltd.

11. Mattiske Consulting Pty Ltd, 2002b. Vegetation Monitoring of Wetlands at Kemerton. March 2002. Unpublished report prepared for GHD Pty Ltd and Sons of Gwalia Ltd.

12. Mattiske Consulting Pty Ltd, 2003a. Vegetation Monitoring of Wetlands at Kemerton. March 2003. Unpublished report prepared for GHD Pty Ltd and Kemerton Silica Sands.

13. Mattiske Consulting Pty Ltd, 2004a. Vegetation Monitoring of Wetlands at Kemerton. March 2004. Unpublished report prepared for Kemerton Silica Sands. March 2004 report on the vegetation monitoring finding of fieldwork undertaken in EPP wetlands 4, 8 and 9.

14. Mattiske Consulting Pty Ltd, 2004b. Assessment of Rehabilitated Wetland Areas – Kemerton Silica Sands Limited – Kemerton Operations. May 2004. Unpublished report prepared for Kemerton Silica Sands.

15. Mattiske Consulting Pty Ltd, 2005. Assessment of Rehabilitated Wetland Areas – Kemerton Silica Sands Limited – Kemerton Operations. September 2005. Unpublished report prepared for Kemerton Silica Sands.

16. McCullough, C., Lund, M. and van Etten, E., 2007. Synthesis of Existing Data and Knowledge Gaps for the Rehabilitation of Kemerton Silica Sand Mine Dredge Ponds. Unpublished report for Kemerton Silica Sand.

17. van Etten, E., McCullough, C.D. and Lund, M.A., 2008a. Evaluation of Rehabilitation Efforts at the Kemerton Silica Sand Pty Ltd Project Area (June 2007). Centre for Ecosystem Management Report No. 2008-10, Edith Cowan University, Perth, Australia. Unpublished report for Kemerton Silica Sand Pty Ltd.

18. van Etten, E., McCullough, C.D. and Lund, M.A., 2008b. Synopsis of Wetland Characterisation Study: Potential Implications for P.E.R. Centre for Ecosystem Management Report No. 2008-17a, Edith Cowan University, Perth, Australia. Unpublished report for Kemerton Silica Sand Pty Ltd.

19. McCullough, C. and Lund, M., 2008. Aquatic Macroinvertebrates in Seasonal and Rehabilitated Wetlands of the Kemerton Silica Sand Pty Ltd Project Area. Mine Water and Environment Research/Centre for Ecosystem Management Report No. 2008-16, Edith Cowan University, Perth, Australia. Unpublished report to Kemerton Silica Sand Pty Ltd.

20. van Etten, E., McCullough, C.D. and Lund, M.A., 2009. Evaluation of Post-Mining Rehabilitation at the Kemerton Silica Sand Pty Ltd Project Area (October 2008). Centre for Ecosystem Management Report No. 2008-10, Edith Cowan University, Perth, Australia. Unpublished report for Kemerton Silica Sand Pty Ltd.

The Centre for Ecosystem Management at Edith Cowan University has been conducting ongoing research and development on the rehabilitation programme at KSS. A focus of their work was on the nature of final pit lake environs formed by dredging silica sand below the water table, and how best to merge these environs with the remnant wetlands of the region. Existing rehabilitation was reviewed and a report was prepared titled *Synthesis of Existing Data and Knowledge Gaps for the Rehabilitation of Kemerton Silica Sand Mine Dredge Ponds. Kemerton Silica Sand Pty Ltd* (McCullough *et al.* 2007) which outlined the strategy for ongoing research and monitoring.

Recommendations to improve future rehabilitation were outlined and included (McCullough *et al.* 2007):

- Direct return of topsoil (or as rapid as possible).
- Avoid spreading topsoil too thinly or thickly (aiming for 150 millimetres).
- Dividing slopes to be rehabilitated in three zones:
  - Flooded (within seasonal lake fluctuations).
  - Fringing (within two metres of lake levels).
  - Upland (>two metres above lake levels).
- Topsoil for ‘Fringing’ and ‘Upland’ zones should be sourced from similar vegetation (dampland and upland margins respectively), whereas revegetation of ‘Flooded’ zone should focus on planting, sandbanking, woody debris and brushing.
- Litter, mulch and slow-release fertiliser should be spread on soil surface after topsoil placement.
- Target criteria for each zone in terms of structure, dominance and key species are outlined, together with recommended method for species re-establishment.
- Weed and herbivore management programmes should be improved.
- An initial outcome of investigations by Edith Cowan University on lake geometry suggests that minimising the east-west dimension of open water reduces wave action and shore erosion from the predominant winds over the property (east in summer and west/south-west in winter).

- Make slopes gradual as they seem to be more stable and easier to revegetate than steeper slopes. Greater battering to a lower angle should be encouraged to prevent lake margin erosion and loss of establishing vegetation.

Assessment of fringing terrestrial rehabilitation and wetlands for water quality and invertebrate populations occurred on 26 to 28 September and 12 October 2007 as part of the research programme (McCullough & Lund, 2008).

2. EXISTING ENVIRONMENT

2.1 FLORA AND VEGETATION

Detailed flora and fauna studies have been conducted for the KSS site and its immediate surrounds over a time period greater than ten years, with ten botanical studies and seven fauna studies conducted.

The vegetation on the KSS property has been mapped in detail by E.M Mattiske and Associates (Mattiske) (1993a, 1993b, 1993c and 1993d) and Bennett (2004). These studies identified a total of 24 plant communities and 27 vegetation mapping units, three of which comprise disturbed stages of plant communities.

2.1.1 Species of Conservation Significance

A number of species of flora listed under both the Environment Protection and *Biodiversity Conservation Act 1999 (EPBC Act)* or the *Western Australian Wildlife Conservation Act 1950 (WC Act)* have been recorded at KSS or habitat which may support these species has been recorded at KSS. Seven Priority flora species, as defined by the Department of Environment and Conservation (DEC) have been recorded on the KSS property. Five have been recorded in the proposed mine extension area. These are:

1. *Boronia juncea* subsp. *juncea* (P1).
2. *Acacia semitrullata* (P3).
3. *Dillwynia dillwynioides* (P3).
4. *Goodenia filiformis* (P3).
5. *Caladenia speciosa* (P4*).*
6. *Eucalyptus rudis* subsp. *cratyantha* (P4).

All these species are also recorded in other locations on the property, outside the proposed mine extension area. *Boronia capitata* subsp*. gracilis* (P1) and one population of *Dillwynia dillwynioides* (P3) are located close to the boundary of the proposed mine extension area. Minor adjustment of the proposed mine boundary has been undertaken to avoid direct impact to these locations. All locations of Priority species are in areas not scheduled to be mined until late in the project, at least 25 years from commencement. More details on each of the species recorded in the proposed mine extension area are given below.

1. *Boronia juncea subsp. juncea* (P1) occurs in low scrub in sand between Bunbury and Mandurah and flowers in April (Mattiske, 2003b). Mattiske (1993c) located four populations in excess of 50 plants, and two of less than three plants in communities H1, H2, F1 (and abutting F1, F3, H1 and H2). Bennett (2004) found the species to be common through a lot of the wetlands, but only where there was standing water present during the September survey. This species has been recorded once in the mine extension area. Around 100 individuals of this species was recorded at Map Grid of Australia

(MGA) 50 6334965 N 386199 E in the mine extension area (Bennett, 2004). *Boronia juncea* subsp. *juncea* (P1) has been recorded at 27 other locations across the KSS property. This species is relatively common throughout the region (Appendix 2, Bennett, 2004).

2. *Acacia semitrullata* (P3) has been found in wetland areas and sandplains in white/grey sand. The flowering period is June to August. Mattiske (2003b) recorded this species throughout the KSS property. Muir Environmental (Muir) (1999) recorded populations along swamp fringes and damplands. During the Bennett (2004) survey, *Acacia semitrullata* (P3) was found to be very common through the damp and slightly higher ground. It also occurred as scattered plants throughout the KSS property. This species has been recorded in four locations in the mine extension area. Fifty-five individuals of *Acacia semitrullata* (P3) from four locations will be taken through progressive mining at KSS. *Acacia semitrullata* (P3) is very common throughout the KSS property, including good populations in the proposed offset areas.

3. *Dillwynia dillwynioides* (P3) was located by Bennett (2004) in areas that were currently in standing water or had recently been so. Around 10 individuals of *Dillwynia dillwynioides* (P3) occurs at one site in the proposed mine extension area. *Dillwynia dillwynioides* (P3) is common throughout wetlands on the KSS property with a further 22 sites recorded with many sites with good populations in excess of 20 individuals (Bennett, 2004). *Goodenia filiformis* (P3) was located by Mattiske (1993b,c) within the KSS property, however, this taxon may not occur in the area due to taxonomic changes since work has been undertaken (Bennett, 2004). It was not recorded during the 2003 surveys by Bennett (2004). *Goodenia filiformis* (P3) is only found near Albany (Bennett, 2004). The species located by Mattiske (1993b, c) within the KSS property is likely to be *Goodenia pulchella* subsp. Coastal Plain B (L.W. Sage 2336) and is not a Priority species (L. Sage, pers. Comm. in Bennett, 2004).

4. *Caladenia speciosa* (P4) inhabits Eucalypt and Banksia woodlands in the dunes above paperbark swamps on white, grey or black sand. The flowering period is September to October. Mattiske (1993c) recorded this species within the KSS property. *Caladenia speciosa* (P4) was recorded at three sites by Bennett (2004). One individual of this species was recorded in the mine extension area.

5. *Eucalyptus rudis subsp. cratyantha* (P4) was located by Bennett (2004). Often this species occurred as an individual tree, but it was also found in a few locations where it was the dominant tree in the upper storey, particularly in the northern section east of the limestone track. This species has been recorded in two locations in the mine extension area with 10 and 11 individuals recorded at these. A further two locations of *Eucalyptus rudis* subsp. *cratyantha* (P4) are recorded outside the mine extension area with 10 and 15 species at these sites.

2.1.2 Weeds

A total of 58 weed species have been recorded on the KSS property during vegetation surveys. Weed species were most numerous in the Asteraceae (11 taxon), Poaceae (10 taxon) and Papilionaceae (seven taxon) families. Weed encroachment into bushland areas has generally been observed to be low with the exception of tracks, and pasture and cleared areas adjacent to farming properties (Mattiske, 2003b).

The most common weed species are annuals or short lived perennials, dominated by *Briza maxima* (Blowfly grass), *Briza minor* (Shivery grass), *Hypochaeris glabra* (Smooth catsear) and *Lagurus ovatus* (Hairs tail grass).

Five aggressive weed species have been recorded at the KSS property, namely:

- *Gomphocarpus fruticosus* (Cotton Bush) (P1 and P4 requirements), a Declared Plant pursuant to section 37 of the *Agriculture and Related Resources Protection Act, 1976*:
  - P1 Requirements - The movement of plants or their seeds is prohibited within the State. This prohibits the movement of contaminated machinery and produce including livestock and fodder.
  - P4 Requirements - The infested area must be managed in such a way that prevents the spread of seed or plant parts within and from the property on or in livestock, fodder, grain, vehicles and/or machinery. Treat to destroy and prevent seed set all plants:
  - Within 100 metres inside of the boundaries of the infestation.
  - Within 50 metres of roads and highwater mark on waterways.
  - Within 50 metres of sheds, stock yards and houses.
- *Typha occidentalis* (Bullrush) in seasonally inundated woodlands. Mattiske (2003b) reported that the disused settling pond is a major area of *Typha orientalis* invasion. Typha control programmes have been implemented across the KSS property to control this species and have been successful managing infestations. Weed management is ongoing.
- *Watsonia meriana* var. *bulbillifera* (Bulbil Watsonia) on the lower slopes of *E. marginata- Banksia* spp. Woodlands.
- *Chamaecystis palmensis* (Tagasaste) in cleared pasture areas.
- *Centaurea melitensis* (Maltese Cockspur).

Control programs have been implemented across the KSS property and have successfully managed infestations. Weed management is ongoing.

2.1.3 Dieback

Phytophthora cinnamomi is a soil borne fungus that is a major plant pathogen in the south west of Western Australia. It is the cause of the plant disease known as ‘dieback’. Dieback mapping of the KSS property undertaken by CALM in 2002 indicated that approximately 75% of the property is either dieback infested or can not be protected from dieback. The main areas of dieback free and protectable land are the larger Bassendean dunes. Wetland and lowland areas of the property are either already infested or are unprotectable from natural spread of the fungus.

The main dieback management tool used on site is quarantine. Site activities are concentrated around the dredge pond and plant site. With the exception of access to production and monitoring bores, there is no reason for access to other parts of the property. Movement of vehicles into non production areas of the property is restricted, with permission required from the General Manager.

2.2 FAUNA

2.2.1 Conservation Significance

Fauna of conservation significance are listed on state or threatened/migratory species lists or DEC species lists (Table 1 to Table 3). Fauna species have been assessed using data from the following sources:

- *EPBC Act* administered by DEWHA. The *EPBC Act* also requires compilation of a list of migratory species that are recognised under international treaties including the:
  - *Japan Australia Migratory Bird Agreement 1981* (JAMBA). Species listed under JAMBA are also protected under Schedule 3 of the *WC Act*.
  - China Australia Migratory Bird Agreement 1998 (CAMBA).
  - Republic of Korea-Australia Migratory Bird Agreement 2007 (ROKAMBA).
  - *Bonn Convention 1979* (The Convention on the Conservation of Migratory Species of Wild Animals).
- *WC Act* administered by DEC.
- DEC Priority Fauna list. A non-legislative list maintained by DEC for management purposes.

Table 1: *EPBC Act* Threatened Fauna Categories

Category	Code	Description
Extinct	E	There is no reasonable doubt that the last member of the species has died.
*Extinct in the Wild	EW	A species: (a) is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame.
*Critically Endangered	CE	A species is facing an extremely high risk of extinction in the wild in the immediate future.
*Endangered	EN	A species: (a) is not critically endangered; and (b) is facing a very high risk of extinction in the wild in the near future.
*Vulnerable	VU	A species: (a) is not critically endangered or endangered; and (b) is facing a high risk of extinction in the wild in the medium-term future.
Conservation Dependent	CD	A species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered.
*Migratory	Migratory	(a) all migratory species that are: (i) native species; (ii) from time to time included in the species to the Bonn Convention; (b) all migratory species from time to time included in annexes established under JAMBA, CAMBA and Rokamba; and (c) all native species from time to time identified in a list established under, or an instrument made under, an international agreement approved by the Minister.
Marine	Ma	Species in the list established under s248 of the *EPBC Act*.

Note: * Only species in those categories are matters of national environmental significance under the *EPBC Act*.

Table 2: *Wildlife Conservation Act* Threatened Fauna Categories

Category	Code	Description
Schedule 1	S1	Fauna which is rare or likely to become extinct.
Schedule 2	S2	Fauna which is presumed extinct.
Schedule 3	S3	Birds which are subject to an agreement between the governments of Australia and Japan (JAMBA) relating to the protection of migratory birds and birds in danger of extinction.
Schedule 4	S4	Fauna that is otherwise in need of special protection.

Note: The *Wildlife Conservation Act* also uses the categories defined by the *EPBC Act* to further define the status of species in the S1 category.

Table 3: Western Australian DEC Priority Fauna Categories

Category	Code	Description
Priority 1	P1	Taxa with few, poorly known populations on threatened lands.
Priority 2	P2	Taxa with few, poorly known populations on conservation lands.
Priority 3	P3	Taxa with several, poorly known populations, some on conservation lands.
Priority 4	P4	Taxa in need of monitoring. (Not currently threatened or in need of special protection, but could be if present circumstances change).
Priority 5	P5	Taxa in need of monitoring. (Not considered threatened, but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years).

2.2.2 Fauna Surveys

Fauna surveys have been undertaken at KSS and the surrounding area over a number of years and include:

- Surveys conducted around several wetlands from Mialla Lagoon, south close to Old Coast Road for Alcoa of Australia (Bamford and Watkins, 1983).
- Surveys conducted on the KSS property as part of environmental assessment and monitoring for the operations in the period 1993 to 2001 (Ninox Wildlife Consulting 1994, Bamford and Bamford 1998, 1999, 2000, 2001).
- Studies carried out for the Department of Resource Development over the whole Kemerton region in 1998 to determine the conservation value of the Buffer Zone (Bamford and Bamford 1999).

Sixteen fauna studies have been conducted within the KSS property since 1993 as presented in Table 4. This included targeted surveys for the Southern Brush-tailed Phascogale (*Phascogale tapoatafa ssp.),* Chuditch (*Dasyurus geoffroii*), Carnaby's Black-Cockatoos (*Calyptorhynchus latirostris*) and Western Ringtail Possum (*Pseudocheirus occidentalis*). The Chuditch, Carnaby's Black-Cockatoos and Western Ringtail Possum were identified as the primary reason for designating the project as a Controlled Action under the *EPBC Act*.

Table 4: Fauna Studies on the KSS Property

No.	Author	Date	Title
1	Ninox Wildlife Consulting	Jan-93	Report: Vertebrate fauna assessment of the Kemerton Silica Sand project.
2	M.J. Bamford and Ninox Wildlife Consulting	Oct-93	Vertebrate fauna assessment of the Kemerton Silica Sand project.
3	Ninox Wildlife Consulting	Feb-94	The Kemerton Silica Sand project area: Vertebrate fauna assessments December 1992 - December 1993.
4	M.J. & A.R. Bamford, Consulting Ecologists	Jan-98	Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Program; 1997.
5	M.J. & A.R. Bamford, Consulting Ecologists	Feb-99	Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Program; 1998.
6	M.J. & A.R. Bamford, Consulting Ecologists	May-00	Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Program; 1999.
7	M.J. & A.R. Bamford, Consulting Ecologists	Jul-01	Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Program; 2000 - 2001.
8	M.J. & A.R. Bamford, Consulting Ecologists	Sep-02	Kemerton Silica Sand Pty Ltd: Summary report on Fauna Surveys; 2001 - 2002.
9	M.J. & A.R. Bamford, Consulting Ecologists	Feb-03a	Assessment of Fauna values in the KSS property.
10	M.J. & A.R. Bamford, Consulting Ecologists	Feb-03b	Kemerton Silica Sand Pty Ltd: Fauna Monitoring 18th December 2002.
11	M.J. & A.R. Bamford, Consulting Ecologists	May-04	The status of the Chuditch (*Dasyurus geoffroii*) in areas proposed for expansion by KSS.
12	M.J. & A.R. Bamford, Consulting Ecologists	Jun-04	The utilisation by Short-billed Black-Cockatoos (*Calyptorhynchus latirostris*) of the proposed dredge mining extension area of KSS.
13	McCullough, C. D. & Lund, M. A.	Dec-08	Aquatic macroinvertebrates in seasonal and rehabilitated wetlands of the Kemerton Silica Sand Pty Ltd project area.
14	Galeotti, D.M. , McCullough, C.D. & Lund, M. A.	Jun-08	Current State of Knowledge of the Black-stripe Minnow *Galaxiella nigrostriata* (Pisces: Galaxiidae) in Western Australia.
15	G. Harewood	February 2009	Fauna Assessment (Level 1) and Targeted Fauna Survey (Western Ringtail Possum and Southern Brush-tailed Phascogale) in the Mine Expansion Area

Studies carried out for the KSS project provide specific information regarding fauna of the KSS property. The other studies were conducted over broader areas than the KSS property alone and provide information on fauna at a more regional level (Bamford, 2003a). A considerable body of information on the fauna and their habitat associations of both the KSS property and the Kemerton region are therefore available.

Fauna studies carried out in the Kemerton region include opportunistic observations, systematic searching, trapping for reptiles and mammals (approximately 1,000 trap nights in total at all sites at Kemerton), netting for bats and spotlighting. Fauna of the region is considered to be well documented.

Bamford (2003a) reviewed results of earlier studies focusing on areas of special interest in the western part of the KSS property. Bamford (2003a) produced lists of fauna species present or expected to occur in the Kemerton region and specifically on the KSS property. Where species have not been recorded, but are expected to occur in the area, the preferred species habitat, where such preferences are known to be very specific, were also recorded. Bamford (2003a) concluded that:

- The Kemerton region supports a rich fauna, because it includes a large area of remnant and regrowth native vegetation, while much of the surrounding coastal plain has been developed for agriculture.
- The area supports a high number of CS3 species, not formally recognised for conservation significance, but are regionally important. In the Kemerton region, these species have declined elsewhere on the Swan Coastal Plain.
- Many species of conservation significance are present in the Kemerton region because it is one of the largest contiguous areas of native vegetation on the Swan Coastal Plain between Bunbury and Perth.

MBS Environmental conducted a review of the latest Bamford fauna surveys and produced a consolidated fauna report (MBS, 2008).

KSS has sponsored a two year Masters Research Program at the School of Natural Sciences at Edith Cowan University on the Jollytail (*Galaxiella nigrostriata*) (Galeotti *et al.* 2008). The research aims to establish which ecological parameters are significant to the conservation of Jollytail populations. Jollytail are known to exist in two populations on the Swan Coastal Plain, approximately 30 kilometres north of Perth in Melaleuca Park, and at KSS, with a wider distribution on the south coast (Morgan *et al.* 1998; Galeotti *et al.* 2008). The Kemerton Wetlands have a wide range of habitat variation over 12 seasonal wetlands (McCullough *et al.* 2007) and Jollytail have been recorded at least once in each of these wetlands (Bamford, 2006).

Little is know about Jollytail habitat preference at a local wetland scale. It remains unknown what preference larvae, juvenile and adult Jollytail have for typical aquatic habitat features such as emergent vegetation type, shade requirements, submerged logs and woody debris, or the type of benthic substrate. The preferred physico-chemical water properties for Jollytail are also uncertain. To fully understand their habitat requirements, water properties such as dissolved oxygen, salinity, water depth ranges or flow velocity, are required (Galeotti *et al.* 2008). Knowledge of physico-chemical water properties are important for rehabilitating wetlands for fish re-introductions and baseline information for future monitoring of water quality as an indicator of fish health.

This research will take place using the three known population areas of Jollytail in south-western WA. Field work was carried out between October and November 2008 and involved three trips to KSS, one to Melaleuca Park north of Perth and an extended trip between Augusta and Walpole. A total of 27 wetlands at six locations were surveyed, with 196 fish caught out of 213 transects. As part of the habitat requirements/analysis, water samples were collected at each wetland and analysed for nutrients and metals. To obtain diet information, macroinvertebrate transects were conducted at all 11 wetlands that were surveyed for fish at KSS. Some of the fish specimens have already been measured for length and weight and then dissected for stomach content analysis and to provide tissue samples for stable isotope analysis. This research is on-going and is the Masters is due for completion in early 2009. The results of the research project will help KSS design and construct rehabilitation that best enhances long term survival prospects of Jollytails, and investigate ways of protecting Jollytails from Gambusia.

MBS Environmental commissioned Greg Harewood to conduct a Level 1 terrestrial fauna survey as defined in EPA Guidance Statement 56 (EPA, 2004) and a targeted survey for the Western Ringtail Possum and the Southern Brush-tailed Phascogale in the proposed mine extension area (Harewood, 2009). The assessment included a desktop analysis, a daytime site reconnaissance survey that included opportunistic fauna observations, a night time survey and a four night trapping program using Elliot's and cage traps. The field survey was carried out by Greg Harewood (B.Sc. Zoology) on a number of days and nights between 28 January and 6 February 2009. The results of the targeted inspection of the site for evidence of Western Ringtail Possums failed to find any sign of this species and it is concluded that they are not present on site or are only present rarely as transient individuals (Harewood, 2009). The Southern Brush-tailed Phascogale was captured several times during the trapping program and it use of the site is now confirmed.

Potentially, 20 native mammals (includes nine bat species), 127 bird, 10 frog, 34 reptile and six fish species could be expected to occur in or utilise at times, the KSS area. Of the 197 native animals that are listed as potentially occurring at the site, eight are considered to be endangered/vulnerable or in need of special protection. In addition seven migratory species may frequent the site at times. Ten DEC priority species may also use the site. Eight introduced species may also be present.

2.2.3 Listed Fauna Species

A Threatened and Priority Fauna search was conducted on the 17 December 2008 to determine the conservation significant species of mammals, birds and reptiles that are known to occur in the Kemerton region and are listed under the *WC Act* and the *EPBC Act*. A search of the database managed by DEWHA was undertaken on 12 December 2008. The results are presented in Table 5 Additional details including the likelihood of being present within KSS property and the proposed mine extension area are discussed below.

Table 5: Conservation Significant 1 Fauna Species Likely to be Found at KSS

Species	Type	Common Name	Conservation Status		KSS Property
			WC Act	*EPBC Act*	
Botaurus poiciloptilus	Bird	Australasian Bittern	S1		+
Calyptorhynchus latirostris	Bird	Carnaby's Black-Cockatoo	S1	Endangered	*
Calyptorhynchus banksii sub. *naso*	Bird	Forest Red-tailed Black-Cockatoo	S1		+
Calyptorhynchus baudinii	Bird	Baudin's Black-Cockatoo	S1	Vulnerable	+
Dasyurus geoffroii	Mammal	Chuditch, Western Quoll	S1	Vulnerable	+
Phascogale tapoatafa ssp.	Mammal	Southern Brush-tailed Phascogale	S1		*
Pseudocheirus occidentalis	Mammal	Western Ringtail Possum	S1	Vulnerable	+
Setonix brachyurus	Mammal	Quokka	S1	Vulnerable	+

Source: Bamford (2003a)
Notes: * Species recorded.
+ Species expected to occur.

Carnaby's Black-Cockatoo (Endangered)
Carnaby's Black (or Short-billed) Cockatoo is endemic to south-western Australia. Carnaby's Black-Cockatoo is reliant on native remnant woodlands, predominantly Salmon Gum (*Eucalyptus salmonophloia*) or Wandoo (*E. wandoo*), shrubland or heath dominated by Proteaceous species. A breeding population is known to occur around the Bunbury region. The KSS site is within foraging range of this population (Bamford, 2003a; Cale, 2003). Carnaby's Black-Cockatoo has been recorded in site surveys in November 2003 and May 2004 (Craig *et al*. 2004) and small flocks were sighted in 2009 within the proposed mine extension area (Harewood, 2009). Numerous examples of foraging activity (chewed jarrah nuts and Banksia cones, pine cones and marri nuts) were observed within the mine extension area. Some or all of this activity could be attributed to Baudin's or Forest Red-tailed Black-Cockatoos (Harewoood, 2009). Carnaby's Black-Cockatoo is a frequent visitor to the general area for foraging. Two potential nest hollows are present within the mine extension area, although the probability of breeding on site is considered low (Harewood, 2009). The value of the KSS property for breeding was assessed to be low in the regional context, with no evidence of breeding and few potentially suitable nest hollows present.

The value of foraging habitat on the KSS property was assessed to be similar to or less than the value of foraging habitat at control sites in the region (Craig *et al*. 2004). Craig et al. (2004) considered the KSS property is likely to provide opportunistic pickings from woodlands rather than a continual, reliable food source and as such, Carnaby's Black-Cockatoo is likely to be a transitional species and a seasonal visitor. The proposed action will result in a temporary reduction in foraging habitat for Carnaby's Black-Cockatoo, although the post mining landform will contain Proteaceous species, which the Cockatoo favours (Cale, 2003). The proposed action is not considered likely to have significant long-term impact on Carnaby's Black-Cockatoo.

Baudin's Black-Cockatoo (Vulnerable)
Baudin's Black Cockatoo is endemic to the south-west of Western Australia, and the KSS mine extension area is located within the known distribution range for this species. It is a more specialised feeder of Eucalypts and tends to be favour moist, heavily forested areas dominated by Marri, Karri and Jarrah species (DEWHA, 2008c). Suitable habitat is limited on the KSS area as historic logging has removed most large Eucalypt trees. Baudin's Black-Cockatoo was not recorded in site surveys in November 2003 and May 2004 (Craig *et al.* 2004). Evidence of Baudin's Black-Cockatoo foraging (chewed marri nuts) were observed within the mine extension area in 2009, while numerous Banksia cones showing signs of cockatoo foraging (seeds and grubbing) were observed (Harewoood, 2009). Some or all of this activity could be attributed to the Carnaby's and not the Baudin's Black-Cockatoos (Harewoood, 2009). While Baudin's Black-Cockatoo may visit woodlands of the property, it is unlikely to use the area extensively. Significant impacts on this species from the proposed action are likely to be a reduction in habitat due to an altered post-mining landscape.

Chuditch, Western Quoll (Vulnerable)
Chuditch tend to rely on large trees for habitat and breed in areas where predators are not controlled. Chuditch require dense bush and scrub in order to provide abundant cover, which is also thought to reduce their vulnerability to predators (Orell and Morris, 1994). Over a year, an adult female Chuditch may utilise an estimated 66 to 110 logs and burrows within her home range. Typically female Chuditch have a home range of three to four square kilometres and seldom overlap with other females. The male Chuditch has a home range of 15 square kilometres (Orell and Morris, 1994). Given these home ranges, if the Chuditch does occur on the KSS property, it is expected to be in very low numbers (Bamford, 2004a).

Bamford *et al.* (2004) conducted a trapping survey in the western portion of the KSS property to provide specific survey information on the possible presence of the Chuditch. No Chuditch, or any other mammals, were trapped during the survey. Bamford (2004a) report that although no Chuditch were trapped during this survey, small numbers are clearly present in the region. They have also been recorded in the Leschenault Peninsula Conservation Park, 10 kilometres to the west. In a trapping study carried out across the Kemerton Industrial Park in 1998, no Chuditch were caught (M. Bamford pers. records). This suggests that at least at that time, the Chuditch was scarce in the region. Vegetation clearance associated with the proposed mine extension has the potential to impact on the habitat and population of the Chuditch by removing an area of thick remnant vegetation, thereby reducing the possible habitat range of this species. Given Chuditch have not been recorded in recent (Bamford, 2004a) or historical (Ninox Wildlife Consulting, 1994) surveys, it seems unlikely that the KSS property provides a preferred habitat for this species.

Western Ringtail Possum (Vulnerable)
The Western Ringtail Possums prefer peppermint dominated forest near the coast, rather than Jarrah-Banksia woodland and scrub within the KSS property. A targeted survey for Western Ringtail Possum was undertaken in January 2009 in response to consultation with DEC and DEWHA that indicated reintroduction of this species to areas north of KSS had occurred in recent years and individuals had reportedly been observed adjacent to KSS. The results of a targeted inspection of the site for evidence of Western Ringtail Possum failed to find any sign of this species and it is concluded that they are not present on site or are only present rarely as transient individuals, suggesting that the Western Ringtail Possum is currently not utilising vegetation on site as potential habitat. This is thought to be primarily because of the general

poor quality of the habitat present and because of historical events that have resulted in the localised extinction of the species in this specific area. There is some potential for individuals to either be present now in very low densities or to at times move into the area from nearby areas of better habitat quality or known extant populations (Harewood, 2009).

Quokka (Vulnerable)
Quokkas used to occur more extensively in low lying scrub from the coast to jarrah-marri forest across south-western Australia, but they are now restricted to swamps with dense vegetation (Maxwell *et al.* 1996).Quokkas have not been recorded in site fauna surveys of the KSS site. Bamford (2003a) lists this species as known or believed to have become extinct in the Kemerton region since European settlement. It is considered unlikely that the mine extension will have adverse impacts on this species given the known range is highly restricted to undisturbed areas.

Forest Red-tailed Black-Cockatoo
The Forest Red-tailed Black-Cockatoo is restricted to the Eucalypt forests of the south-west of Western Australia. Forest Red-tailed Black-Cockatoos have been found breeding in the Darling Range, and on the Swan Coastal Plain. They feed on the seeds of Marri (*Corymbia calophylla*), *Jarrah* (*Eucalyptus marginata*), Blackbutt (*E. patens*) and Sheoak (*Allocasuarina fraseriana*) among others. Birds nest in hollows in Marri or Jarrah with an entrance diameter of 12 to 41 centimetres (Johnstone and Storr, 1998). Several small flocks of this species were observed within the mine extension area during site surveys (Harewood, 2009) and it has previously been recorded by Bamford (2004b). As noted in Bamford (2003a), the woodlands of the KSS property have been disturbed by logging in the past and now contain few very large trees, reducing the number of large tree hollows suitable for nest sites. This species appears to be a frequent visitor to the KSS property for the purposes of foraging, though the small number of potential nest hollows present and the probability of breeding on site is low (Harewood, 2009).

Southern Brush-tailed Phascogale
Harewood (2009) found that almost all of the Jarrah/Banksia Woodland to Open Woodland Communities present within the mine extension area (Mattiske (2003b) vegetation communities A1 to A3) represent potential Phascogale habitat. Areas with the highest densities of habitat trees represent the best habitat, though other factors are likely to be important. Phascogales may also use log piles of previously cleared trees for daytime refuge. Two Phascogales were captured within the mine extension area and evidence of another was found (Harewood, 2009). The location of Phascogales within the mine extension area indicates they are likely present in other areas on the KSS property. The proposed action is not considered likely to have significant long-term impacts on Phascogale habitat.

Australasian Bittern
The Australasian Bittern (Vulnerable) is a waterbird favouring swamps with dense reed cover. There is little habitat of this nature in the Kemerton region, but it is known to inhabit nearby Benger Swamp and may occasionally visit the KSS property. Suitable habitat for the Australasian Bittern within the mine extension area is very limited, it is anticipated that there would be no impact to this species (Harewood, 2009).

2.3 WETLANDS

On the original KSS property, nine wetlands were gazetted under the *EPP 1992*. Five of these were transferred to DEC in 1994 to form Kemerton Nature Reserve. A portion of another (EPP8) is also included in the reserve and an additional wetland was added to the reserve in the land swap for the Muchea Limestone TEC in 2005. EPP4 and the balance of EPP8 remain on the KSS property and one EPP wetland has been incorporated in the existing approved mine area.

The KSS property is located in an area that contains wetlands of the Jandakot consanguineous wetland suite (Semeniuk, 1987). Primary wetlands identified for the Jandakot consanguineous wetland suite are damplands and sumplands, which occur in peat or peaty sand or humic sand overlying quartz sand where the groundwater level is at or near the surface developing water table basins. A classification system was developed based on landform and water permanence (WRC, 2001). Wetland classifications are presented in Table 6.

Table 6: Wetland Classification and Descriptions

Water	Landform			
	Basin	Flat	Channel	Slope
Permanently inundated	Lake	River		
Seasonally inundated	Sumpland	Floodplain	Creek	
Seasonally waterlogged	Dampland	Palusplain		Paluslope

Source: WRC (2001).

The WRC (2001) evaluated wetlands on the Swan Coastal Plain to assess the level of significance of a wetland, using the characteristics of landform and water permanence. Each management categories provide guidance on the nature of management and protection individual wetlands should be afforded (WRC, 2001). Three management categories were developed based on geomorphic characteristics of Conservation, Resource Enhancement or Multiple Use.

2.3.1 Wetland Fauna Survey

Significant fauna in the mine extension area can include wetland invertebrate species, as well as vertebrate fauna associated with wetlands.

The Centre for Ecosystem Management at Edith Cowan University was commissioned to undertake ongoing studies at the KSS property. Their objective was to assess aquatic macroinvertebrate communities and water quality within wetlands in the mine extension area and to assess the condition and conservation status of wetlands within the project area and Kemerton nature Reserve. Information obtained from this survey will provide a comprehensive ecological knowledge base on existing aquatic invertebrate populations and water chemistry of existing wetlands and the rehabilitation pond. It will provide valuable analogue reference information for post-mining rehabilitation of dredge ponds in the mine extension area.

Wetlands in the mine extension area, as well as adjacent EPP wetlands and the rehabilitated dredge pond lake were surveyed by Edith Cowan University on 26 to 28 September and 12 October 2007. Early spring was chosen, as this season generally represents the time of peak water levels for wetlands on the Swan Coastal Plain (McCullough and Lund, 2008). All the EPP wetlands and the majority of the wetland areas were identified on aerial photographs. A particular focus was the conservation category wetlands (13255, 1663, 1656 and 1906) that lie in the proposed expansion area.

Seventeen water bodies including 13 natural wetlands were sampled for water quality and macroinvertebrates, a further eight potential wetland sites were visited, but were dry. Areas of seasonal inundation were included for monitoring in the mine extension area, but at the time of monitoring, the wetlands were dry, therefore no baseline data relevant to the proposal is available for comparison. Edith Cowan University recommends further assessment of these wetlands during wet conditions. At each site, the wetland was walked around and notes were taken on habitat type, condition and water depth, if appropriate.

Wetlands were sampled in a stratified design where habitat heterogeneity was apparent. Different aquatic habitat types were identified as shallow and deep open water, and vegetated and bare littoral edge. Aquatic macroinvertebrates were collected with a 250 µm mesh sweep net along a 10 metre transect through each habitat. Each wetland macroinvertebrate sample was replicated at least three times, with up to five replicate for very large water bodies (McCullough and Lund, 2008). Each wetland habitat type was also sampled in replicate for basic physico-chemistry parameters of temperature, dissolved oxygen (DO), specific conductance (conductivity, EC), pH, Oxidation-Reduction Potential (ORP), turbidity and chlorophyll ***a*** concentration.

Macroinvertebrate sorting began with a big-pick from the two millimetre fraction. The sample filtrate was then placed into a four-channel Bogarov tray and sorted by two passes with an Olympus SZ-STU2 stereo microscope. Macroinvertebrates from both the larger fraction CPOM sieving and from the smaller fraction sorting tray were also identified under the same microscope. Initially, all uncommon (<200 individuals) were sorted, identified and counted. A 20 percent subsample of the remaining fraction (organic matter and crustacean taxa) was then counted for common taxa (>200 individuals) (McCullough and Lund, 2008).

A total of 147 taxa of macroinvertebrate were collected across all sites, the majority of species had distributions limited to a single wetland; only one species occurred across all sites (Necterosoma sp. larvae) (McCullough and Lund, 2008). The most diverse sites were EPP1 and EPP5. EPP1 appears to be permanent and has water quality similar to the North Lake suggesting that it might be a suitable analogue.

The rehabilitated dredge pond and newly created wetland (Site 4) were less species diverse than the majority of natural wetlands but Site 4 showed good species diversity, particularly as it had only just been established. Macroinvertebrate communities of EPP wetlands were numerically dominated by zooplankton, chironomid larvae and beetles and bugs. EPP4, particularly, was dominated by and contained a high abundance of conchostrocans. Nevertheless, the aquatic macroinvertebrate community of EPP 4 appeared to be typical of other KSS project area wetlands in both number of animals and taxa and also in community composition.

KSS project area wetlands containing water were generally of similar temperature. Natural wetlands were generally slightly acidic, however, artificial water bodies were slightly alkaline. Specific conductance was moderate and typical of seasonal wetlands of the Swan Coastal Plain (McCullough and Lund, 2008). Dissolved oxygen was slightly super-saturated in artificial water bodies, and around 80% in natural water bodies. Turbidity was low in all EPP wetlands, but moderate in artificial water bodies and CC wetlands.

Habitats within natural wetlands did not appear to demonstrate either significantly different water quality or significantly different macroinvertebrate communities. This may be because many of the taxa encountered in these seasonal wetlands are cosmopolitan and do not have narrow ecological niches that would separate them across the habitats sampled. There also appeared to be no difference between littoral and open water aquatic macroinvertebrate communities suggesting riparian vegetation is not significant for aquatic macroinvertebrate community structure within these natural wetlands (McCullough and Lund, 2008).

Macroinvertebrates samples were collected in 2008 (except from Site 7), however the samples are awaiting analysis (McCullough and Lund, 2008).

3. REHABILITATION OBJECTIVES

The overall objective for rehabilitation at KSS is to maintain the diversity of flora through the avoidance or management of adverse impacts and ensure that rehabilitation achieves a stable landform and functioning ecosystem that is consistent with the surrounding landscape and other environmental values.

Specific objectives are to:

- Rehabilitate the post-mining terrestrial environment similar to equivalent pre-mining landforms.
- Rehabilitate permanent lakes to a level similar to adjacent wetlands with permanent or near permanent water.

3.1 PURPOSE AND SCOPE

The purpose of the Rehabilitation Management Plan (RMP) is to describe:

- Vegetation protection measures.
- Rehabilitation and closure objectives.
- Strategies and actions necessary to address progressive and final land rehabilitation.

The strategies are designed to ensure maintenance free rehabilitation over the long term.

The RMP provides an operating framework for management of rehabilitation issues during operational and decommissioning phases of the KSS project. It addresses rehabilitation of areas disturbed by mining and associated infrastructure and achievement of net conservation gain to enable the pre-mining land use to resume on completion of mining activities.

The RMP includes a consultation programme and review schedule to ensure its ongoing currency and relevance during the life of mine. Consultation with the local community and government stakeholders will be an important component of the rehabilitation process.

Annual rehabilitation plans will be prepared. These plans will document the scope of work for the coming season.

4. REHABILITATION STRATEGY

4.1 PREVIOUS REHABILITATION AT KEMERTON

Success of rehabilitation from historical disturbance associated with installation of the Dampier to Bunbury gas pipeline approximately 25 years ago provides a local benchmark and precedent demonstrating that high standards of rehabilitation are achievable in the Kemerton area. Woodman (2005) undertook comparative surveys of regenerated vegetation in the gas easement with adjacent undisturbed areas. Results indicated that wetland communities along the easement have recovered to a level where regenerating communities closely resemble adjacent undisturbed vegetation. Upland woodland communities have not regenerated to the same extent as wetland communities, though the requirement to remove trees from the easement to protect the integrity of the pipe has significantly contributed to this. This information was noted by the EPA in Bulletin 1204.

KSS considers that the standard achieved from this past work provides a local benchmark that rehabilitation is achievable to a standard similar to pre-disturbance levels. Current best practice techniques for rehabilitation have improved since the 1980s. With the proposed 50 year mine life and results from the 25 year old rehabilitation, KSS considers achievable completion criteria can be set for rehabilitation areas to closely resemble similar undisturbed vegetation communities within the life of mine.

4.2 EXISTING MINE AREA

A Conceptual Rehabilitation Plan (CRP) has been developed for the existing mine area and is shown in Figure 3. The CRP is to reconstruct a diversity of lake shapes, beaches and surrounding terrestrial landforms including ephemeral wetlands and uplands.

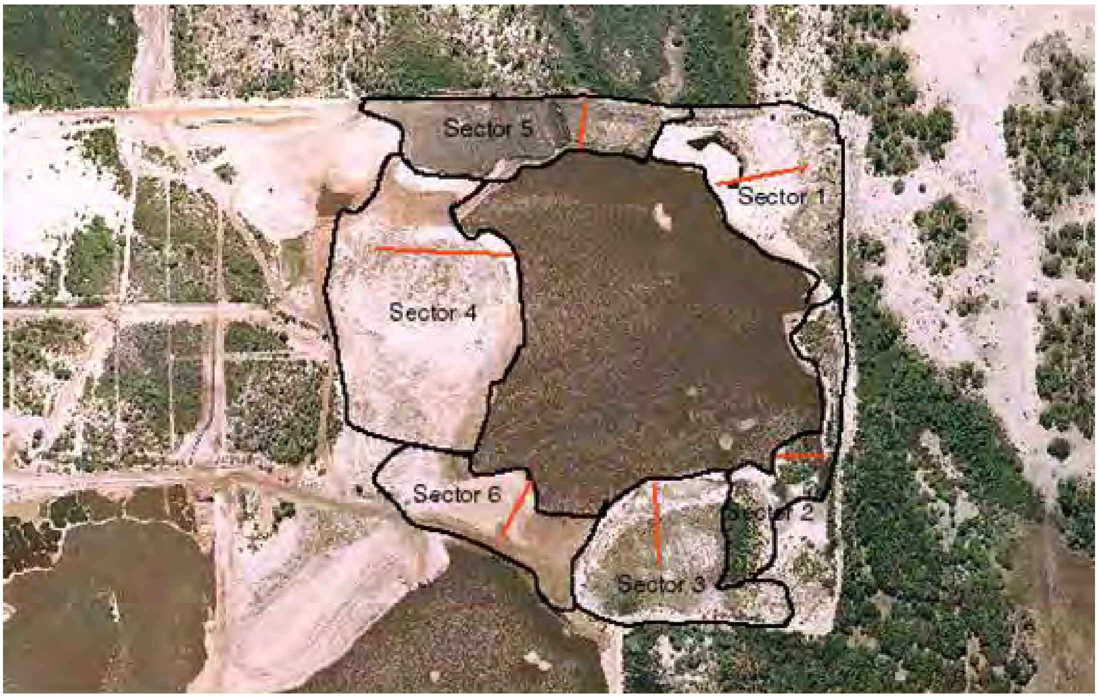
KSS has engaged the Centre for Ecosystem Management at Edith Cowan University as rehabilitation consultants for the next three years, to conduct ongoing research and development of the rehabilitation programme for completed mine areas. Ongoing research and monitoring will include such aspects as assessment of fringing terrestrial rehabilitation and wetlands, water quality and invertebrate populations.

The Edith Cowan University study has focussed on the main rehabilitation area around the northern most dredge pond of the Kemerton active mining area hereafter referred to as "North Lake" (Figure 2). This area was mined and the pond created in the late 1990's. Rehabilitation of the surrounding slopes commenced in 2001 and is continuing. Active mining is currently occurring in dredge ponds to the south, but little rehabilitation has occurred on the surrounding slopes, although rehabilitation occurred at the southern edge of the dredge ponds in 2007.

Mattiske (2005) reported that rehabilitation of the eastern margin of the current dredge pond commenced in early 2001 when topsoil was spread. Additional seedlings were planted in 2002. Transects were monitored in 2004 and 2005. Although 14 weed species were recorded, vegetation to the east and south-east of the pond were growing strongly (Mattiske, 2005), but vegetation to the north-east of the lake was not as vigorous. Mattiske (2005) believes that a combination of waterlogging, wind exposure and/or soil compaction may be impeding plant growth. In winter 2006, remedial actions were undertaken to address these issues.

Assessment of exiting rehabilitation was made through re-measurement of existing permanent monitoring transects established by Mattiske and Edith Cowan University in 2007 (van Etten *et al.* 2008b). van Etten *et al*. (2008b) identified six distinct rehabilitation areas (Sectors) around the northern dredge pond based on location and age of rehabilitation. These are presented in Table 7 and shown in Figure 2. Transects were also established across several natural wetlands over the same time period to characterise the biotic patterns of such wetlands, identify likely processes which drive or influence such patterns and to examine likely dynamics in vegetation (van Etten *et al*. 2008b). Each monitoring transect was positioned transverse to the slope and extended from the lake shoreline to the end of the rehabilitation at the top of the slope. They varied in length from 80 to 200 metres. At each five metre interval along transects a two by two metre sampling quadrat was established and the cover and abundance of each plant species was recorded.

Figure 2: Aerial Photograph from 2006 showing Rehabilitation Sectors around North Lake



Source: van Etten *et al.* (2009)
Note: Position of monitoring transects are shown by red lines.

The measurements of natural wetlands also facilitated comparisons to rehabilitation. This was achieved through comparing:

- Structural attributes of the vegetation.
- Plant composition using the multivariate techniques of ordination.
- Comparing dominance and diversity patterns within plant communities.
- Soil and topographic features.

Table 7: Summary of Rehabilitation History and Monitoring around North Lake

Sector	Monitoring Transect	Area (ha)	Treatment(s)	Monitoring History
1 (north-east)	Mattiske #1	~2	**Feb 2001:** contoured and spread with topsoil (and understorey debris). **Autumn/winter 2002:** ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags. **Autumn 2006:** ripped, hand-seeded, brushed, herbicide and fertilised/limed.	March 2004: Mattiske August 2005: Mattiske June 2007: CEM October 2008: CEM
2 (east)	Mattiske #4	~2	**Feb 2001:** contoured and spread with topsoil (and understorey debris). **Autumn/winter 2002:** minor ripping on contour, herbicide treatment and planting of seedlings (in gaps only); fertilised and covered with tree bags.	March 2004: Mattiske August 2005: Mattiske June 2007: CEM October 2008: CEM
3 (south-east)	Mattiske #5	~1	**Feb 2001:** contoured and spread with topsoil (and understorey debris). **Autumn/winter 2002:** major ripping on contour, herbicide treatment, planting of seedlings' fertilised and covered with tree bags. **Autumn 2006:** hand-seeded and fertilised/limed.	March 2004: Mattiske August 2005: Mattiske June 2007: CEM October 2008: CEM
4 (west)	Mattiske #7	~4	**April 2003:** contoured and spread with 20 cm topsoil (and understorey debris).	March 2004: Mattiske August 2005: Mattiske June 2007: CEM October 2008: CEM
5 (north)	New Transect (#10)	~2	**Autumn 2006:** contoured and spread with 10 year old, stored topsoil (with some understorey debris).	June 2007: CEM October 2008: CEM
6 (south)	New Transect (#9)	~2	**Autumn 2006:** contoured and spread with direct fresh topsoil return (understorey debris). Most topsoil from dampland Area. Upland soil placed on higher ground.	June 2007: CEM October 2008: CEM

In November 2008, Edith Cowan University reported changes to rehabilitation in the existing mine areas since 2007. Monitoring has shown a slight to modest improvement in rehabilitation since monitoring in mid 2007 (van Etten *et al*. 2009). This improvement can be attributed to moist conditions provided by above average late autumn and early winter rains. This improvement was despite observations of drought death over a particularly dry summer and previous year (2007 was close to driest year on record). Plant cover showed most marked increase from the previous year, with plant abundance and species richness generally stable overall (van Etten *et al*. 2009).

Generally plant cover increased more substantially in low-lying areas closer to North Lake, with new species appearing more readily in such areas (van Etten *et al*. 2009). Areas higher in topographic profile have seen the loss of typically fringing/flooded zone species. Therefore it is apparent that some degree of species sorting according to moisture and flooding preferences is occurring. Natural recolonisation in lower areas by sedges, melaleucas and other wetland species is seemingly also occurring (van Etten *et al*. 2009).

Site differences revealed in previous monitoring were mostly maintained and can be clearly related to differences in rehabilitation technique (van Etten *et al*. 2009). This and previous monitoring confirm that good to excellent ecological restoration can be achieved at KSS through the use of fresh topsoil. Matching of topsoil to topographic position is demonstrating improved overall rehabilitation success. Recent rehabilitation of low-lying areas using topsoil has achieved excellent results at KSS (van Etten *et al*. 2009).

Rehabilitation monitoring results indicate that some areas of the existing operation are rehabilitating well and others require fine-tuning. By combining this information with that gleaned from the literature on mine-site rehabilitation/restoration, as well as from expert opinion and current accepted practice at other mine sites of south-west Western Australia., a general set of recommended rehabilitation principles and strategies have been derived for future practice at Kemerton. The RMP for KSS addresses these issues and Edith Cowan University will continue to provide expert advice on improving rehabilitation success at KSS. The RMP will be updated regularly as knowledge increases.

4.2.1.1 Recent Rehabilitation of Wetland Area

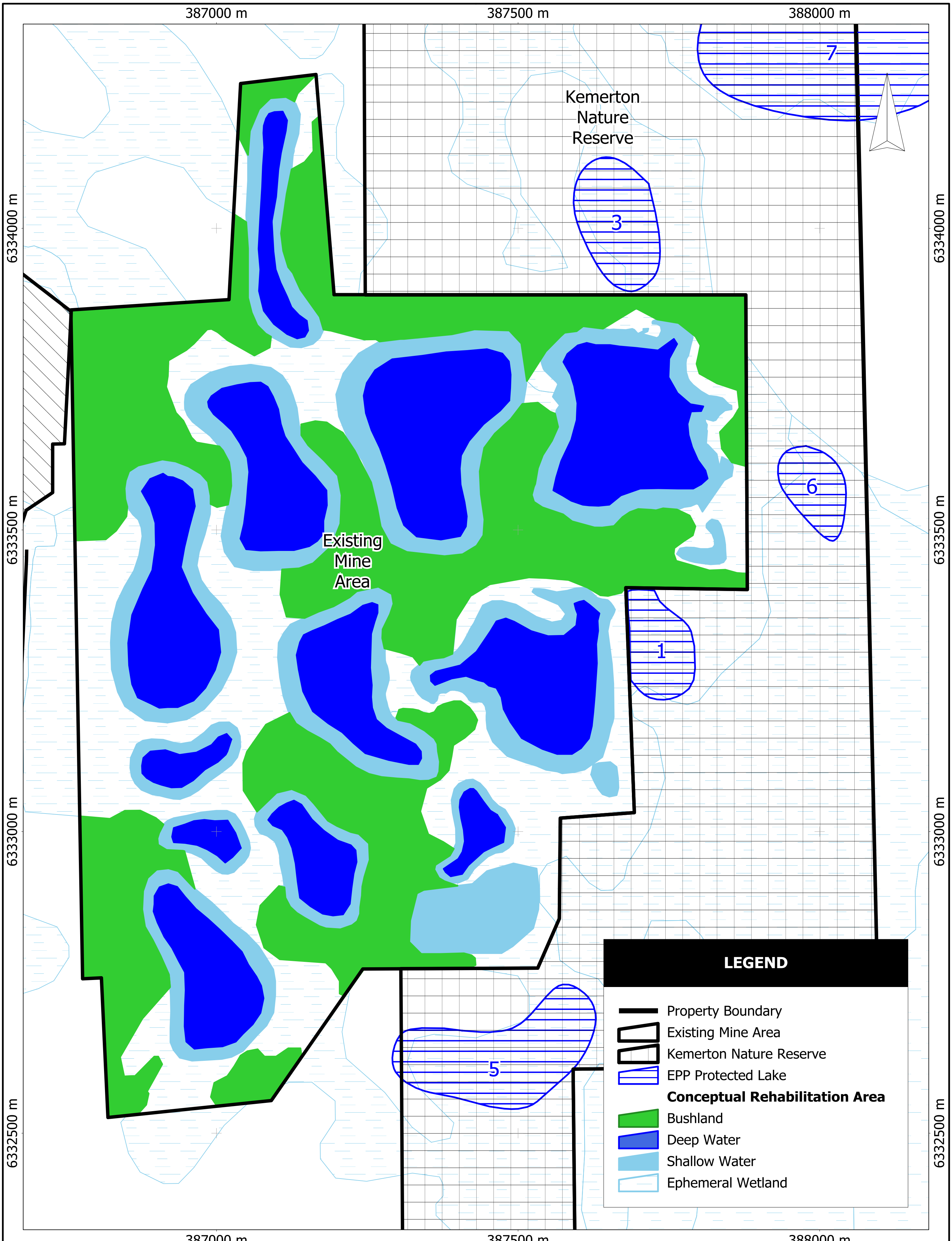
In mid 2007, a new area south of North Lake was rehabilitated using topsoil and spreading of brush and logs. A monitoring transect was established in this area (Transect 11) and monitored for the first time in November 2008 (van Etten *et al*. 2009).

This area is low lying, and at November 2008, contained large areas submerged by water. Areas under shallow water or waterlogged had very high plant cover in the order of 60 - 100% (van Etten *et al*. 2009). This represents prolific growth over one year post rehabilitation and confirms the readiness for plant establishment in low lying areas which are flooded or waterlogged for most of the year as long as appropriate (i.e. wetland or fringing wetland) topsoil is used (van Etten *et al*. 2009).

Although visually the area appeared dominated by a single species (*Juncus pallidus*), the species richness was relatively high with an average of eight species per four metre squared quadrat (highest of 10 per quadrat). Most of the species were rushes, sedges and related species. Encouragingly many seedlings of Melaleuca and other Myrtaceous shrubs typical of fringing wetlands were found, particularly in quadrats close to the deep water edge. This suggests that more diverse structure and typical fringing wetland structure of paperbarks and other shrubs may develop over time (van Etten *et al*. 2009).

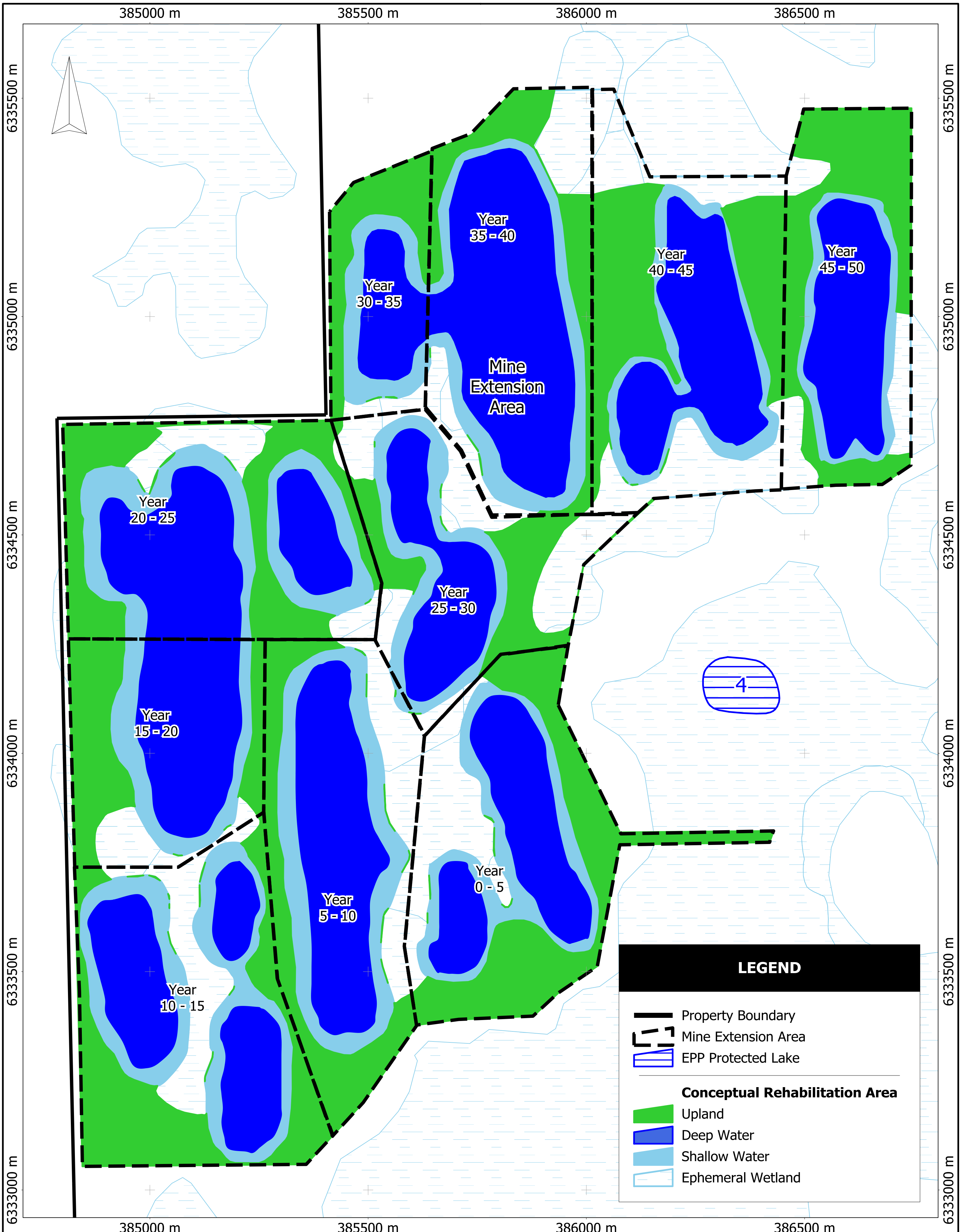
4.3 MINE EXTENSION AREA

A CRP has been developed for the proposed mine extension area and is shown in Figure 4. The CRP is to reconstruct a diversity of lake shapes, beaches and surrounding terrestrial landforms including ephemeral wetlands and uplands.



MBS ENVIRONMENTAL Environmental + Water Resource Consultants 4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale: 1:8000 Original Size: A4 0 250 m	Kemerton Silica Sand Pty Ltd	Conceptual Rehabilitation Plan Existing Mine Area Figure 3

W:\Kemerton Silica Sand\Drawings\Maps 2009\Rehabilitation\Rehabilitation.map 19/02/2009 CRP Ex Mine Area



MBS ENVIRONMENTAL Environmental + Water Resource Consultants 4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale: 1:11000 Original Size: A4 0 250 m	Kemerton Silica Sand Pty Ltd	Conceptual Rehabilitation Plan Mine Extension Area Figure 4

W:\Kemerton Silica Sand\Drawings\Maps 2009\Rehabilitation\Rehabilitation.map 19/02/2009 Conceptual Rehabilitation Layou

As a result of mining, there is a net change in landform type where approximately 170 hectares of permanent lakes will replace 72 hectares of existing ephemeral wetlands, 45 hectares of Bassendean upland, 32 hectares of Spearwood upland and 21 hectares of cleared land, historically used for process sand residue. Post mining rehabilitation will return approximately 48 hectares of ephemeral wetlands and 65 hectares of upland.

There are currently few permanent water bodies on the site. Rehabilitation of the lakes created at conclusion of mining provides an opportunity to expand this habitat type in the local area. There are opportunities for the introduction and maintenance of iconic threatened and regionally significant fauna species. These species include the Water Rat (*Hydromys chrysogaster*), Black-striped Jollytail (*Galaxias nigrostriata*), and various frog and waterbird species.

4.4 REHABILITATION LANDFORM PLAN

The mining method used to extract silica sand is a continuous dredging process. Ore is pumped from the dredge to the existing processing plant. Residual sand material is returned to the dredge pond. This process allows progressive rehabilitation to occur.

Overburden to the resource profile and returned sand is used to build embankments within the pond, isolating completed portions of the pond from the active dredging area. The completed lakes undergo further backfilling to restore beaches and other landforms prior to return of topsoil and vegetative establishment. Earthworks are undertaken to return completed mine areas to similar levels to undisturbed locations, recognising that changes will occur due to the volume loss from the mining process.

Taking into account initial outcomes of investigations by Edith Cowan University on lake geometry, the conceptual rehabilitation landform plan shows ponds which have been orientated on a north-south alignment as much as possible. This will reduce wave action and consequent shore erosion compared to east-west orientated ponds given predominant winds over the property is east in summer and west/south-west in winter.

Development of final detailed landform design will be undertaken progressively, incorporating outcomes of rehabilitation research during the life of mine.

4.4.1 Landform Restoration

KSS aim to construct a diversity of lake shapes, beach angles and island refuges in rehabilitated cells. This will involve reconstructing surrounding terrestrial landforms including ephemeral wetlands and drylands.

Gradual slopes (<5%) are preferred to steeper ones as these more closely replicate natural wetland ecosystems of the region, result in larger areas of fringing wetland vegetation and are less prone to water and wind erosion (Figure 5).

The four landforms reconstructed in the post mining environment are:

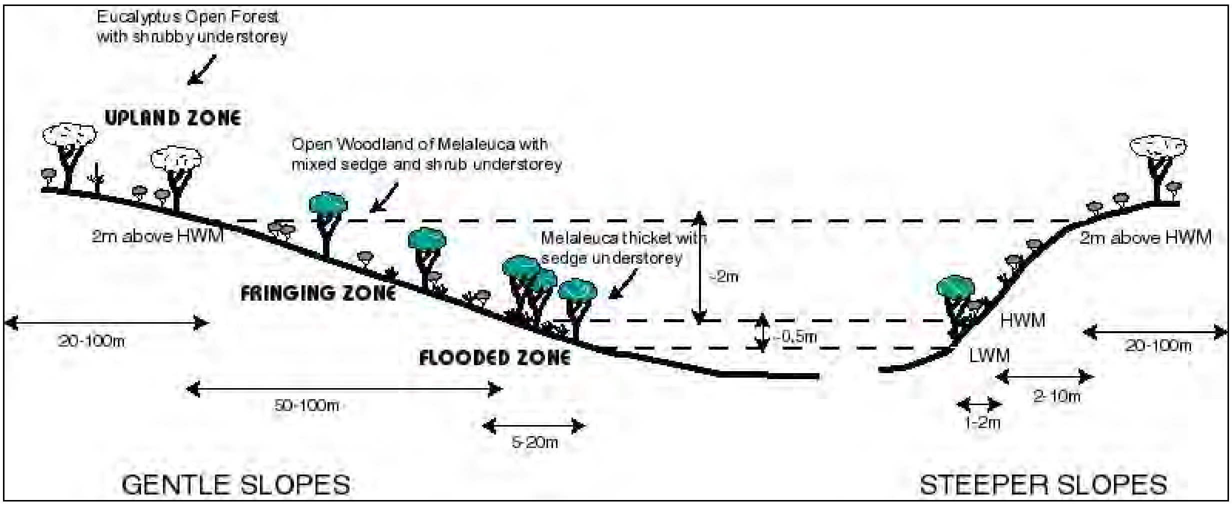
1. Upland - greater than two metres above the lake.
2. Fringing - between zero to two metres above the high water line of the lake.

3. Flooded - within seasonal lake fluctuation zone.
4. Lake - open water part of the lake.

These landforms are shown conceptually in Figure 5 and Figure 6.

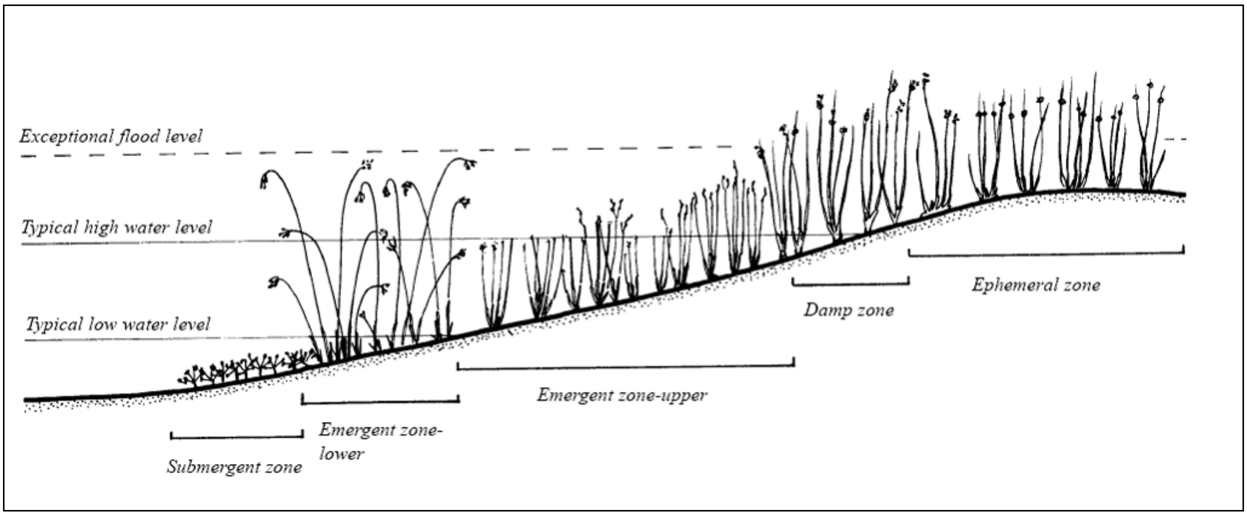
Plant species from similar communities mapped in the pre-mining survey will be used in rehabilitation of each of the respective zones.

Figure 5: Landform Profile



Source: Water and Rivers Commission (2001)

Figure 6: Wetland Profile



Source: Water and Rivers Commission (2000)

4.4.1.1 Uplands

Studies have shown that woodland areas on dunes do not appear to recover from disturbance as well as the wetland heath communities (Woodman, 2005). In this situation active rehabilitation in the form of an applied seed mix to increase the establishment of native species may be necessary.

4.4.1.2 Fringing

KSS recognise the importance of being able to establish fringing vegetation around lakes and establishing ephemeral wetland vegetation. Establishment of a representative riparian margin around rehabilitated dredge ponds appears to be important, not just from a value in its own right, but also to help achieve water quality that will better mirror that of surrounding natural wetlands. Establishment of even a simple sedgeland margin (e.g. *Schoenoplectus validus)* around rehabilitated areas appears to significantly improve macroinvertebrate structure to that of a more natural community (McCullough and Lund, 2008). EPP1 appears to be a potential analogue for the dredge ponds.

The Centre for Ecosystem Management and Edith Cowan University conducted an assessment of the rehabilitation at KSS in mid 2007 and then later reviewed changes in November 2008 (van Etten *et al.*, 2009). Overall, there has been a slight to modest improvement in rehabilitation with plant cover increasing more substantially in low-lying areas closer to the lake. The monitoring indicated that good to excellent ecological restoration can be achieved at KSS post-mining through the use of fresh topsoil matched to the topographic position in the landscape where it originated.

Post mining landform restoration will recreate seasonal wetlands (palusplains, damplands and sumplands) in between the permanent lakes.

Therefore zonation should be based primarily on (vertical) distance above lake levels, rather than distance along slope from lake edge. A range of levels will be established in fringing landforms to account for the change in groundwater level due to evaporation of open water and changing climate. Groundwater modelling and site monitoring results will be used to define levels in the post mining environment, to ensure there will always be at least some seasonally waterlogged and inundated areas.

4.4.1.3 Flooded

For the existing operations, monitoring bores KMB10, KMB11 and KMB12 are located near the dredge pond. Water level monitoring in bores around the dredge pond has occurred since 1996. The results, as well as modelled effects on groundwater levels, will be used in establishing beaches where the annual groundwater fluctuation will provide zones as shown in Figure 6. Long term monitoring indicates seasonal variation in the superficial aquifer is around one metre, however monitoring bores close to natural wetlands indicate annual water depth fluctuations of up to two metres.

Rehabilitation techniques should focus on stabilisation of slopes using logs and other woody debris, sandbags (which could include planted sedges), and tubestock planting of sedges, paperbarks (*Melaleuca* trees) and other species tolerant of flooding. Rootstock of paperbarks have been observed resprouting and rooting when washed up at lake water edge and could be a convenient method to re-establish such key species. Flooding regimes vary from lower slopes (more or less permanently flooded) to upper reaches (flooded for a few weeks only) of this zone; therefore careful locating of species according to their preferred flooding regime will be required.

4.4.1.4 Lakes

McCullough and Lund (2008) have undertaken a baseline ecology assessment in the existing dredge pond and rehabilitation cell for physical (water chemistry) and biological attributes. This work is part of an ongoing rehabilitation research programme to re-establish ecological functions in wetlands and lakes of the post mining environment.

Aquatic Invertebrates

The mine extension area currently has no permanent water bodies. Analogue sites to establish a comparative database of aquatic invertebrates, to be established in the rehabilitated dredge ponds, are from the EPP wetlands to the east of the mine extension area.

Although some of these EPP wetlands have permanent or near permanent water, they are geomorphically very different from the rehabilitated dredge ponds. They are located at the interface of the Bassendean and Pinjarra Plain systems and have clay pans or underlying clay soils. In comparison, the completed dredge ponds, mined in deep Bassendean sand, are underlain by Spearwood soils containing limestone and shells.

KSS aims to ensure water quality in the rehabilitated lakes is capable of re-establishing aquatic algae, invertebrate and vertebrate fauna populations.

Edith Cowan University has undertaken a baseline ecological assessment in the existing dredge pond and rehabilitation lakes for physical (water chemistry) and biological attributes. This work is part of an ongoing rehabilitation research program to re-establish ecological functions in wetlands and lakes of the post mining environment. Preliminary sample analysis show abundant aquatic macroinvertebrates, dominated by zooplankton crustacean including daphnid and other cladoceran families, calanoid copepods and ostracods. There appeared to be no difference between littoral and open water aquatic macroinvertebrate communities suggesting riparian vegetation is not significant for aquatic macroinvertebrate community structure of these wetlands (McCullough and Lund, 2008).

Water Quality

Water quality in the rehabilitated lakes needs to be capable of re-establishing aquatic algae, invertebrate and vertebrate fauna populations.

Background flow through water quality to the pit-lakes is relatively good, with an average pH of 6.0 and an average salinity (total dissolved salts (TDS)) value of approximately 250 milligrams per litre. Predicted groundwater quality indicates that salinity and selected ions in the pit lakes will increase with time. While the increasing trend of salinity, especially following year 60, would decrease to become almost equilibrium after 85 years, chloride and sulphate will continue to steadily increase with time. pH value is also considered relatively likely to increase with time, but this, depending on the groundwater recharge and new freshwater input, may remain in equilibrium with values slightly above circum-neutrality.

The potential for acid sulfate soils is present given the high water table and low lying nature of the area. Soils tested over the proposed mine extension area exhibit Non Acid Forming, Potentially Acid Forming and Acid Neutralising Capacity capability. The presence of fine pyritic material has been observed in the current tailings stream. However, as mining has operated at the site for ten years and monitoring has not indicated any development of acid formation, the risk of acid soil generation is considered low. In the fringing wetland environment, any acidity generated will be contained in the rehabilitated lake which also contains carbonaceous material, generally at the base of the lake.

4.5 FAUNA

The remaining undisturbed 900 hectares of the KSS property is considered to provide sufficient refuge habitat for fauna temporarily displaced by mining activities. Undisturbed wetland and upland woodland abut the mine extension area, providing opportunity for faunal re-colonisation from these areas as rehabilitation establishes.

Targeted programs aim to expand habitat for fauna currently with a restricted range on the property. As a result, long-term impact of clearing on fauna is expected to be limited. As rehabilitation areas mature to provide preferred habitats, re-colonisation from adjacent undisturbed areas is expected to occur.

KSS aims to protect the biodiversity of fauna species on the KSS property. Management and mitigation measures to achieve these aims and reduce risk include:

- Conservation Significance 1 Species:
  - Conduct surveys to identify potential Cockatoo tree hollows prior to annual land clearing to ensure hollows are not currently being used for breeding. Tree hollows suitable for Cockatoos will be relocated to other areas, preferably within newly rehabilitated areas. Hollows will either be remounted on trees outside the mine extension area, or if this is not practical, replaced with similar sized nest boxes **(Commitment 7.7.4a).** Tree hollows suitable for Cockatoos may be used by Carnaby’s Black-Cockatoo, but Baudin’s Black-Cockatoo is not expected to nest in the Kemerton region.
  - Planting of tree species likely to develop hollows and provide Cockatoo habitat in the long term **(Commitment 7.7.4b).**
  - Control slope gradients to minimise erosion and soil loss. Finished slopes will include a zone of shallow beach approximately 30 to 40 metres wide before sloping at a stable angle of repose (approximately one in four) to the base of the rehabilitated lake **(Commitment 7.2.1.4c).**
  - Minimising the amount of vegetation that will be cleared at any one time. Progressive clearing of an average of five hectares per year will be carried out in Autumn when species are less likely to be breeding **(Commitment 7.7.4d).** This will enable any Threatened or Migratory Fauna species to migrate to other areas of the KSS property.
  - Progressive rehabilitation mining with local provenance seed to encourage colonisation from surrounding vegetative areas, to re-establish vegetation and hence fauna **(Commitment 7.7.4e).** Rehabilitation will provide restored habitat for recolonisation over time.
  - Conduct targeted survey for Chuditch, Western Ringtail Possum and Quokka prior to annual land clearing to ensure that populations of these Vulnerable species will not be affected by the planned clearing. If evidence of their presence

is found, trapping will be undertaken and captured individuals relocated to suitable alternative sites on the property **(Commitment 7.7.4f).**

- Erecting nest boxes suitable for use by Western Ringtail Possums where annual surveys show Possums are present in areas planned to be cleared in the short term. Nest boxes will be placed in adjacent undisturbed areas where suitable foraging habitat is present **(Commitment 7.7.4g).**
- Planting areas of peppermint (*Agonis flexuosa*) within upland woodland areas to be rehabilitated post mining. Peppermint trees will be planted in clumps to encourage interlocking branches **(Commitment 7.7.4h).**
- Pre-clearance surveys will be undertaken within suitable habitat to determine the presence/absence of targeted vertebrate conservation significance species will not be affected by the planned clearing. If evidence of their presence is found, trapping will be undertaken and captured individuals relocated to suitable alternative sites on the property **(Commitment 7.7.4i).**

- Iconic Species:
  - On-going research by Edith Cowan University into establishing dense understorey, returning habitat logs and rocks, return of aquatic vertebrate and invertebrate species to the dredge ponds will provide preferred habitat for the Water Rat.
  - Selection of appropriate species in rehabilitated areas to provide food resource for target Possum species (McCullough *et al.* 2007; McCullough and Lund, 2008).
- Other fauna species:
  - Relocate habitat logs and brush for ground dwelling fauna. Habitat logs and brush are re-spread in areas undergoing rehabilitation as part of current operations **(Commitment 7.7.4l).** This practice will continue.
  - Further macroinvertebrate and wetland research will be funded through ECU to establish baseline conditions as analogues for future rehabilitation **(Commitment 7.7.4m).**
  - Relocation of nest hollows in undisturbed areas on the property for use by other bird and mammal species will offset habitat lost through the development **(Commitment 7.7.4n).**

4.5.1 Iconic Species

There are a number of fauna species recorded on the property that KSS consider at least iconic at the local level. Currently, these species are known to occur in a restricted number of locations. A key objective of the rehabilitation programme is to re-establish preferred habitat for these species, which results in increased numbers and distribution of these species in the KSS property. These species include:

- Black-striped Jollytail *Galaxiella nigrostriata* (P3) — The Kemerton population is a relict, with only one other population known on the Swan Coastal Plain, near Muchea north of Perth, and the main population occurring in wetlands along the south coast east of Margaret River.

• Rakali or Water Rat *Hydromys chrysogaster* (P4)	An aquatic species recorded in EPP7. It requires permanent or near permanent water.
• Honey Possum *Tarsipes rostratus*	The Honey Possum is known from several sites in the region including the KSS property, especially in shrubland and heath.
• Western Pygmy Possum *Cercartetus concinnus*	The Western Pygmy Possum is known from a single specimen recorded in 1993 in the western part of the KSS property (Ninox Wildlife Consulting, 1994). It is commonly associated with Eucalypts so is presumably present in the woodlands of the KSS property and throughout the Kemerton region.

4.5.2 Habitat Restoration for Specialised Terrestrial Fauna

Specialised habitat restoration that is being included in the rehabilitation program includes:

- Conduct surveys to identify potential Cockatoo tree hollows prior to annual land clearing to ensure hollows are not currently being used for breeding. Tree hollows suitable for Cockatoos will be relocated to other areas, preferably within newly rehabilitated areas. Hollows will either be remounted on trees outside the mine extension area, or if this is not practical, replaced with similar sized nest boxes **(Commitment 7.7.4a).**
- Planting of tree species likely to develop hollows and provide Cockatoo habitat in the long term **(Commitment 7.7.4b)**.
- Erecting nest boxes suitable for use by Western Ringtail Possums where annual surveys show Possums are present in areas planned to be cleared in the short term. Nest boxes will be placed in adjacent undisturbed areas where suitable foraging habitat is present **(Commitment 7.7.4g).**
- Planting areas of peppermint (*Agonis flexuosa*) within upland woodland areas to be rehabilitated post mining. Peppermint trees will be planted in clumps to encourage interlocking branches **(Commitment 7.7.4h).**
- Relocate habitat logs and brush for ground dwelling fauna. Habitat logs and brush are re-spread in areas undergoing rehabilitation as part of current operations **(Commitment 7.7.4l).** This practice will continue.

4.5.3 Habitat for Specialised Aquatic Fauna

There are currently few permanent water bodies at KSS. The creation of both permanent lakes and seasonally inundated wetlands in the post mining environment provides the opportunity to expand habitat for local iconic species the Jollytail and Water Rat and various frog species and will provide new preferred habitat for native fauna including waterfowl.

Protection and enhancement of habitat and populations of these key species may present an effective component of rehabilitation. Monitoring of rehabilitated wetlands will occur to ensure water quality and ecology functions are sufficiently established to enable survival of iconic fish.

5. REHABILITATION METHODS

The RMP is a dynamic document, which incorporates results of monitoring and research during the life of mine in subsequent revisions of the document. Periodic monitoring will quantify success against short and long term criteria.

The RMP is based on undertaking rehabilitation in line with the following:

- Progressive rehabilitation.
- Seed collection from local sources.
- Match species selection to equivalent rehabilitation landforms.
- Detailed rehabilitation plans for each landform type.
- Protection of iconic species.
- Provision of specific habitat features, such as logs with hollows.
- Introduction of iconic species into new areas.
- Undertake trials and research on specific projects.
- Weed control.
- Feral animal control.
- A monitoring schedule for works completed.
- A reporting and review schedule for the plan.

5.1 VEGETATION

Native vegetation will be established in rehabilitation areas utilising the following hierarchal system:

1. Seed bank in topsoil and applied vegetation.
2. Additional seed broadcast over rehabilitation areas.
3. Seedlings grown from local seed.
4. Other methods for recalcitrant species - including direct transplanting; transplanting from rhizomes/bulbs, tip cuttings and (possibly) tissue culture.

Key species and structural goals for each rehabilitation zone are summarised in Table 8. This information has been derived primarily from surveys of rehabilitation and comparisons with their natural wetland analogues. Most species have been demonstrated to return via (fresh) topsoil, although some dominant species may require supplementary seeding and/or planting to achieve their required density. However, a few species are not readily returned via topsoil. These include some sedges/rushes which rely mainly on vegetative reproduction, and members of the Proteaceae family which can have difficult to germinate seeds (*Banksia littoralis*). These will need to be grown in a nursery and planted into rehabilitated areas, and/or be seeded by hand. Although legumes have returned readily from topsoil, supplementary seeding by hand is recommended (using scarified seed) as a good initial cover of legumes is generally beneficial for nitrogen input and soil stability.

Table 8: Dominant Species of the Three Rehabilitation Zones and their Main Revegetation Method

Characteristics	Key Species (Typical dominant species are in bold)
Upland	
Open eucalypt woodland with shrubby understorey. **Structural Goals (% cover):** • 10-30% Trees. • 10-20% Tall shrubs. • 30-60% Low shrubs and ground cover.	***Eucalyptus rudis*** T (S + P) ***Corymbia calophylla*** T (S + P) ***Lepidosperma longitudinale*** T ***Pteridium esculentum*** P ***Astartea scoparia*** T ***Acacia pulchella*** T (S) *Hardenbergia comptoniana* T (S) *Agonis flexuosa* T (S) *Xanthorrhea priessii* P *Acacia saligna* T (S) *Dasypogon bromeliifolius* T (S) *Calytrix leshcenaultii* T *Jacksonia furcellata* T (S) *Hypocalymma angustifolium* T *Banksia littoralis* S (P) *Macrozamia reidlei* P (S) *Kunzea recurva* T *Eucalyptus marginata* T
Flooded	
Melaleuca thicket with sedge understorey. **Structural Goals (% cover):** • 50-80% Trees. • 20-50% Sedges.	***Melaleuca rhaphiophylla*** P ***Melaleuca teretifolia*** P ***Baumea articulata*** P ***Lepidosperma longitudinale*** P ***Melaleuca preissiana*** P *Melaleuca viminea* (P) *Juncus pallidus* (P) *Astartea scoparia* (P)
Fringing	
Open Melaleuca woodland with mixed sedge and shrubby understorey. **Structural Goals (% cover):** • 10-30% Trees. • 20-50% Low shrubs. • 20-50% Sedges and other monocots.	***Melaleuca rhaphiophylla*** T (S) ***Melaleuca teretifolia*** T (S) ***Baumea articulata*** T (S) ***Lepidosperma longitudinale*** T ***Melaleuca preissiana*** T (S) *Astartea affinis* T *Kunzea ericifolia* T *Acacia saligna* T *Melaleuca lateriflora* T *Astartea scoparia* T *Leptocarpus* sp T (P) *Kunzea recurva* T

Characteristics	Key Species (Typical dominant species are in bold)
	Melaleuca incana subsp. *incana* T *Meeboldina scariosa* T *Acacia pulchella* T *Hakea trifurcata* T (S) *Melaleuca lateriflora* T (S) *Banksia littoralis* T (S) *Taxandria linearifolia* T *Juncus pallidus* T *Calothamnus lateralis* T *Pericalymma ellipticum* T *Hakea tuberculata* T (P) *Cassytha racemosa* S (P) *Euchilopsis linearis* T *Viminaria juncea* T *Cytogonidium leptocarpoides* T *Bossiaea eriocarpa* T *Banksia littoralis* S (P)

Source: van Etten *et al*. 2008
Note: This list will be subject to change based on seed availability.
Revegetation Method: T – topsoil.
P - planting of greenstock.
S - direct seeding.
Supplementary revegetation method to achieve necessary density and dominance are in parenthesis.

Species of the Flooded Zone will be required to be planted from tubestock given topsoil and seed are unlikely to stay at site. The use of sedges planted into sandbags has proven to be a valuable establishment technique that also renders banks more stable (van Etten *et al*. 2008). The duration of flooding increases with distance along slope which often results in distinct zoning of species. Such zonation may need to be replicated when planting in this zone based on available knowledge of flooding tolerance of wetland species (Water & Rivers Commission, 2001).

The main method to return plant species on upland and fringing zones will be direct return of topsoil. The use of fresh topsoil has been shown to achieve the best results at Kemerton and elsewhere. However, for certain species and areas, topsoiling should be supplemented with direct seeding using locally collected seed. The use of seed collected from native vegetation within the proposed mine area addresses one aspect of the National Strategy for the Conservation of Australia's Biological Diversity (1996), namely to:

"Achieve the conservation of biological diversity through the adoption of ecologically sustainable agricultural and pastoral management practices".

This also addresses the issue of collecting seed from appropriate provenance where information of genetic differentiation between populations of plant species is lacking i.e. if not sure, it is best to collect locally.

Sufficient seed can be collected for rehabilitation purposes from vegetation on site. Seed will be applied at a rate of 0.5 kilograms per hectare for lowland areas and two kilograms per hectare for upland areas.

Some species are locally abundant and set copious quantities of seed. Seed can be collected in sufficient quantity for direct seeding over rehabilitation areas. Other species set seed infrequently or in low amounts. For these, the preferred method of propagation is to germinate the available seed, grow them in nurseries, for planting out as tubestock.

A number of species can be quite successfully transplanted. Plants can be relocated into either native vegetation areas that will not be disturbed or completed mine areas undergoing rehabilitation. Most notable of these are Grass Trees (*Xanthorrhoea preissii* and *X. brunonis*). These species are typically difficult and slow to return from topsoil and/or direct seeding. Other herbaceous species such as ***Hibbertia hypericoides*** and ***Patersonia occidentalis*** can also be directly transplanted in rehabilitation sites with a high level of success.

Consultation with commercial transplanters has been undertaken who have been transplanting Grass Trees for many years. Their reported success rate is relatively high (approximately 75%). Transplanting of Grass Trees does not appear to be season-sensitive, as long as transplanted trees can be well watered during their first year. The period between autumn and spring (April to October) is usually considered appropriate to implement the work.

The target species for rehabilitation (Table 8) should be regarded as interim list that will be expanded upon with future research and survey.

5.1.1 Priority Species

Seven Priority flora species have been recorded on the KSS property. Five have been recorded in the proposed mine extension area. Methods of re-establishment for these species are:

- *Acacia semitrullata* (P3) - Flowers May to September. Seed pods 60 - 75 millimetres (Marchant *et al.* 1987). Seed can be collected and propagated in a nursery for planting as seedlings.
- *Boronia juncea* supsp. *juncea* (P1) - Not considered a prolific or regular seeder. Collect seed if available and propagate in a nursery for planting as seedlings. Other propagation techniques also need to be assessed.
- *Caladenia speciosa* (P4) – Not considered a prolific or regular seeder. Collect seed if available and propagate in a nursery for planting as seedlings. Other propagation techniques also need to be assessed.
- *Dillwynia dillwynioides* (P3) - Produces seed pods containing one or two seeds, but not considered to be a prolific or regular seeder. Collect seed if available and propagate in a nursery for planting as seedlings. Other propagation techniques may also need to be assessed.
- *Eucalyptus rudis* subsp. *cratyantha* (P4) - Hemispherical seed capsule approximately five by eight millimetres (Marchant *et al.* 1987). Seed can be collected and propagated in a nursery for planting as seedlings or if sourced in sufficient quantity can be direct seeded in specific 'cluster' locations.

5.1.2 Weeds

Weed management will be a necessary component of rehabilitation at KSS. Sandy, upland areas seem to most prone to weed invasion and control of weeds will be required where weeds are dominant to enable successful growth of native species in rehabilitation. However a strategic and targeted approach to weed control should be adopted in preference to large scale spraying as some level of weed cover may be beneficial in preventing wind erosion, especially on exposed slopes. Spot spraying or application of grass selective herbicide (e.g. Fusilade) is recommended in small patches where weeds are likely to be competing with native species and where new plantings/seeding has occurred.

A complementary strategy as part of a more integrated approach to weed management would be to control weeds in lands surrounding rehabilitation; particularly along tracks and disturbed vegetation (such weed infestations provide a ready supply of weed seed into rehabilitation). Most weeds prefer growing space and full sunlight, therefore encouragement of good cover of native species is likely to be best long-term approach to minimise the adverse effects of weeds.

Gomphocarpus fruticosus (Cotton Bush) a Declared Plant has two requirements P1 and P4 that must be met. These are (DAF, 2008):

- P1 Requirements - The movement of plants or their seeds is prohibited within the State. This prohibits the movement of contaminated machinery and produce including livestock and fodder.
- P4 Requirements - The infested area must be managed in such a way that prevents the spread of seed or plant parts within and from the property on or in livestock, fodder, grain, vehicles and/or machinery. Treat to destroy and prevent seed set all plants:
  - Within 100 metres inside of the boundaries of the infested property.
  - Within 50 metres of roads and highwater mark on waterways.
  - Within 50 metres of sheds, stock yards and houses.

Treatment must be done prior to seed set each year. Properties with less than two hectares of infestation must treat the entire infestation. Additional areas may be ordered to be treated. Recommended treatment methods include:

- Herbicides Glyphophosate or Triclopyr during the active growing period from September to December before fruit forms.
- Slash established bushes during winter and burn, cultivate or grub seedlings and regrowth.
- Roundup Biactive or Razor preferred treatment in wet areas or along water courses near shallow water.

Control programs have been implemented across the KSS property and have successfully managed infestations. Weed management is ongoing. Weed hygiene will be implemented during all operations in accordance with the Weed Inspection List (Appendix 5).

5.1.3 Dieback

The main dieback management tool used on site is quarantine. Site activities are concentrated around the dredge pond and plant site. With the exception of access to production and monitoring bores, there is no reason for access to other parts of the property.

Hygiene management will be in accordance with the Dieback Hygiene Protocol for the project and will include the following provisions **(Commitment 7.5.4g)**:

- All vehicles and machinery will arrive at the project area clean and free from soil, mud, soil slurry and vegetation material, in accordance with the Weed Inspection List.
- Soil and vegetation stripped from the mine area will be stored in marked areas.
- No soil or vegetation material will be transported around the project area.
- Movement of vehicles into non-production areas of the property is restricted, with permission required from the General Manager.
- All vehicles and machinery will be cleaned down prior to leaving the project site to prevent the spread of *P. cinnamomi* from the project area to areas of uninfested native vegetation in the region.

5.2 SOIL

The Edith Cowan University study has confirmed the importance of using fresh topsoil as the prime method for plant species return across most rehabilitation areas. Topsoiling has the potential to return most of the plant biodiversity seen in native vegetation in the KSS area, but as it is unlikely to return all species, with key functional groups (eg. resprouters, small herbs) likely to be missing, it should be complemented with direct seeding and planting of targeted species.

KSS aims to conserve surface soil to help with long-term site rehabilitation and minimise environmental degradation. Management and mitigation measures to achieve these aims and reduce the risk rating include:

- Wind and water erosion:
  - Strip and stockpile topsoil (where required) in dry and preferably still wind conditions, to minimise dust generation and assist rapid revegetation **(Commitment 7.2.1.4a).**
  - Control slope gradients to minimise erosion and soil loss. Finished slopes will include a zone of shallow beach approximately 30 to 40 metres wide before sloping at a stable angle of repose (approximately one in four) to the base of the rehabilitated lake **(Commitment 7.2.1.4b).**
  - Routinely inspect rehabilitated and disturbed surfaces for erosion, particularly after significant rainfall **(Commitment 7.2.1.4c).**
  - Implement appropriate remediation measures if soil erosion is observed during routine inspections **(Commitment 7.2.1.4d).**
- Soil management:

- Place stockpiled topsoil in windrows less than three metres high to minimise loss of seed viability and soil biota **(Commitment 7.2.1.4e).**
- Strip and replace topsoil fresh and dry (known as the autumn direct return) to a maximum depth of about 100 millimetres where practicable and place directly onto rehabilitation areas or stockpiles **(Commitment 7.2.1.4f).**
- Complete direct replacement wherever practicable **(Commitment 7.2.1.4g).**

5.3 WETLANDS

5.3.1 Lake Beaches

Water levels in lakes to be established as a result of mining are likely to be constant with seasonal fluctuations over a smaller range of elevations than the predicted ‘base case’ water table for the same areas. Lake water levels have an overriding effect on water table levels in adjacent areas. Modelling indicates that there will be a net discharge of water in the lake areas due to increased water losses by evaporation from the open water compared to water losses by evapotranspiration from the same areas in the ‘base case’, which have belowground water tables. Annual fluctuations of the water table are likely to be one to two metres.

The range of lake levels is estimated to be around 0.5 metres, but will vary in response to seasonal rainfall patterns. Finished slopes will include a zone of shallow beach of approximately 30 to 40 metres wide before sloping at a stable angle of repose (approximately one in four) to the base of the rehabilitated lake.

Clay material may need to be imported or separated from fines in the process plant and re-deposited back in specific locations in the rehabilitated dredge pond to provide a soil profile with sufficient structure to support tunnels for the Water Rat.

5.3.2 Sand Bars - Islands

Islands will be created on the lake slopes by pumping extra sand onto sections close to the deep water zone. These islands may be used for bird refuges, to escape feral animals during the breeding season. The use of logs and rocks close to the deep water zone may be able to provide habitat for Water Rats in summer periods.

5.4 FAUNA

5.4.1 Black-striped Jollytail

Palusplain wetlands throughout the mine extension area do not support populations of Black-striped Jollytail. This species is restricted to a few EPP wetlands on the eastern side of the property in the Kemerton Nature Reserve. The creation of both permanent lakes and seasonally inundated wetlands in the post mining environment provides the opportunity to expand habitat for this local iconic species.

A key element in achieving the objective of expanding the range of this species is exclusion of the introduced pest fish Gambusia (*Gambusia holbrooki*) from dredge ponds in the mine extension area. This introduced fish has been present in the dredge pond of the existing operation for many years.

There is good evidence from around Perth and Australia that Gambusia negatively impact on frog populations (by attacking tadpoles) (Sommer, 1997) and macro invertebrate communities (McCullough, 1998; Ling, 2004). It is suspected that Gambusia may also impact on Jollytail populations, the significance of which is not known.

KSS has sponsored a two year Masters Research Program at the School of Natural Sciences at Edith Cowan University on the "Ecological requirements and population genetics of remnant black-stripe minnow (Pisces: Galaxiidae, *Galaxiella nigrostriata*) populations in seasonal wetlands of south-western Australia." There are four study components to the project: habitat and diet preferences, aestivation requirements and population genetic structure. All components will provide information to help conserve this threatened species, direct wetland rehabilitation requirements and may be used to identify habitats likely to contain 'new' populations. The results of the research project will help KSS design and construct rehabilitation that best enhances long term survival prospects of Jollytails, and investigate ways of protecting Jollytails from Gambusia.

The primary method of excluding Gambusia from the mine extension area is through quarantine (not allowing the fish to enter the dredge pond in the first place). Once established in a permanent water body, Gambusia is difficult, if not impossible, to eradicate.

Gambusia can not survive desiccation, so seasonally inundated wetlands are also proposed in rehabilitated areas, to complement permanent rehabilitated lakes. These will provide refuge and nursery areas for Jollytails, frogs and macro invertebrates in the event that Gambusia does enter rehabilitated lakes.

Quarantine of the mine extension dredge ponds to prevent Gambusia being transferred from the existing mine area will be achieved by **(Commitment 7.7.4j):**

- Cleaning all dredging equipment and pipes prior to relocation to the mine extension area.
- Preventing direct pumping of water from existing dredge ponds to the mine extension area ponds.

Gambusia can not survive desiccation, so seasonally inundated wetlands are also proposed in rehabilitated areas, to complement the permanent rehabilitated lakes. These will provide refuge and nursery areas for Jollytails, frogs and macroinvertebrates in the event that Gambusia does enter rehabilitated lakes.

Once the lake biology is stable and at a successful stage of rehabilitation, Jollytails will be caught and released into the lakes in the rehabilitated areas. This will be determined by continued studies by the Masters student and by Edith Cowan University in the existing mine area.

5.4.2 Frogs

Reconstructed seasonally inundated and waterlogged locations also provide nursery areas for frog populations. Sumplands, separate to margins of permanent lakes will provide nursery frog ponds, even if the lakes are colonised by Gambusia. As these areas will dry out over summer, no residual population of Gambusia will exist in these sumplands, even if they are colonised by Gambusia.

5.4.3 Water Rat

The Water Rat (*Hydromys chrysogaster*) usually lives in the vicinity of permanent water bodies. Nests are made in tunnels in banks or occasionally in logs. They eat large aquatic insects, fish, crustaceans, frogs and lizards.

The rehabilitation research programme will investigate factors aimed at providing habitat in the rehabilitated dredge ponds to support introduced populations of Water Rats. Ongoing research into establishing dense understorey, returning habitat logs and rocks, return of aquatic vertebrate and invertebrate species to the dredge ponds will provide preferred habitat for this native mammal.

Water Rats will be trapped and released in the lakes once successful rehabilitation and aquatic ecology has been accomplished. This will be determined by continued studies by Edith Cowan University in the existing mine area.

5.4.4 Western Pygmy and Honey Possums

Bamford (2003a) notes that the persistence of the Honey Possum and Western Pygmy Possum on the KSS property is particularly unusual, reflecting the large area and diversity of native vegetation.

The Honey Possum is known from several sites in the region including the KSS property, especially in shrubland and heath. The Western Pygmy Possum is known from a single specimen recorded in 1993 in the western part of the KSS property (Ninox Wildlife Consulting, 1994). It is commonly associated with Eucalypts so is presumably present in the woodlands of the KSS property and throughout the Kemerton region. Targeted trapping and relocation of these and other icon species in advance of clearing will ensure minimal impact on these species from the project. The mine schedule (Figure 1) indicates this area will not be accessed until five years from commencement of operations.

Relocation of small nest hollows suitable for vertebrates (Figure 7) into undisturbed areas and the placement of habitat logs and trash in areas undergoing rehabilitation will ensure habitats for both Possum species. Rehabilitation using nectar producing plants of the Proteaceae and Myrtaceae will provide habitat and forage areas for both species of Possums on the property. These and other research projects are aimed at restoring suitable habitat for targeted species in rehabilitation areas for foraging and breeding.

The use of feral animal control measures will also help in the re-colonisation of the Western Pygmy and Honey Possums and other fauna on the KSS property.

5.4.5 Feral Animal Control

Foxes, feral cats, rabbits and wild pigs are all present on the KSS property. In order for successful return of fauna species such as Water Rats and Possums, feral animals need to be controlled. KSS will continue to undertake feral animal control to minimise impacts from feral animals on native species. This will include control of pigs, foxes and rabbits **(Commitment 7.7.4o)**. A number of control options available are discussed below.

1080 is a very effective control method for rabbits, foxes, feral cats and wild pigs. Baiting is the most cost effective and efficient means of reducing feral animals. In liaison with DEC or DAF, 1080 baiting using meat, eggs and oats will be carried out on the KSS property. Important precautions that will be taken include:

- Notification to neighbours.
- Erection of warning signs.
- Careful use of 1080 in high risk areas.
- Responsible security, storage and disposal of baits.
- Effective personal care.

Alternative methods of control if 1080 baiting is not acceptable due to close proximity to neighbours (<two kilometre radius) include baiting programmes for pigs, foxes and feral cats, shooting for wild pigs and Pindone baiting for rabbits.

5.5 SCHEDULE OF WORKS

This section of the RMP integrates the sequential stages clearing, excavation and rehabilitation. It schedules various activities in the optimum season(s) and timing with other site activities. Scheduling of site activities takes into consideration the following factors:

1. Growing season for plants and seed used in rehabilitation generally corresponds to the local ‘wet season’. In this location, this period is from mid to late May to September. With the highly permeable sands of the site, maximising the time for plants to germinate and establish prior to the soil profile drying and temperatures rising means plants and seed should be applied from late May to the end of June.
2. Pre-clearance surveys will be undertaken within suitable habitat to determine the presence/absence of targeted vertebrate conservation significance species will not be affected by the planned clearing. Targeted surveys for Chuditch, Western Ringtail Possum and Quokka prior to annual land clearing to ensure that populations of these Vulnerable species will not be affected by the planned clearing will also be carried out. If evidence of their presence is found, trapping will be undertaken and captured individuals relocated to suitable alternative sites on the property.

   A suitably qualified and licensed person will be commissioned to undertake the programme. Individuals will be relocated to nearby vegetation on the property, outside the proposed clearing boundary, which approximates their existing habitat. Fauna relocation needs to consider not only the schedule constraints arising from site activity, but also constraints due to seasonal breeding and activity cycles of different fauna. For example:

– The breeding season for Cockatoo species can be from July to March, with eggs being laid generally from July to November. Clearing trees and hollow relocation is to be scheduled for periods when eggs or young are not in the nest.

– Possums breed mostly in winter and young leave the nest at six to seven months old (late summer). Clearing of trees and hollow relocation is to be scheduled for periods when young are not in the nest.

These constraints indicate an optimum fauna relocation period of early autumn (March and April). This schedules the sequential activities of relocating fauna, clearing vegetation, topsoil striping and relocating all in March, April and early May. Seeding and planting then follow in late May and June.

3. Other schedules include seed collection from local species. Seed set from spring flowering for most species occurs from late spring to summer (November to February). Seed from some species may also be collectable during the clearing programme in April. Seedlings grown in nurseries from local seed need to be sown in October/November to be advanced enough for out-planting in May and June the following year.

4. As shown by tasks 4 and 5 presented in Table 9, clearing of the next block to be dredged must be undertaken, in order for topsoil to be stripped and returned onto the block undergoing rehabilitation, before ripping, planting and seeding of this block can occur. Salvaging Grass Trees from the current clearing block therefore cannot be undertaken if these plants are to be directly replanted in the current rehabilitation block. Alternatives to achieve successful salvaging and transplanting of these species are provided in Appendix 1.

5. Topsoil stripped in advance of mining is intended, as much as possible, to be directly returned to completed portions of the site where progressive rehabilitation is underway. To maximise the potential benefits of topsoil the following guidelines should be adhered to:

   - Topsoil should be as fresh as possible, with direct return the best approach where feasible (Rokich *et al.* 2000). This would require integration of mining and rehabilitation plans so that topsoil obtained when native vegetation of new mining areas is cleared is transported directly to a rehabilitation site. In some cases this may not be possible for a reason such as the area being stripped is larger than the area available for progressive rehabilitation. In this case, surplus topsoil may need to be stockpiled.
   - Topsoil should be spread to a maximum depth of 10 centimetres, to optimize revegetation of species rich plant communities (Rokich *et al.* 2000).
   - Topsoil should receive minimal screening and sieving as rootstock and underground storage organs (bulbs, tubers etc) may provide source of propagules and consequently, regeneration for some species. Also organic matter and woody debris in soil is likely to be beneficial to soil stability and nutrient status.

Table 9: Rehabilitation Task Register

No.	Tasks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	High risk dust period												
2	Primary rehabilitation earthworks												
3	Fauna relocation												
4	Clear vegetation, strip topsoil and direct return												
5	Ripping, planting and seeding												
6	Transplant Grass Trees[1]												
7	Seed collection												
8	Seeds to local nursery to grow tube stock plants												
9	Rehabilitation monitoring												

Notes: 1. From block in advance of current clearing block.

- Litter and other debris on the soil surface should be separated and spread over the topsoil. This would enhance organic matter status of topsoil, contribute to an on-going pool of nutrients in the ecosystem, and provide improved soil surface protection, especially during summer.

Topsoil should be placed on soils/landforms which more closely reflect the characters of it origin (rather than broadly spread over all slopes). Interim guidelines recommend dividing topsoil into three zones (see next section for details).

The optimum time to move topsoil is autumn, generally from April to May (Rokich *et al.* 2000). This coincides with the following factors:

- The topsoil is dry, allowing easier handling.
- Any disturbed seed will not germinate until substantial rains in late autumn and winter (see point 1).
- Dieback activity in the soil is at a minimum.
- The period of high strength winds is over (see point 2).

6. Ideally, preparatory rehabilitation earthworks need to occur in the period when strong local winds are abating (March) and be completed prior to when optimum topsoil return, planting and seeding needs to be undertaken (from April to June).
7. The dry spring and summer period are also characterised by strong local 'sea breeze' winds from the west and south west. These are usually strongest from November to March. While the subject site is on the lee side of the Spearwood Dunes, so to some extent protected from the brunt of these winds, this period is the highest risk time for dust generation and loss of seed via wind erosion.

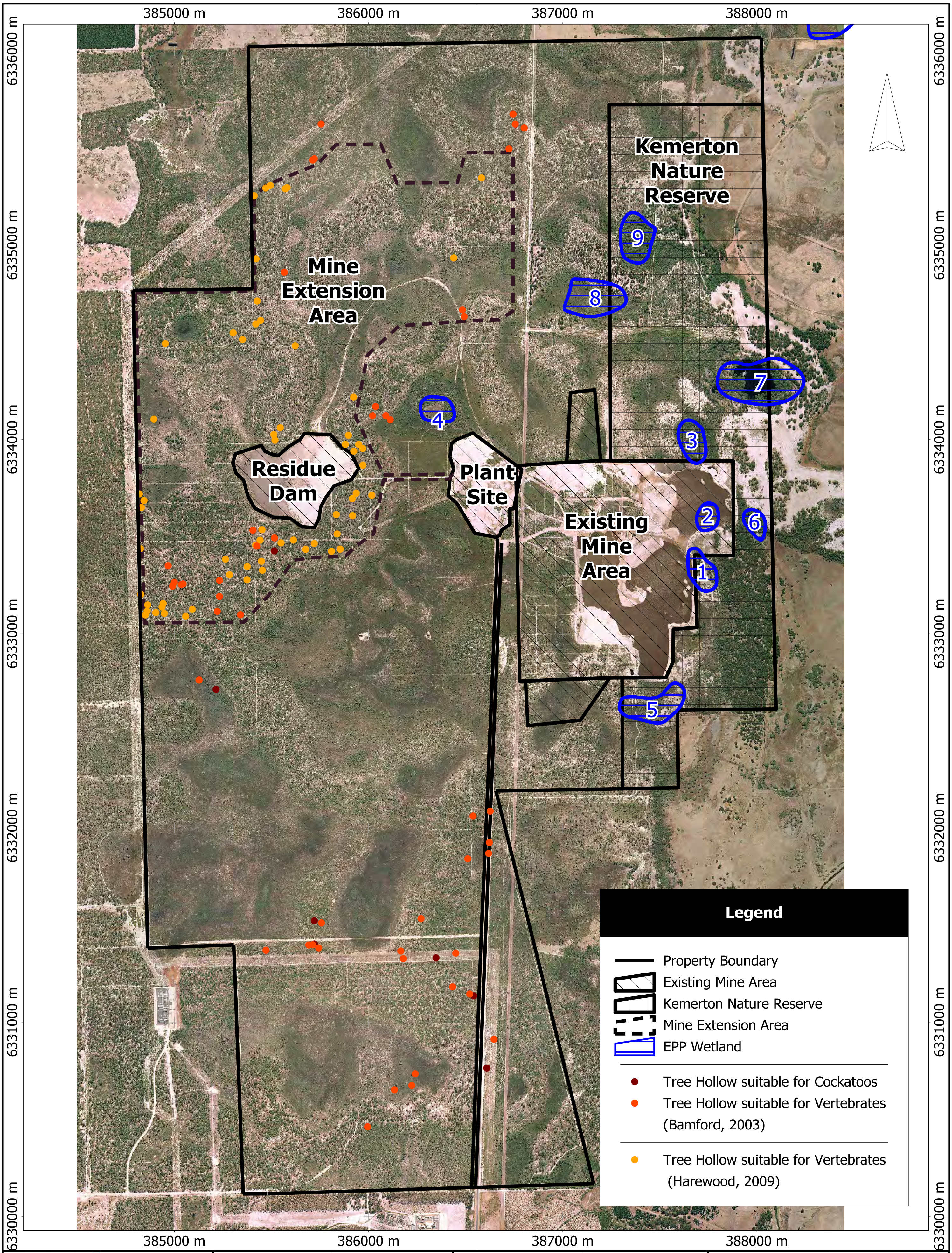
5.6 CLEARING

Clearing is to follow the following process:

1. Areas for clearing shall be clearly marked in the field with survey pegs and flagging.
2. The General Manager shall inform the clearing contractor in person of any clearing conditions (including topsoil and vegetation removal requirements) prior to commencing work.
3. Millable and firewood timber will be salvaged from site for use. Tree hollows suitable for Cockatoos or vertebrates will be removed for remounting on suitable trees in undisturbed areas (Figure 7). Any hollows damaged in the salvage process and unable to be remounted will be replaced by an artificial nest box. This ensures the number of possible nest hollows remains at its current level.
4. All trees, logs and stumps will be removed and stockpiled for use as habitat logs in rehabilitation areas.
5. Available seed from trees being cleared will be collected for use in rehabilitation.
6. Grass Trees and other species suitable for direct transplanting will be removed and transplanted in rehabilitation areas.

7. Suitable vegetation will be removed and placed in windrows for mulching.
8. The area cleared shall be recorded in the Clearing Register (Appendix 2). The register shall record the location of land clearing, surface area, and volume of topsoil removed and where it was stockpiled.
9. Understorey vegetation remaining shall be shall be collected with topsoil and stockpiled, or where possible replaced immediately on topsoiled areas ready for rehabilitation. Topsoil stockpiles shall be no greater than three metres high and located away from water inundation or vehicle traffic. Stockpiles will be divided in two zones:
    - Fringing (within two metres of lake levels).
    - Upland (>two metres above lake levels).

    The separate zones will be signposted so as not to cause confusion.
10. A topsoil stockpile register shall be maintained by the General Manager (Appendix 3).
11. Native species such as Grass Trees will be salvaged in advance of the clearing operation.



MBS ENVIRONMENTAL Environmental + Water Resource Consultants 4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale: 1:25000 Original Size: A4 Air Photo Date: 2006 Grid: MGA94(50) 0 500 m	Kemerton Silica Sand Pty Ltd	Fauna Habitat Trees Figure 7

W:\Kemerton Silica Sand\Drawings\Maps 2009\Flora and Wetlands.map 19/02/2009 Fauna Habitats Layout

6. COMPLETION CRITERIA

EPA (2006) requires that completion criteria must be sufficiently stringent to ensure that the overall objectives of rehabilitation have been met. These criteria must also be designed to allow effective reporting and auditing to define an endpoint for rehabilitation activities. Guidelines published by ANZMEC/MCA (2000) for completion criteria state they should be:

1. Specific enough to reflect unique set of environmental, social and economic circumstances.
2. Flexible enough to adapt to changing circumstances without compromising objectives.
3. Include environmental indicators suitable for demonstrating that rehabilitation trends are heading in the right direction.
4. Undergo periodic review resulting in modification if required due to changed circumstances or improved knowledge.
5. Based on targeted research which results in more informed decisions.

KSS specific progressive rehabilitation completion criteria targets have been developed using data from pre-mining site flora surveys. Plant species data in the different communities, provided in Appendix B of Mattiske (2003b) is summarised in Table 10. This has been used establish completion criteria targets for rehabilitation of similar reconstructed landforms (Table 11).

It is important to clearly define target criteria. For example, 20% species richness is very different per quadrat or transect compared with the overall vegetation community. Also species which are characteristic of particular analogue communities needs to be defined. The number of species recorded in each community type, yet many of these could be relatively uncommon is presented in Table 10. Defining a 'core group' of common species and a 'secondary group' of less common species, each with their own progressive completion targets, may be a more realistic approach than setting target completion criteria based on an average of the entire data set.

Table 10: Vegetation Survey Data

Upland		Fringing		Lowland	
Community	**Species No.**	**Community**	**Species No.**	**Community**	**Species No.**
A1	71	C2	17	E4	9
A2	46	C3	27	F3	7
A3	117	D1	16	G4	1
B1	36	D2	57	H3	14
C1	18	D3	14		
		E1	28		
		E2	36		
		E3	13		
		F1	52		
		F2	13		
		G1	73		
		G2	18		
		G3	19		
		H1	90		
		H2	54		
Av.	**58**		**35**		**8**

Source: Mattiske (2003b) Appendix B.
Data refers to total number of plant species recorded in each community during flora surveys.

Table 11: Target Diversity Completion Criteria

	Analogue (average)	Years	5	10	15	20	25
		% of analogue	20%	50%	70%	90%	95%
Upland	58		11	29	40	52	55
Lowland fringing	35		7	17	24	31	33
Lowland flooded	8		2	4	5	6	7

Completion criteria, objectives and interim targets specific to the project including consideration of soil stability, vegetation cover, diversity, species richness and abundance, fauna and hydrology criteria are presented in Table 12. Rehabilitation completion criteria will be assessed by periodic monitoring of rehabilitation areas against similar undisturbed locations (analogue sites), with similar landform and vegetation characteristics. Interim targets will be reviewed against ongoing rehabilitation monitoring results during the life of mine, with progression towards defined scores set as staged completion targets **(Commitment 9.8a)**.

Rehabilitation, closure planning and completion criteria are adaptive processes that change during the project life, in the light of results of rehabilitation monitoring, research and evolving industry best practice. KSS will continue to update these aspects in operational documents, such as the RMP, during the life of mine.

Table 12: Closure Criteria, Objectives and Interim Targets

Criteria	Objective	Interim Targets
Hydrology		
Water quality and quantity	Quality and flows of surface and groundwater are to be consistent with pre-mining values. Hydrological management is required for effective establishment of vegetation and to ensure site stability.	Monitoring showing surface water quality consistent with pre-mining levels or licenced values. Monitoring showing groundwater levels consistent with modelled forecast or licenced levels.
Landform		
Soil stability	Soil profiles reconstructed to ensure vegetation establishment and landform stability.	Rehabilitated areas should have no active erosion rills greater than 10 metres long by 0.1 metres deep. Finished slopes will include a zone of shallow beach of approximately 30 to 40 metres wide before sloping at a stable angle of repose (approximately one in four) to the base of the rehabilitated lake.
Vegetation		
Richness (diversity)	Total number of plant species found in monitoring quadrats. Specified targets are based on site survey data. Setting appropriate targets requires knowledge of similar habitats and proportion of plant species unlikely to recruit or propagate from seed in the short term. On-going monitoring of control sites is essential to track changes due to lowering rainfall and other adverse impacts regionally separate to mining operations.	Rehabilitated areas achieving progressive targets. Targets to be reviewed based on ongoing monitoring results.
Density	The number of native plants, weeds and bare ground measured in quadrats.	Rehabilitated areas achieving an interim target of 50% density to analogue sites after five years. Interim targets to be reviewed based on on-going monitoring results.
Cover	Sustainable rehabilitation requires vegetation cover to be sufficient to stabilise landforms and soils and exclude weeds. In most cases, completion criteria based on relative cover (percentage of area) is used.	Rehabilitated areas achieving an interim target of 50% cover to analogue sites after five years. Interim targets to be reviewed based on ongoing monitoring results.

Criteria	Objective	Interim Targets
Weed management	Effective weed management requires: (a) Low relative cover of minor weeds. (b) Absence or isolation of major environmental weeds capable of becoming dominant at the expense of native plants.	Monitoring and photographic records showing weed species in native vegetation rehabilitation areas limited to levels that do not affect plant growth and survival. Declared weed species controlled over rehabilitated areas and the KSS site.
Pests and diseases	Effective management of alien or native species of animals, fungi or microbes that can have major impact on plant survival and productivity.	All vehicles moving through dieback infested areas are subject to standard hygiene control measures. Soil and vegetation disturbance limited to dry conditions.
Fauna		
Tree planting	Planting of tree species likely to develop hollows and provide Cockatoo habitat in the long term.	Target restoration of habitat characteristics.
Tree planting	Planting areas of peppermint (*Agonis flexuosa*) within upland woodland areas to be rehabilitated post mining. Peppermint trees will be planted in clumps to encourage interlocking branches.	Target restoration of habitat characteristics.
Tree hollow relocation	Relocation of nest hollows in undisturbed areas on the property for use by other bird and mammal species will offset habitat lost through the development. Habitat logs and brush are re-spread in areas undergoing rehabilitation as part of current operations	Complete relocation/replacement of hollows as soon as practicable.
Iconic species	Selection of appropriate species in rehabilitated areas to provide food resource for target Possum species. Progressive rehabilitation will encourage colonisation from surrounding vegetative areas., dense vegetation favoured by the Southern Brown Bandicoot	Target restoration of habitat characteristics such as shrubby revegetation with abundant nectar and tree/log hollow rather than number of animals, as they may be quite rare in the first place.
Feral animal control	1080 baiting using meat, eggs and oats will be carried out on the KSS property. If 1080 baiting is not acceptable due to close proximity to neighbours (<2 kilometre radius), trapping programs for foxes and feral cats, pigs and Pindone baiting for rabbits will be used.	Complete 200 hectares of trapping per annum. Feral animal densities are particularly dense in Kemerton Nature Reserve and efforts will be concentrated in this and other parts of the KSS property.

Criteria	Objective	Interim Targets
Lakes		
Cover	Sustainable rehabilitation requires the cover of emergent (beach) vegetation to be sufficient to stabilise landforms and soils and exclude weeds.	Rehabilitated areas achieving an interim target of 50% cover to analogue sites after five years. Interim targets to be reviewed based on ongoing monitoring results.
Iconic Species	Criteria for aquatic iconic species (Water Rat, Jollytail) as well as waterbird utilisation.	Introduction of Jollytail to rehabilitated lakes upon completion of mining.

Source: EPA (2006a).

7. MONITORING AND MAINTENANCE

The schedule of monitoring to ensure success of the rehabilitation programme is presented in Table 13. Monitoring rehabilitated areas assists in ensuring that any areas requiring remedial work are identified.

Monitoring will be carried out on a regular basis to assess:

- The physical stability of the landform of rehabilitated areas.
- The success of vegetation and fauna re-colonisation in rehabilitated areas.
- Water quality and ecology of lakes.

Maintenance procedures will be carried out where necessary and may include:

- Reseeding and replanting areas that may not have regenerated.
- Weed control.
- Repair significant erosion.
- Fire breaks.

The frequency of monitoring and maintenance in individual areas is expected to decrease as rehabilitation progresses and will cease in consultation with regulators when rehabilitation objectives and completion criteria are achieved. The results of management and monitoring activities will be reported as required to regulatory authorities.

Table 13: Rehabilitation Monitoring Schedule

Parameter
First year after rehabilitation
Establishment of permanent monitoring transects in each area of rehabilitation. These are orientated from lake edge to uplands (thereby capturing each rehab zone).
Quadrats along transects monitored for cover and density of each plant species.
Soil testing – texture, organic carbon, pH, conductivity and nutrients.
Microtopography (especially impact in flooded zones which may be prone to erosion).
Biannual / Triennial
Quadrats along transects monitored for cover and density of each plant species.
Soil testing – texture, organic carbon, pH, conductivity and nutrients.
Microtopography (especially impact in flooded zones which may be prone to erosion).

8. RECORDS AND REPORTING

8.1 RECORD KEEPING

The General Manager is responsible for recording rehabilitation activities conducted on site. The record check list of the rehabilitation works for each mine area is provided in Appendix 3. This includes:

- Information on the pre-mining vegetation, topsoil removal, handling and storage techniques utilised.
- The extent and timing of each activity.
- Details on the rehabilitation treatments, including:
  - Rehabilitation earthworks.
  - Seed bed preparation.
  - Species used in the rehabilitation programme.
- Results of the rehabilitation monitoring programme.
- Scope of any remedial work.

Records relevant to the RMP that shall be maintained include items presented in Table 14.

Table 14: Rehabilitation Records to be maintained at KSS

Record	Location	Responsibility
Area Cleared	Appendix 2	General Manager
Vehicle inspection checklist	Appendix 4	General Manager
Weed control activities	Appendix 5	General Manager
Record of Rehabilitation	Appendix 3	General Manager

8.2 ANNUAL ENVIRONMENT REPORT

The following land management and rehabilitation information shall be reported in the AER:

- Total land cleared in the reporting year including information regarding the vegetation type removed i.e. upland, fringing or flooded vegetation.
- Area rehabilitated within and adjacent to mining areas.
- Rehabilitation monitoring results.
- Weed control activities.
- Any non-compliance and corrective actions with respect to land management.
- Decommissioning of infrastructure.

8.3 MANAGEMENT PLAN REVIEW

The General Manager will ensure that the RMP is reviewed annually. This will ensure the plan remains current with mine practices. The review will occur in September to October of each year, to enable review of the past year's rehabilitation efforts and planning for the next year's rehabilitation in May through June to be included in the report.

9. DECOMMISSIONING AND CLOSURE

The 50 year mine life of the current proposal does not require detailed closure planning at this time. KSS will prepare a Preliminary Decommissioning and Closure Plan (PDCP), conforming to the Conceptual Closure Plan as defined in Section 2.3 of the Australian and New Zealand Minerals and Energy Council and Minerals Council of Australia (2000) guidelines within five years of commencing operations in the mine extension area **(Commitment 7.13.4a)**.

Further revisions of the plan will be developed periodically during the life of mine, incorporating results of rehabilitation research and current government and industry guidelines. A final plan will be prepared two years prior to mine closure, consistent with the Australian and New Zealand Minerals and Energy Council and Minerals Council of Australia (2000) guidelines.

KSS believes implementation of management measures described above will serve to mitigate any impacts associated with implementing the proposal and result in an acceptable environmental outcome at closure of the operations.

10. REFERENCES

Arbortech Pty Ltd, 1997. Kemerton Silica Sand Environmental Monitoring Report. Unpublished report for Kemerton Silica Sand.

Australian and New Zealand Minerals and Energy Council and Minerals Council of Australia (ANZMEC/MCA), 2000. A strategic framework for mine closure. Environment Australia, Canberra.

Bamford Consulting Ecologists (Bamford), 2008. Fauna Assessment of the Proposes South Binningup Development. Unpublished report for RPS Consulting/Mirvac.

Bamford, M.J. and Bamford, A.R. (Bamford), 1998. Kemerton Silica Sands Mine. Annual report on fauna monitoring program; 1997. Unpublished report by Bamford Consulting Ecologists for Arbotech, Perth.

Bamford, M.J. and Bamford, A.R. (Bamford), 1999. Kemerton Silica Sand Mine. Annual Report on Fauna Monitoring Program, 1998. Unpublished report by Bamford Consulting Ecologists for Ecos Consulting, Perth.

Bamford, M.J. and Bamford, A. R. (Bamford), 2000. Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Program. Unpublished report for Kemerton Silica Sand Pty Ltd, May 2000.

Bamford, M.J. and Bamford, A. R., (Bamford), 2001. Kemerton Silica Sand Mine: Annual report on Fauna Monitoring Program; 2000 – 2001. Unpublished report for Kemerton Silica Sand Pty Ltd, July 2001.

Bamford, M.J. and Bamford, A. R. (Bamford), 2002. Kemerton Silica Sand Pty Ltd: Summary report on Fauna Surveys; 2001 - 2002. Unpublished report for Kemerton Silica Sand Pty Ltd, September 2002. .

Bamford, M.J. and Bamford, A. R. (Bamford), 2002. Kemerton Silica Sand Pty Ltd: Summary report on Fauna Surveys; 2001 - 2002. Unpublished report for Kemerton Silica Sand Pty Ltd, September 2002. .

Bamford, M.J. and A.R., Bamford (Bamford), 2003a. Assessment of Fauna Values in the KSS Property. Unpublished report for Kemerton Silica Sand.

Bamford, M.J. and Bamford, A. R. (Bamford), 2003b. Kemerton Silica Sand Pty Ltd: Fauna Monitoring 18th December 2002. Unpublished report for Kemerton Silica Sand Pty Ltd, February 2003.

Bamford, M.J. and Bamford, A. R. (Bamford), 2004a. The status of the Chuditch (*Dasyurus geoffroii*) in areas proposed for expansion by KSS. Unpublished report for Kemerton Silica Sand Pty Ltd, May 2004.

Bamford, M.J. and Bamford, A. R. (Bamford), 2004b. The utilisation by Short-billed Black-Cockatoos (*Calyptorhynchus latirostris*) of the proposed dredge mining extension area of KSS.. Unpublished report for Kemerton Silica Sand Pty Ltd, June 2004.

Bamford, M.J., and Bamford A.R. (Bamford), 2006. Kemerton Silica Sands Mine: Report on fauna monitoring programme; 2000. Bamford Consulting Ecologists, Unpublished Report, Perth, Western Australia.

Bamford, M.J and Ninox Wildlife Consulting, 1993. Vertebrate fauna assessment of the Kemerton Silica Sand project. Unpublished report for Kemerton Silica Sand Pty Ltd. October 1993.

Bennett Environmental Consulting Pty Ltd, 2004. Kemerton: Significant Flora and Wetlands. Unpublished Report for MBS Environmental.

Cale, B., 2003. Carnaby's Black-Cockatoo (*Calyptohynchus latirostris*) Recovery Plan 2002 - 2012. Department of Conservation and Land Management, Wanneroo. Retrieved on the 25 September 2008 from http://www.dec.wa.gov.au/pdf/plants_animals/threatened_species/frps/carnabys_wmp36.pdf

Craig, M., Bamford, M, and Wilcox, J., 2004. The Utilisation by Short Billed Black-Cockatoos (*Calyptorhynchus latirostris*) of the Proposed Dredge Mining Extension Area of Kemerton Silica Sand. Unpublished report for Kemerton Silica Sand Pty Ltd.

Department of Agriculture and Food, 2008. Declared Plant in Western Australia. Cotton Bush (*Gomphocarpus fruticosus*). Accessed from http://agspsrv95.agric.wa.gov.au/dps/version02/01_plantview.asp?page=3&contentID=22&

Department of the Environment, Water, Heritage and the Arts, 2008c. *Calyptorhynchus baudinii* in Species Profile and Threats Database. Department of the Environment, Water, Heritage and the Arts, Canberra. Retrieved on the 25 September 2008 from http://www.environment.gov.au/sprat.

Ecos Consulting (Aust) Pty Ltd, 1998. Kemerton Silica Sand Environmental monitoring Report. Unpublished Report for Kemerton Silica Sand.

Ecos Consulting (Aust) Pty Ltd, 2000a. Rehabilitation Trials Final Assessment Report. May 2000. Unpublished Report for Kemerton Silica Sand.

Ecos Consulting Pty Ltd, 2000b. Assessment of Impacts on Sedimentation on Wetland Four. Unpublished report prepared for Sons of Gwalia, June 2000.

Ecos Consulting Pty Ltd, 2000c. Establishing of Monitoring Quadrats at Kemerton Silica Sand. Unpublished report prepared for Sons of Gwalia, August 2000.

EPA, 2006. Rehabilitation of Terrestrial Ecosystems: Guidance No 6 for the Assessment of Environmental Factors.

Environmental Protection and Biodiversity Conservation Act, 1999 (Commonwealth).

Galeotti, D.M., McCullough, C.D. and Lund, M. A., 2008. Current State of Knowledge of the Black-stripe Minnow *Galaxiella nigrostriata* (Pisces: Galaxiidae) in Western Australia. Edith Cowan University, Centre for Ecosystem Management Report 2008-12. Unpublished report to Kemerton Silica Sands Pty. Ltd., Perth, Western Australia. http://www.ecu.edu.au/chs/cem/CSML-ECU/ecology.htm

Harewood, G., 2000. Fauna Assessment (Level 1) and Targeted Fauna Survey (Western Ringtail Possum and Southern Brush-tailed Phascogale) in the Mine Expansion Area. Unpublished Report for Kemerton Silica Pty Ltd.

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

Ling, N., 2004. Gambusis in New Zealand: really bad or just misunderstood? New Zealand Journal of Marine and Freshwater Research **38**: 473-480.

Marchant, N.G., Wheeler, J R., Rye, B.L., Bennett, E.M., Lander, N.S. and Macfarlane. T D., 1987. Flora of the Perth Region Western Australian Herbarium, Department of Agriculture, WA

Martinick Bosch Sell Environmental Pty Ltd (MBS), 2008. Kemerton Silica Sand: Collation of Fauna Reports on the KSS Property. Unpublished report for Kemerton Silica Sand.

Martinick Bosch Sell Environmental Pty Ltd (MBS), 2008. Public Environmental Review – Extension of Kemerton Silica Sand. Report for Kemerton Silica Sand Pty Ltd.

Mattiske, E.M. and Associates (Mattiske), 1993a. Gwalia Consolidated Limited - Kemerton Sand Project: Flora and Vegetation Studies. Report One - February 1993. Unpublished report prepared for John Consulting Services.

Mattiske, E.M. and Associates (Mattiske), 1993b. Gwalia Consolidated Limited - Kemerton Sand Project: Flora and Vegetation. Report Two - June 1993. Unpublished report prepared for John Consulting Services.

Mattiske, E.M. and Associates (Mattiske), 1993c. Gwalia Consolidated Limited - Kemerton Sand Project: Updated Flora and Vegetation Report. Report Three - November 1993. Unpublished report prepared for John Consulting Services.

Mattiske, E.M. and Associates (Mattiske), 1993d. Gwalia Consolidated Limited - Kemerton Sand Project: Vegetation Mapping of Proposed Transport Corridor. Report Four - November 1993. Unpublished report prepared for John Consulting Services.

Mattiske Consulting Pty Ltd (Mattiske), 2001a. Vegetation Monitoring of Wetlands at Kemerton. April 2001. Unpublished report prepared for GHD and Sons of Gwalia Ltd.

Mattiske Consulting Pty Ltd (Mattiske), 2001b. Vegetation Monitoring of Wetlands at Kemerton. July 2001. Unpublished report prepared for GHD and Sons of Gwalia Ltd.

Mattiske Consulting Pty Ltd (Mattiske), 2002a. Vegetation Monitoring of Wetlands at Kemerton. February 2002. Unpublished report prepared for GHD and Sons of Gwalia Ltd.

Mattiske Consulting Pty Ltd (Mattiske), 2002b. Vegetation Monitoring of Wetlands at Kemerton. March 2002. Unpublished report prepared for GHD and Sons of Gwalia Ltd.

Mattiske Consulting Pty Ltd (Mattiske), 2002c. Kemerton Sand Project Flora and Vegetation. April 2002 report providing an updated summary of previous botanical studies within the Kemerton project area.

Mattiske Consulting Pty Ltd (Mattiske), 2003a. Vegetation Monitoring of Wetlands at Kemerton. March 2003. Unpublished report prepared for GHD and Kemerton Silica Sands.

Mattiske Consulting Pty Ltd (Mattiske), 2003b. Kemerton Silica Sand Review of Flora, Vegetation and Conservation Values on Kemerton Project Area. May 2003 report providing an updated summary of previous botanical studies within the Kemerton project area.

Mattiske Consulting Pty Ltd (Mattiske), 2004a. Vegetation Monitoring of Wetlands at Kemerton. March 2004. Unpublished report prepared for Kemerton Silica Sands. March 2004 report on the vegetation monitoring finding of fieldwork undertaken in EPP wetlands 4, 8 and 9.

Mattiske Consulting Pty Ltd (Mattiske), 2004b. Assessment of Rehabilitated Wetland Areas – Kemerton Silica Sands Limited – Kemerton Operations. May 2004. Unpublished report prepared for Kemerton Silica Sands.

Mattiske Consulting Pty Ltd (Mattiske), 2005. Assessment of Rehabilitated Wetland Areas – Kemerton Silica Sands Limited – Kemerton Operations. September 2005. Unpublished report prepared for Kemerton Silica Sands.

Mattiske Consulting Pty Ltd (Mattiske), 2009. Updated Review of Vegetation Communities - Kemerton Silica Sand Pty Ltd. Unpublished memo for Kemerton Silica Sand Pty Ltd, February 2009.

McCullough, C.D., 1998. The voracious mosquitofish: Gambusia or Damnbusia? Forest and Bird. In McCullough, C., Lund, M. and Van Etten, E. 2007. Synthesis of Existing Data and Knowledge Gaps for the Rehabilitation of Kemerton Silica Sand Mine Dredge Ponds. Unpublished report for Kemerton Silica Sand.

McCullough, C., Lund, M. and van Etten, E., 2007. Synthesis of Existing Data and Knowledge Gaps for the Rehabilitation of Kemerton Silica Sand Mine Dredge Ponds. Unpublished report for Kemerton Silica Sand.

McCullough, C. and Lund, M., 2008. Aquatic Macroinvertebrates in Seasonal and Rehabilitated Wetlands of the Kemerton Silica Sand Pty Ltd Project Area. Mine Water and Environment Research/Centre for Ecosystem Management Report No. 2008-16, Edith Cowan University, Perth, Australia. Unpublished report to Kemerton Silica Sand Pty Ltd.

Morgan, D.L., Gill, H.S. and Potter, I.C., 1998. Distribution, Identification and Biology of Freshwater Fish in South Western Australia. Records of the Western Australian Museum Supplement No 56. In Bamford, M.J. and A.R., 2003a. Assessment of Fauna Values in the KSS Property. Unpublished report for Kemerton Silica Sand Pty Ltd.

Muir Environmental, 1999. Report of Biological Survey - Phase 1: Kemerton Industrial Estate. Vol 1 Report and Vol 2 Appendices. Unpublished Report for Landcorp.

National Strategy for the Conservation of Australia's Biological Diversity, 1996. Accessed from http://www.environment.gov.au/biodiversity/publications/strategy/index.html.

Ninox Wildlife Consulting, 1994. The Kemerton Silica Sand project area: Vertebrate fauna assessments December 1992 - December 1993. Unpublished report for Kemerton Silica Sand.

Orell, P. and Morris, K., 1994. Chuditch Recovery Plan 1992 – 2001. Western Australia Wildlife Management Program No. 13. Western Australia Department of Conservation and Land Management, Wanneroo. Retrieved on the 25 September 2008 from http://www.environment.gov.au/biodiversity/threatened/publications/recovery/chuditch/pubs/chuditch.pdf.

Rokich, D., Dixon, K.W., Sivasithamparam, K. and Meney, K.A., 2000. Topsoil Handling and Storage Effects on Woodland Restoration in Western Australia. Restoration Ecology. **8**(2): 196-208.

Rockwater Pty Ltd, 2008. Kemerton Silica Sand Pty Ltd. Groundwater Monitoring Review. July 2005 to June 2008 (GWL 60367(2&3)). Unpublished report prepared for Kemerton Silica Sand Pty Ltd, September 2008.

Semeniuk, C.A., 1987. Wetlands of the Darling System -a Geomorphic Approach to Habitat Classification. *J. Roy. Soc. West. Aust*. **69**: 95-111. In EPA 1993. A Guide to Wetland Management in the Perth and Near Perth Swan Coastal Plain. Bulletin 686.

Sommer, B., 1997. Predation by ***Gambusia holbrockii*** (Girard) (Pisces:Poecillidae) on tadpoles: feeding trials and microhabitat utilisation in two contrasting wetlands on the Swan Coastal Plain. BSc 9hons0 thesis, Edith Cowan University, Perth, Australia.

van Etten, E., McCullough, C.D. and Lund, M.A., 2008a. Synopsis of Wetland Characterisation Study: Potential Implications for P.E.R. Centre for Ecosystem Management Report No. 2008-17a, Edith Cowan University, Perth, Australia. Unpublished report for Kemerton Silica Sand Pty Ltd.

van Etten, E., McCullough, C.D. and Lund, M.A., 2008b. Evaluation of Rehabilitation Efforts at the Kemerton Silica Sand Pty Ltd Project Area (June 2007). Centre for Ecosystem Management Report No. 2008-10, Edith Cowan University, Perth, Australia. Unpublished report for Kemerton Silica Sand Pty Ltd.

van Etten, E., McCullough, C.D. and Lund, M.A., 2009. Evaluation of Post-Mining Rehabilitation at the Kemerton Silica Sand Pty Ltd Project Area, November 2008. Centre for Ecosystem Management, Edith Cowan University, Perth, Australia. Unpublished report for Kemerton Silica Sand Pty Ltd.

Water and Rivers Commission (WRC), 2000. Using rushes and sedges in revegetation of wetland areas in the south west of WA. Water and Rivers Commission, River Restoration Report No. Report No. RR 8. Retrieved on the 26 September 2008 from http://portal.water.wa.gov.au/portal/page/portal/WaterQuality/Publications/RiverRestoration/Content/RR8.pdf.

Waters and Rivers Commission (WRC), 2001. Position Statement: Wetlands.

Wildlife Conservation Act, 1950 (Western Australia).

Woodman Environmental Consulting Pty Ltd (Woodman), 2005a. Kemerton Lateral Pipeline: Flora, Vegetation, and *Phytophthora Cinnamomi* Assessment. Unpublished report for Ecos Consulting (Aust) Pty Ltd.

Woodman Environmental Consulting Pty Ltd (Woodman), 2005b. Kemerton Lateral Pipeline: Rehabilitation Plan. Unpublished report for Ecos Consulting (Aust) Pty Ltd.

APPENDICES

APPENDIX 1:
PROCEDURE FOR SALVAGING AND TRANSPLANTING GRASS TREES

GRASS TREES TRANSPLANTING

*Procedures for salvaging and transplanting Grass Trees (*Xanthorrhoea *species) for inclusion in rehabilitation of the site.*

REFERENCE MATERIAL

- Botanic Gardens and Parks Authority (2008). Transplanting Grass Trees. Retrieved from http://www.bgpa.wa.gov.au/o/content/view/385//.

INFORMATION

As shown by the sequence of activities described in the RMP section 5.5, each block to be quarried must be firstly cleared and then topsoil stripped and directly returned to the block undergoing rehabilitation. Salvaging Grass Trees from the clearing block therefore cannot be undertaken if these plants are to be directly replanted in the current rehabilitation block. For optimum survival rates, these plants should be salvaged from their current location and directly transplanted into their new location.

There are two possible solutions to this sequencing problem.

1. Selectively remove Grass Trees from the block in advance of the one currently being cleared. This allows these plants to then be immediately transplanted into the rehabilitation block after topsoil return has occurred. These plants are therefore removed from their current location a year in advance of their block being cleared.
2. An alternative to on site direct salvage and transplant described above is to commission commercial Grass Tree relocation and supply contractors to remove target species well in advance of the quarry front and temporarily store them in bulk bags in their off site nursery. A defined number are then returned to site at the scheduled time for outplanting in rehabilitation areas.

The second option has the benefit in ensuring all plants returned to site have recovered from any salvage/transplant shock and therefore have a higher chance of successful establishment. It is recognised not all plants excavated from site will survive relocation. By using an off site nursery as a holding facility, only individuals that survive the excavation process are returned to site.

It is KSS preference to use option 2 to transplant Grass Trees, for the following reasons:

- Dedicated excavation programmes can be implemented. Required equipment is mobilised to site at the cooler times of the year (to reduce transplant shock) and a ‘mass excavation’ of plants salvaged, two and three blocks in advance of the current active block.
- Experienced personal undertake excavation, bagging, storage and return transplanting of plants.

Transplanted plants require irrigation over the first summer. For this reason, grouped out-planting is preferred, so an irrigation system off the site water bore can supply a grouped number of plants efficiently.

ACTIONS

The follow has to occur for a successful transplantation:

- Commission local commercial Grass Tree removalists, to remove plants in advance of quarrying and return plants to rehabilitation areas.
- Equipment brought to site must be clean and free of attached soil.
- At completion of transplanting make a depression or 'saucer' around the plant for future irrigation.
- Install irrigation system off site bore to enable central watering system of transplanted plants.
- Water twice per week for 20 minutes and record dates in Table 1 below.

RECORDS

To achieve compliance with the procedure and for audit purposes, an annual record of Grass Tree transplanting numbers and success is to be maintained. This is to comprise the details presented in Table 1 and Table 2 below.

Table 1: Watering Record

Month	Week	Date	Date	Month	Week	Date	Date
October	Wk1			January	Wk1		
	Wk2				Wk2		
	Wk3				Wk3		
	Wk4				Wk4		
November	Wk1			February	Wk1		
	Wk2				Wk2		
	Wk3				Wk3		
	Wk4				Wk4		
December	Wk1			March	Wk1		
	Wk2				Wk2		
	Wk3				Wk3		
	Wk4				Wk4		

Table 2: Grass Tree Transplanting

What	Who	When	No. plants	Signature	Date	Reference Location
Record number of Grass Trees excavated from site.	General Manager	After removal				This form
Record number of Grass Trees returned to site.	General Manager	After transplanting				This form
Record number of Grass Trees alive at end of watering period.	General Manager	After end March				

APPENDIX 2:
CLEARING REGISTER

CLEARING REGISTER

Date	Description	Area Cleared (ha)	Topsoil Stockpiled (Y/N)	Vegetation Stockpiled (Y/N)	Survey Pickup of Cleared Area Stored as .dxf file

APPENDIX 3:
REHABILITATION RECORD

RECORD OF REHABILITATION

	Rehabilitation Documentation	
Location: ____________________________________		
		Factor
1	Clearing (Date)	
Topsoil Management		
2	Topsoil removal (Date)	
3	Topsoil deposition (Location)	
4	Topsoil storage (Location)	
5	Topsoil dieback status. (Free = Green), (Positive or indeterminate = Yellow)	
Landform Design		
6	Land forming earthworks (Date)	
7	Planting /seeding soil preparation technique	
Erosion Control		
8	Erosion and drainage controls constructed	
Soil Nutrition		
9	Fertiliser /soil ameliorants used	
Rehabilitation and Completion Criteria		
10	Planting /seeding species used	
11	Monitoring and maintenance	See Section 7.
13	Completion criteria assessment	

APPENDIX 4:
MACHINERY AND VEHICLE INSPECTION CHECKLIST

MACHINERY AND VEHICLE INSPECTION CHECKLIST

It is important that earthmoving machinery is in an acceptable condition before it enters site working areas in relation to safety, weeds, hydrocarbons, emissions and noise.

This inspection must be completed by the Site Supervisor in the presence of the machinery Supervisor.

Date of arrival/inspection: --

Name of machinery Supervisor: --

Name of person conducting inspection: --

What kind of machine? --

Please list any problem weeds at the last site. --

Was the machine cleaned before it left the last site? Yes ☐ No ☐

Are buckets, tracks, blades etc free of soil and vegetation? Yes ☐ No ☐

Are the tyres free of seeds? Yes ☐ No ☐

Is machine free of fuel and oil leaks? Yes ☐ No ☐

Is the exhaust/muffler in good working order? Yes ☐ No ☐

Work required/comments:

If you have answered NO to any of these questions, please carry put the required cleaning and/or maintenance before the machine enters the site. This form must be signed by the machine Supervisor and Site Supervisor when all cleaning and/or maintenance is completed.

Signed

Machine Supervisor -- Date --------------

Vehicle Wash down Procedure

- Wash down machine in designated wash down bay.
- Remove all soil and vegetation including seeds.
- Ensure runoff, soil and any seeds are contained on the hardstand or directed to the sediment basin.
- Carry out final inspection with site personnel before moving into site.

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INSPECTION
EQUIPMENT AND VEHICLE COMPLIANCE

CHECK	YES	NO	N/A	ACTION REQUIRED	BY WHO/DATE
Are project vehicles fitted with relevant safety stickers prior to use?					
Do relevant cabins have an Australian Standard approved rollover structure?					
Are earthmoving equipment and vehicles equipped and maintained with suitable brakes?					
Are earthmoving equipment and vehicles fitted with adequate headlights?					
Do vehicles have suitable audible warning devices?					
Are vehicles equipped with a flashing light?					
Are vehicles equipped with an ‘In Service’ fire extinguisher?					
Are earthmoving equipment and vehicles fault/defect inspected and maintained as per manufacturer’s specifications?					
Are there up to date records of inspections and maintenance?					

DATE: ________________________________

AREA: ________________________________

INSPECTOR:________________________________

SIGNATURE:________________________________

APPENDIX 5:
WEED INSPECTION CHECKLIST

SITE WEED INSPECTION CHECKLIST

Name of Inspector (Print): ________________________ Date: ________________________

Weather Conditions Prior to Inspection: ____

Weed Inspection Areas	Date Completed	Weeds Present (Yes/No)	Actions to be Taken
Processing Plant and product stockpile areas			
Office area			
Contractors workshop			
Laydown yard			
Production bore (s) and surrounds			
Storage areas			
Access roads			
Mine pit areas			
Wash down bay			

Weed Management Register	
Eradication	**Record**
Weed Species	
Area (m^2)	
Location	
Photo or sample of weed attached	
Eradication method	
Name (print) **Signature** **Date**	
Post Eradication	**Follow up Actions**
New weed population (y/n)	
New growth (y/n)	
Follow up of eradication	
Evidence of weed death (photo)	
Name (print) **Signature** **Date**	

APPENDIX 20:
KEMERTON SILICA SAND
PROPOSED ENVIRONMENTAL OFFSET PACKAGE

Environmental offsets reporting form

See *EPA Guidance Statement No. 19: environmental offsets - biodiversity*

Please note that the EPA may request additional information.

Section A: Administrative information
1. Proposal or scheme name: Kemerton Silica Sand Pty Ltd: Extension of Dredge Mining Operations
2. Summary of proposal or scheme: Kemerton Silica Sand Pty Ltd (KSS) is proposing an extension to the current approved mining operation undertaken on Lot 32 and Lot 501 Rhodes Road, Wellington. The proposed extension of sand dredging operations at KSS is required to access silica sand resources suitable for both glass manufacturing and export. Approval is being sought to mine an additional 283 hectares (21.3%) of the current KSS property. This will allow long-term management of the site and implementation of long-term environmental management and rehabilitation plans. The proposed area contains sufficient silica sand resources to allow mining for about 50 years. Access to the area will enable secure long term resource extraction to take place and provide sufficient overburden to implement rehabilitation of dredge ponds in mined areas to create functioning wetland environments.
Section B: Type of environmental asset (s) – State whether Critical or High Value, describe the environmental values and attributes
Critical Assets: • Remnant Native Vegetation (Bassendean – Central and South vegetation complex). • Remnant Native Vegetation (Spearwood vegetation complex). • Conservation Category Wetlands. • *Acacia semitrullata* (P3). • *Boronia juncea* subsp. *juncea* (P1). • *Caladenia speciosa* (P4). • *Dillwynia dillwynioides* (P3). • *Eucalyptus rudis* subsp. *cratyantha* (P4). **Environmental Values:** After an extensive community consultation process, the community has identified the following environmental values relating to environmental health, structure, composition, function and beneficial uses: • Provision of food, habitat and shelter for native biota and threatened species. • Maintenance of interaction between species.

- Cycling, filtering and retention of nutrients.
- Maintenance of geological and geochemical processes.

Environmental Attributes: 110.7 hectares of Conservation Category wetlands and 154.0 hectares of remnant native vegetation. The area has 16 vegetation communities with the majority of the mine extension area (95%) occupied by three major vegetation community types, namely:

- *Type A:* Type A1 – A3: Woodland to Open Woodland of Eucalyptus marginata - Banksia species. 154.2 hectares in the mine extension area of a total of 481.5 hectares on the property (32.0%).
- Type G1 – G4: Shrubland of Myrtaceae and Proteaceae species. 20.0 hectares in the mine extension area of a total of 87.5 hectares on the property (22.9%).
- Type H1 – H3: Closed Heath of Myrtaceae species. 73.9 hectares in the mine extension area of a total of 468.9 hectares on the property (15.8%).

The majority of communities are well represented in other parts of the KSS property. Populations of *Acacia semitrullata* (P3), *Boronia juncea* subsp. *juncea* (P1), *Caladenia speciosa* (P4), *Dillwynia dillwynioides* (P3) and *Eucalyptus rudis* subsp. *cratyantha* (P4) will be cleared from within the remnant native vegetation.

Based on survey s and assessments of the site, the habitat area could support 20 native mammal species, 34 reptile species, 127 bird species, 10 amphibian species and six fish species. These include a number of threatened or priority species such as *Mammals*: Chudtich, Western False Pipistrelle, Brush-tailed Phascogale, Western Ringtail Possum, Quokka and Brush-tailed Possum; *Reptiles*: Perth Lined Lerista and South west Carpet Python: *Birds*: Fork tailed Swift, Great Egret, Australasian Bittern, Forest Red-tailed Black Cockatoo, Baudin’s Black Cockatoo, Carnaby’s Black Cockatoo Peregrine Falcon, White Bellied Sea Eagle, Little Bittern, Black Bittern, Rainbow Bee-eater, Barking Owl, Nankeen Night Heron and Masked Owl.

Section C: Significant impacts (describe the significant adverse environmental impacts related to the proposal or scheme before mitigation measures are applied)

1. Clearing of native remnant vegetation (Bassendean – Central and South vegetation complex and Spearwood vegetation complex).
2. Clearing and disturbance of Conservation Category Wetlands.
3. Loss of populations of *Acacia semitrullata* (P3), *Boronia juncea* subsp. *juncea* (P1), *Caladenia speciosa* (P4), *Dillwynia dillwynioides* (P3) and *Eucalyptus rudis* subsp. *cratyantha* (P4).
4. The primary impacts on fauna will be attributed to the loss of habitat associated with clearing native vegetation and displacement of fauna through mining activities such as noise and traffic.

Section D: Mitigation measures (describe all measures to Avoid, Minimise, Rectify and Reduce)

Avoid: Mine extension area avoids impacts on 882.7 hectares of Critical Assets located above silica sand resources. Critical assets avoided include:
• Critically Endangered, DRF (*Caladenia procera* species from one known location).
• Priority flora species (populations of *Boronia capitata* subsp. *gracilis* (P2) and *Acacia flagelliformis* (P4)).
• EPP wetlands and associated catchments (EPP4, EPP8).
• Conservation Category wetlands in good condition (428.5 hectares) including recently avoided sump in UFI 1906 to the north of the mine extension area.
• Multiple Use wetlands in good condition (6.5 hectares).
• Resource Enhancement wetlands in good condition (18.9 hectares).
• Remnant vegetation (428.8 hectares of Bassendean – Central and South vegetation complex).
 	
Proposed land swap avoids impacts on 75.3 hectares of disturbance of Critical Assets previously approved for dry mining. This includes avoidance of disturbance of:
• 0.31 hectares of EPP5
• 11.1 hectares of Conservation Category wetlands (1.2 hectares of which is in the Kemerton Nature Reserve). Of which:
    • 0.62 hectares of the catchment of EPP3.
    • 2.65 hectares of the catchment of EPP4.
    • 0.06 hectares of the catchment of EPP5.
    • 0.05 hectares of the catchment of EPP8.
    • 0.56 hectares of the catchment of EPP9.
63.9 hectares of remnant native vegetation (Bassendean – Central and South vegetation complex (11.4 hectares of which is in the Kemerton Nature Reserve)).
 	
Minimise:
• Impacts on Critical and High Value assets has been minimised by proposing a mine extension area which proposes mining of about 24.2% of the known silica sand resource in order to protect environmental values.
• Rehabilitation methodology will minimise long term impacts on groundwater resources (quality).
• Comprehensive commitments made within PER to prevent or minimise adverse environmental impacts on a range of environmental aspects.

Rectification:

- Progressive rehabilitation over a 50 year life of mine planned.
- Comprehensive Rehabilitation Plan developed and research well advanced to ensure continuous improvement process in place for rehabilitation.
- Disturbed areas from previous activity on the KSS property will be rehabilitated as part of the proposal. Material obtained from mine extension will allow improved rehabilitation of existing dredged areas.
- Re-establishment of Priority flora species addressed within rehabilitation plans.
- Re-establishment of habitat for conservation significant fauna species addressed within Rehabilitation Management Plan.

Reduction:

- Progressive rehabilitation over mine life to reduce impact of disturbance.
- Reduced annual water consumption via improved efficiency.
- Significant funds committed to research to allow continuous improvement in rehabilitation of dredge ponds and re-establishment of conservation significant fauna within rehabilitated dredge ponds. Formal agreements entered into for such research programs.

Section E: Significant residual impacts (describe all the significant adverse residual impacts that remain after all mitigation attempts have been exhausted)

The residual impacts include loss of 110.7 hectares of Conservation Category wetlands and 154.0 hectares of remnant native vegetation. Populations of *Acacia semitrullata* (P3), *Boronia juncea* subsp. *juncea* (P1), *Caladenia speciosa* (P4), *Dillwynia dillwynioides* (P3) and *Eucalyptus rudis* subsp. *cratyantha* (P4) will be cleared from within the remnant native vegetation. Although the proponent has committed to undertaking a significant rehabilitation effort, rehabilitation is not always successful and residual impacts may still remain, particularly in the short-term. Therefore to gain a net conservation benefit, offsetting of similar habitat values has been proposed.

Section F: Proposed offsets for each significant residual impact (identify direct and contributing offsets). Include a description of the land tenure and zoning / reservation status of the proposed offset site. Identify any encumbrances or other restrictions on the land that may impact the implementation of the proposed offset and provide evidence demonstrating how these issues have been resolved.

Direct offsets

Rehabilitation: Improving vegetation condition and habitat value of an area (11 ha) of degraded Bassendean woodland in Kemerton Nature Reserve between EPP6 and EPP7. This area was historically grazed and logged. Rehabilitation will involve:

- Control of weeds.
- Control of feral animals.

- Application of local native seed.

This will be undertaken in consultation with the land owners (DEC) and Western Power.

Acquiring Land for Conservation: Transferring land containing critical and high value environmental assets to the State. Critical value assets include:

- 0.01 hectares of EPP5 wetland.
- 24.1 hectares of Conservation Category wetland.
- 2.6 hectares of Multiple Use wetland.
- 4.0 hectares of Resource Enhancement wetland.
- 70.0 hectares of Bassendean - Central and South vegetation complex.
- Population of the Critically Endangered, DRF species *Caladenia procera.*
- Populations of Priority flora; *Acacia semitrullata* (P3) and *Acacia flagelliformis* (P4), *Boronia juncea* subsp. *juncea* (P1), *Caladenia speciosa* (P4).
- Most southern extent of *Verticordia nitens*.

This would increase the total size of Kemerton Nature Reserve to 417.0 hectares. The location of the proposed area of transfer is shown in Figure 28.

Forgoing Right to Disturb: Forgoing the existing right to mine Bassendean - Central and South vegetation complex via dry mining methods in areas outside of the current dredge pond (Ministerial Statement 366 approval). Approximately 20.3 hectares of this 75.3 hectares is located within the proposed mine extension area.

Forgoing this right to mine would prevent disturbance within Kemerton Nature Reserve and protect Conservation Category wetland catchment areas for EPP wetlands. Specifically, forgoing the right to dry mine in the approved areas would protect:

- 11.4 hectares of Bassendean - Central and South vegetation complex, within the Kemerton Nature Reserve.
- 35.3 hectares of Bassendean - Central and South vegetation complex outside of the Kemerton Nature Reserve and not included in the proposed mine extension area.
- 0.3 hectares of EPP5.
- 6.8 hectares of Conservation Category Wetland outside of the Kemerton Nature Reserve and 1.2 hectares of surrounding Conservation Category Wetland within the Kemerton Nature Reserve. Of which:

- 0.62 hectares of the catchment of EPP3.
- 2.65 hectares of the catchment of EPP4.
- 0.06 hectares of the catchment of EPP5.
- 0.05 hectares of the catchment of EPP8.
- 0.56 hectares of the catchment of EPP9.

KSS would forgo this right if the mine extension is approved as it recognises that since original approval was granted in 1994, additional baseline studies undertaken by KSS have shown that these areas have environmental values that make mining less desirable.

Re-establishment: Transfer of land as described above would provide an ecological linkage from north to south of the KSS property. Establishment of the North-South Ecological Linkage - McLarty/Kemerton/Twin Rivers/Preston River/Gwindinnup (Kemerton Buffer Link; Wellesley River, part Brunswick and Collie Rivers; part Dalyellup/Gelorup/Preston River/Plateau Link) was stated as desirable by the EPA in Bulletin 1108 and is included in the Greater Bunbury Regional Scheme.

The land area included in Kemerton Nature Reserve would include critical assets as six EPP wetlands, 51.8 hectares of Conservation Category wetlands, 62.6 hectares of Multiple Use wetlands, 1.6 hectares of Resource Enhancement wetlands and 72.7 hectares of Bassendean - Central and South vegetation complex. It would also include 15.6 hectares of the Muchea Limestone TEC on the interface between the Pinjarra Plain and the Bassendean Dune System.

Contributing offsets

Protection: KSS maintains fencing around its freehold property boundaries to minimise threats from external sources. This has assisted in significantly protecting critical and high value assets since KSS assumed land ownership. KSS provides a buffer to the Kemerton Nature Reserve from threats such as pastoral activities (specifically grazing), fire, weeds, feral animals and unauthorised access.

Removal of Threats: KSS will conduct regular weed, feral animal and fire control on all areas of land transferred from KSS freehold ownership to the State for the duration of mining activities (50^{+} years). KSS currently provides information regarding weed outbreaks, use by feral animals, and harmful unauthorised access and land degradation to assist DEC in management of the Reserve.

KSS has removed livestock from all areas of KSS freehold owned land. Livestock will not be introduced to any KSS freehold land during the duration of mining activities (50^{+} years).

Management: KSS has assisted with Development of the Kemerton Nature Reserve Interim Management Plan. It will assist with review of the Management Plan and finalisation of the Kemerton Nature Reserve Management Plan.

Research: Continue to fund research into the Black -striped Jollytail with the aim of reintroducing individuals to rehabilitated areas. KSS has recently entered into an agreement with Edith Cowan University to fund a Masters project looking at the ecological requirements and population genetics of remnant black-striped Jollytail populations in seasonal wetlands of south-western Australia. KSS will contribute about $52,000 for this project and provide assistance for field based work.

KSS has committed to funding further macroinvertebrate and wetland research at Edith Cowan University to establish baseline conditions as analogues for future rehabilitation. KSS will contribute about $20,000 for this project.

Section G: Spatial data relating to offset site/s (see *EPA Guidance Statement No. 19: environmental offsets- biodiversity*, Appendix 4)

Spatial Data:
Datum: GDA 94 (50)
Projection: Map Grid of Australia (MGA)
Format: Shape File (shp.)

Section H: Relevant data sources and evidence of consultation (consultation with agencies, relevant stakeholders, community and references to sources of data / information). Include details of specific environmental, technical or other relevant advice and information obtained to assist in the formulation of the offset.

See PER for information on consultation.