Excavation and Rehabilitation Management Plan

Lots 1001 and 1002
Preston Beach Road North
Preston Beach

APPENDICES

DOYLES LIME SERVICE

May 2016

Excavation and Rehabilitation Management Plan, Doyles Lime Service, Proposed Preston Beach Pit

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Appendix 1

FLORA AND VEGETATION SURVEY IN EASTERN PART OF LOT 1001 PRESTON BEACH ROAD PRESTON BEACH (WEST OF LAKE POLLARD)

SHIRE OF WAROONA

Proposed Site for Limestone Pit, Looking south over Mhs vegetation (Chenille Honeymyrtle – Mixed Closed Heath), dominants of which include *Melaleuca huegelii* (Chenille Honeymyrtle), *Melaleuca systena* (Coastal Honeymyrtle), *Xanthorrhoea preissii* (Balga, Grass Tree), *Templetonia retusa* (Cockies Tongues) and *Hibbertia cuneiformis* (Cut-leaf Hibbertia), over **Trachyandra divaricata* (Dune Onion-weed) Herbland. Also *Eucalyptus foecunda* and *E. petrensis* Mallees. Note parallel cleared, graded strips through vegetation (also see Plate 2A).
Photograph: ASW Nikon DSC_9095(50), 01/11/2013. .

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SUMMARY and ABSTRACT

This report describes vegetation in a survey area in the eastern part of Lot 1001 Preston Beach Road, and it presents results of searches for rare and other significant flora there. It is based upon reviews of literature and metadata and upon field work. The field work was undertaken by botanist A. Weston on 1 November and 3 December 2013, each time with an assistant.

Five provisional vegetation units were identified in the Lot 1001 survey area, mapped in Figure 1 and described in this report. They, their map unit symbols and their condition assessments are:

• Tuart Woodland, Peppermint Low Woodland & Balga Shrubland	TXp	CD(-D)
• Chenille Honeymyrtle (*Melaleuca huegelii*) – Mixed Closed Heath	Mhs	D-(CD)
• *Melaleuca systena* Open to Closed Heath	Ms	D-CD
• Summer-scented Wattle Heath to Closed Tall Scrub	Ar	CD-D
• Balga (*Xanthorrhoea preissii*) Shrubland	Xp	CD

All vegetation units in the survey area are too degraded, floristically, and too reduced in numbers of species to be confidently assigned by meaningful analysis to a floristic community type (SWAFCT), but if they were in much better condition at least part of the Txp unit might be analysed as closest to SWAFCT25 and the Mhs unit might be analysed as closest to SWAFCT26a, SWAFCT26b, SWAFCT27 or combinations of them. The Xp unit also might have been analysed as closest to SWAFCT25, and the Ms unit also might have been analysed as closest to SWAFCT26b, SWAFCT27 or both. SWAFCT25 is a Priority 3 Ecological Community, and SWAFCT26a is a Threatened Ecological Community.

However, even Griffin (2008, p. 8) found it impossible to assign samples from quadrats with vegetation in much better condition only a few hundred metres north of Lot 1001 to SWAFCT26a, or to any other SWAFCT, with any confidence.

No Threatened or Priority flora was found during the site inspections and it is unlikely that any is in the survey area.

But ENV Australia (2007 Figure 2; 2009 Figure 23; 2010 Figure 3) found *Eucalyptus argutifolia*, a Threatened species of mallee, in a similar habitat approximately two kilometres due north of the survey area and proposed excavation site. It, and other populations of the same species, is in the much larger area on the adjoining land, between Lot 1001 and Boundary Lake. Earlier, Weston (2003) reported finding the same Threatened mallee, and also *Hibbertia spicata* subsp. *leptotheca* (Priority 3) and *Hakea oligoneura* (Priority 4), in the same area.

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FLORA AND VEGETATION SURVEY IN EASTERN PART OF LOT 1001 PRESTON BEACH ROAD

1.0 INTRODUCTION

This report describes and maps units and condition of vegetation in a proposed approximately 7 ha proposed site for a limestone pit, the survey area, which is in an eastern part of Lot 1001 Preston Beach Road. It describes methods and results of searches for rare flora there. It also describes dominants, structure and condition of vegetation between the survey area and Lake Pollard. It is based upon reviews of literature and metadata and upon field work. A. Weston and assistants undertook field work on 1 November and 3 December 2013.

The eastern end of Lot 1001 borders Lake Pollard. The proposed site is approximately 300 m west of the lake and approximately 7 km north of the town of Preston Beach. Figure 1 shows waypoints, vegetation units of the survey area, and parts of Lake Pollard and the lot.

2.0 OBJECTIVES

The principal objectives of this survey are to:

- provide a list of flora recorded in the survey area and descriptions of floristic community types and vegetation units found there,
- assess the condition of the vegetation units,
- determine the presence of Threatened (T), Priority (P), other significant species, Threatened Ecological Communities (TEC) and other significant vegetation units,
- provide a map showing vegetation units and locations of any T, TEC and other significant flora and vegetation found in the survey area, and
- describe the vegetation units that are between the survey area and Lake Pollard.

Ideally, this survey would conform to the description in the EPA's Guidance No. 51 (EPA 2004, p. 39) of a Level 2 Survey, which consists of three or, in some situations and areas, four stages. The first two stages constitute a Level 1 survey. The required three stages of a Level 2 Survey are:

- Background Research or 'desktop' study,
- Reconnaissance Survey, and
- Detailed Survey.

This Lot 1001 survey is more than a Level 1 Survey and less than a Level 2 Survey, for reasons explained in this paragraph. Because a Detailed Survey requires the "replication of plots in vegetation units", because the sampling done for the original southern Swan Coastal Plains survey was in ". . . the least disturbed vegetation available . . ." (Gibson *et al.* 1994, p. 4), and because the survey area's native herbaceous and low shrub vegetation is now too degraded and weedy to produce plot samples (species lists) sufficiently large and typical for meaningful analysis, plot samples would be expected to differ significantly from any of the Gibson *et al.* (1994) Swan Coastal Plain Floristic Community Types (SWAFCTs). An essential component of the Gibson *et al.* techniques is the compilation of a complete list of species for each 10 m by 10 m quadrat (plot) based upon correctly identified plant specimens. This requires sampling quadrats with flora and vegetation in good or better condition and often sampling more than once, preferably at the beginning and end of spring.

It should be possible, however, according to Gibson (pers. comm.), *Bush Forever* (Government of Western Australia 2000, Volume 2, p. 487) and Freeman *et al.* (2009, e.g. pp. 1, 22, 25, 45, 63, 140),

to infer, at least tentatively, which floristic community types, at least of the original 43 described by Gibson *et al*. (1994), occur (or occurred) in a survey area. Inferences of which SWAFCTs occur in particular Bush Forever sites have been made from "information on the floristics of the area and the area's geographic location" (Government of Western Australia 2000, Volume 2, p. 487).

Consequently, Floristic Community Types are inferred for the Lot 1001 survey area; they are not produced by meaningful analysis of plot samples.

3.0 METHODS

Prior to field work a list of 23 Threatened and Priority species, and other taxa (varieties, subspecies), to search for was compiled as Table A, in Appendix A. The listed taxa:

- are the Threatened (T) and Priority (P1, P2, P3 and P4) Flora taxa in the Keighery, Keighery and Longman (2009) report, *A Preliminary List of the Flora and Significant Flora of the Yalgorup National Park*,
- are the Threatened (CR, EN, VU) flora taxa in the results of searches of federal databases with the EPBC Act Protected Matters Search Tool, and
- have the word 'Yalgorup' in the Distribution column in Smith (2012).

The yellow-highlighting in Table A of 11 taxa indicates that there may be suitable habitats for them in the survey area, but not for the other 12. The yellow-highlighted taxa are the principal, but not only, rare taxa searched for.

Table A also gives information about statuses and ranks of the Threatened and Priority Flora listed and their distributions, localities, growth forms, habitats and flowering times. The information in the table is mainly from Smith (2012) and FloraBase (2013), but other references, Western Australian Herbarium (WAH) herbarium specimens and personal observations were also sources.

Field work in the survey area was on 1 November 2013, with assistant Dr. Clem Love, and on 3 December 2013, with assistant Jeremy Leithead. Rare flora plants were searched for, and most plants found were identified and recorded. Keighery, Keighery and Longman (2009) were used as a check-list. The dominant species, crown density of at least the tallest stratum of vegetation and assessed condition of vegetation units were recorded; the vegetation structure categories and condition assessment scale used are outlined in Appendix B.

After the recorded plants were identified and prior to and during report preparation the names assigned to them were checked against FloraBase (2013) for currency and conservation status.

4.0 REGIONAL SETTING

The survey area is in Lot 1001, which is one of several contiguous blocks of privately owned land that are more or less surrounded by Yalgorup National Park or are on the west side of the park. The national park comprises the lakes and much of the coastal and near coastal upland between Dawesville and Binningup. The Lot 1001 survey area is near the northern end of the central half of the Freeman *et al.* (2009, Map 1, p. 104) and Keighery, Keighery and Longman (2009) study area and slightly west of mid-way between its western and eastern boundaries.

Freeman *et al.* (2009, Maps 8a-8d, pp. 111-114) have described and mapped the relatively natural vegetation in the Dawesville to Binningup Region, between the Old Coast Road and the ocean, at a scale of 1:60,000, and Smith (1974), Beard (1979) and Heddle, Loneragan and Havel (1980) have mapped parts of it as parts of larger areas, at a scale of 1:250,000. Reports by Fox, Downes and Maslin (1980), Trudgen (1991**)**, Weston (1998) and others describe flora, vegetation or both in parts of the Dawesville to Binningup Region. Stephens (2013) describes flora and vegetation in Lots 1001 and 1002, while ENV Australia (2007, 2009) has a flora species list and a detailed vegetation map for much of the area between Lake Pollard, Boundary Lake and the ocean. The ENV Australia survey area abuts the northern boundary of Lot 1001.

4.1 LANDFORMS AND VEGETATION COMPLEXES

Freeman *et al.* (2009, p. 16) state that there are two geomorphologic systems in Yalgorup National Park and the rest of the region between Dawesville and Binningup: the Quindalup Dune system, in the west, and the Spearwood Dune system, in the east. They refer to the McArthur and Bartle (1980) description of the Spearwood Dune system being, on hills, outcrops of Tamala Limestone overlain by yellow to brown sands and being, on low dunes and swales, white and pale yellow sands. The dune system in the survey area and north, south and west of it is the Spearwood.

Freeman *et al.* (2009, Map 2, p. 105) show the Lot 1001 survey area as being in the Spearwood System Landform, but with its eastern side bordering the Vasse System Landform and with the Quindalup System Landform a few tens of metre southwest of it.

According to Freeman *et al.* (2009, p. 17), McArthur and Bartle (1980) describe a number of soils units in the Spearwood Dune system.

Also according to Freeman *et al.* (2009, p. 24), the Spearwood Dune Landform is approximately 65% of their Dawesville-Binningup study area and comprises the following three vegetation complexes:

- Cottesloe Vegetation Complex – Central and South,
- Yoongarillup Vegetation Complex and
- Vasse Vegetation Complex.

The Lot 1001 survey area is in the Cottesloe Vegetation Complex – Central and South.

On the north-eastern boundary of the Freeman *et al.* (2009) study area, there is a small band of Karrakatta Complex – Central and South.

4.2 FLORISTIC COMMUNITY TYPES (SWAFCTs)

Freeman *et al.* (2009, pp. 21-30, 42, **68**) identify thirteen Swan Coastal Plain Floristic Community Types (SWAFCTs) in the Dawesville to Binningup region. The twelve they list on page 68 are as follows (they also list two, newer Quindalup Land System FCTs: *S13* and *S14*).

Supergroup 2 – Seasonal Wetlands
16 Highly saline seasonal wetlands (Vasse Land System)
17 *Melaleuca rhaphiophylla – Gahnia trifida* seasonal wetlands (Vasse Land System)
18 Shrublands on calcareous silts (Vasse Land System)
19b Woodlands over [19] sedgelands on Holocene dune swales
Supergroup 3 – Uplands centred on Bassendean Dunes and Dandaragan Plateau
21a Central *Banksia attenuate - Eucalyptus marginata* woodlands (Spearwood Land System)
Supergroup 4 – Uplands centred on Spearwood and Quindalup Dunes
Spearwood Dunes
25 Southern *Eucalyptus gomphocephala – Agonis flexuosa* woodlands (Spearwood Land System)
26a *Melaleuca huegelii – Melaleuca systena* (=*M. acerosa*) shrublands on limestone ridges (Spearwood Land System)
26b Woodlands and mallees on Limestone (Spearwood Land System)
27 Species poor mallees and shrublands on Limestone (Spearwood Land System)
Quindalup Dunes
29a Coastal shrublands on shallow sands (Spearwood Land System)
29b *Acacia* shrublands on taller dunes (Quindalup Land System)
30b Quindalup *Eucalyptus gomphocephala* and/or *Agonis flexuosa* woodlands (Quindalup Land System)

There are also undescribed wetlands that represent new, unclassified SWAFCTs (Freeman *et al.* 2009, p. 25), e.g. Lake Fringing Communities 2 and 3a south of Lake Pollard. Lake Fringing Community 3a is similar to SWAFCT17.

The only SWAFCTs that could be in the Lot 1001 study area are 25, 26a, 26b and 27.

Appendix 2 of Freeman *et al.* (2009, pp. 144-152) describes 12 quadrats and 5 relevés in the Dawesville and Binningup study area identified as SWAFCT 25, 26a, 26b or 27. DPaW (2013a) currently lists SWAFCT26a as endorsed by the Minister for the Environment as Threatened, and DPaW (2013b) currently lists SWAFCT25 as Priority 3.

The ENV Australia (2009) Public Environmental Review (PER) covers a string of private lots in about half of the area between the northern end of Lot 1001, the centre of Boundary Lake, the western side of Lake Clifton and the west coast. An EPA report assesses the PER and, on page 12 (EPA 2011), refers to two occurrences of the Threatened Ecological Community SWAFCT26a (FCT 26a) in the area covered by the PER. The PER's Figure 2 shows many other occurrences. These occurrences and those referred to by Weston (2003) for most or all of the same area are additional to those referred to in Appendix 2 of Freeman *et al.* (2009).

However, Gibson (in Weston and Gibson 1997) states that Floristic Community Type 26a is, south of Perth, known only from the Lake Clifton townsite. This assertion is probably based upon the PATN

analyses of identifications of flora samples from SWAFCT quadrats CLIF-1 and CLIF-2. The quadrats are east of the Dawesville-Binningup Study Area; their coordinates are listed in Gibson *et al.* (1994, p. 222). All occurrences of SWAFCT26a in the Dawesville-Binningup Study Area referred to in this report, including those listed for that area, or parts of it, in Freeman *et al.* (2009) and ENV Australia (2007, 2009, 2010) are inferred from data, not determined by analysis.

Freeman *et al.* (2009, pp. 151, 152) list the following two SWAFCT quadrats for the Lake Pollard area (they are on the south side of Lake Pollard):

- Quadrat YLKP03 (32 49.4633, 115 39.8017) Lake Fringing Community 2, and
- Quadrat YLKP04 (32 49.4983, 115 39.84) Lake Fringing Community 3a.

Elsewhere (Page 154) they list Relevé 2 YLCB-2 as both Lake Fringing Community 3a and Floristic Community Type: *17 (* indicates totally or significantly cleared; plant communities inferred from remnants OR that the SWAFCT is inferred from data, not determined by analysis).

5.0 RESULTS

5.1 VEGETATION

The vegetation in the survey area is described below in terms of units and condition.

The two vegetation units shown by Freeman *et al.* (2009, Map 8b, p. 112) as closer to the Lot 1001 survey area than any others appear to be IV and QW (or an LFC unit), but there appears to be no definition of these combinations of letters. Map 8b has mapping of vegetation on the south side of Lot 1001 and between the survey area and Lake Pollard but not in most of Lot 1001 or in the four lots immediately north of the northern end of Lot 1001, which are the southernmost lots in the ENV Australia (2007, 2009, 2010) report area. The vegetation in the other 21 ENV Australia (2009) report area lots has been mapped, presumably because it is in better condition.

The vegetation between the survey area and Lake Pollard is on a low, flat area which slopes very gently downward towards the east and is, at least in the east, wetland vegetation.

The vegetation east of the survey area, at Waypoint (WP) 279, is *Agonis flexuosa* Open Low Forest over *Xanthorrhoea preissii* Open Heath to Shrubland, with *Macrozamia riedlei*, *Hibbertia cuneiformis* and a few other species of shrubs and a few scattered Tuart trees.

At WP278, fringing Lake Pollard in the western edge of the lake, there is *Melaleuca rhaphiophylla* Open Low forest over *Juncus kraussii* and *Baumea juncea* Sedgelands, with a few *Rhagodia baccata* shrubs at the bases of some *Melaleuca* trees. The *Sonchus* there may be *Sonchus hydrophilus.* A few metres inland, west of there, on ground that was not inundated in late October, there is *Melaleuca rhaphiophylla* Open Low forest over *Baumea juncea, Juncus kraussii* and *Gahnia trifida* Sedgeland. Common herbaceous plants in the sedgeland are *Apium prostratum* (erect to over 50 cm tall), *Galium divaricatum* (erect, with white flowers), *Lobelia anceps* and *Centella asiatica.*

The vegetation south of the survey area, south of the Lot 1001 southern boundary, for some distance, was burnt within the last five years or more. It is probably similar to some of the vegetation in the survey area but, except for the damage caused by the fire, in much better condition.

Figure 1 shows the distribution of vegetation units in the survey area. Each mapped occurrence of a unit has a green letters-symbol for the vegetation unit. A legend box in the figure lists, in red, the assessed condition of the five units. The names in the legend have two components – (1) dominant species and (2) structure. Definitions of terms used for describing vegetation structure and condition, and of symbols for condition, are in tables in Appendix D. Species and other taxa (genera, subspecies and varieties) recorded in each vegetation unit are listed in Appendix B.

The Lot 1001 survey area soils are shown on Freeman *et al.* (2009, p. 106) Map 3 as Spearwood S1a phase.

The five vegetation units mapped as occurring in the Lot 1001 survey area, their map symbols, assessed condition and plate numbers and brief descriptions of them are as follows, with the symbols and names used in Figure 1 in bold.

Tuart Woodland, Peppermint Low Woodland & Balga Shrubland **TXp** CD(-D) Title Page, Plate 1A
Eucalyptus gomphocephala Woodland over and with *Agonis flexuosa* Open Low Woodland over and with *Xanthorrhoea preissii* Shrubland

The TXp vegetation is, mainly, in lower areas on deeper sandy soil. Most of the plants in the vegetation unit are the dominants and **Trachyandra divaricata* and other weedy established aliens.

Chenille Honeymyrtle – Mixed Closed Heath **Mhs** D-(CD)
Melaleuca huegelii – Mixed species Closed Heath Title Page, Plates 1A, 2A, 2B, 3

The Mhs limestone heath, on shallow soil over limestone, in the survey area most commonly comprises *Melaleuca systena, Templetonia retusa, Hibbertia cuneiformis, Xanthorrhoea preissii* and *Hakea prostrata* and taller, but fewer, shrubs of *Melaleuca huegelii* and mallees of *Eucalyptus petrensis* and *Eucalyptus foecunda.* The ground layer, under the shrubs and between them, is mainly **Trachyandra divaricata* and a few other alien weeds.

***Melaleuca systena* Open to Closed Heath** **Ms** D-CD Plates 1A, 1B, 2A
Melaleuca systena Open to Closed Heath

The Ms, upland vegetation in the northern part of the survey area is similar to the Mhs vegetation at the southern end but with slightly deeper soil, with more *Melaleuca systena* shrubs and few, if any, *Melaleuca huegelii* shrubs. The ground layer is similar.

Summer-scented Wattle Heath to Closed Tall Scrub **Ar** CD-D Plate 2B
Acacia rostellifera Closed to Open Heath to Closed Tall Scrub

The Ar shrub vegetation unit is below the base of a rocky slope next to the eastern boundary of the survey area. Its understorey is sparse and of alien species of weeds.

Balga Shrubland **Xp** CD Plates 1A, 1B, 2A
Xanthorrhoea preissii Shrubland

The Xp vegetation unit is in the central, relatively low area and on northern, south-facing slopes. There are few native plants in the unit other than *Xanthorrhoea preissii* shrubs. The understorey is mainly **Trachyandra divaricata* and a few other alien weeds.

5.2 FLORA

Vascular plant species and other taxa (genera, subspecies and varieties) identified in the survey area are listed in Appendix B's Table B. The 21 taxa listed are estimated to constitute at least 60% of the native flora in the bushland. The other 17 taxa are established aliens (weeds). Most of the listed species were recorded in the Mhs vegetation unit, and some were recorded in all five vegetation units.

The only trees in the survey area are Tuarts and Peppermints. The diameter at breast height of the trunks of all of them is estimated to be less than 50 cm.

6.0. DISCUSSION

6.1 FLORISTIC COMMUNITY TYPES (SWAFCTs)

Freeman *et al.* (2009, pp. 27, 144-151) describe 10 quadrats and 2 relevés in the Dawesville-Binningup Study Area identified as SWAFCT 26a, 26b or 27. These 12, and 4 other quadrats and relevés identified in Freeman *et al.* (2009) as SWAFCT25, are listed in the table in this report's Appendix E. Two of the relevés are identified, but not analysed, as comparable to SWAFCT26a, a Threatened Ecological Community; three are identified, not analysed, as comparable to SWAFCT25, a Priority 3 Ecological Community, and one is analysed as comparable to SWAFCT25.

Although the condition of the Lot 1001 survey area's vegetation is too degraded for any meaningful floristic community type analysis to be done, it is possible, on the bases of comparisons, to infer, at least tentatively, which floristic community types may have been there before the vegetation became so degraded as it is now. The vegetation units mapped, in Figure 1, as TXp (Tuart Woodland, Peppermint Low Woodland & Balga Shrubland) and Xp (Balga Shrubland) were probably closest to SWAFCT25; the one mapped as Ar (Summer-scented Wattle Heath to Closed Tall Scrub) comes close to no SWAFCT, and the one mapped as Ms (Chenille Honeymyrtle – Mixed Closed Heath) was probably closest to SWAFCT26b. The one mapped as Mhs (*Melaleuca systena* Open to Closed Heath) was probably closest to SWAFCT26b, SWAFCT26a, SWAFCT27 or a combination of two or all of them.

Six of the limestone SWAFCT quadrats and relevés are identified in Freeman *et al.* (2009, Appendix 2) as SWAFCT27, and 4 are identified as SWAFCT26b. One relevé, YLCN04-4b, on the eastern side of Lake Clifton, was located to better sample SWAFCT26a then was possible with the only other, nearby, degraded relevé, YLCN04-4a. Both relevés were inferred, not analysed, as comparable to SWAFCT26a.

According to Gibson (in Weston and Gibson 1997), SWAFCT26b and SWAFCT27 are difficult to distinguish from each other on aerial photography, even on highly magnified stereoscopic pairs of

high resolution colour aerial photography. He also states that Type 26b/27 is widespread in Yalgorup National Park.

Probably SWAFCT26a is also sometimes difficult to distinguish from SWAFCT26b and SWAFCT27.

In 2003 Weston used the table in Appendix F of this report as an aid to distinguishing between SWAFCT26a, SWAFCT26b and SWAFCT27, but it was not helpful in 2013. The vegetation was too disturbed and weedy.

None of the vegetation mapped in Figure 1, except, possibly, the Mhs heath, is considered to have particular significance. The Heathland Walk Ridge heath shown in Photograph 7 in Freeman *et al.* (2009, p. 91) appears similar to the Mhs heath in the survey area, but it has been neither analysed nor inferred to be SWAFCT 26a. In fact, Freeman *et al* (2009, p. 30) state:

> "The study area supports the most southern limestone ridge in the Swan Coastal Plain (Heathland Walk in Yalgorup National Park) however interestingly no SWAFCT26a was recorded there".

But the ENV Australia (2009, p. 57 and Figure 23) PER refers to additional occurrences of SWAFCT26a well inside the Freeman *et al.* (2009) study area. One of the occurrences is about 500 m north of Lot 1001.

Griffin (2008, p. 8) carried out PATN analyses on samples provided by ENV Australia from 22 quadrats, two of which, 5 and 10, ENV thought might be closest to SWAFCT26a. But none of the PATN analysis results included SWAFCT26a. Griffin's Table 2, Summary of results, lists, in the Summary FCT column, 29b, ??29b, ??29/30, ?30a, 30b and ?30b. Quadrats 5 and 10 could not be assigned to any known communities. Griffin noted that "a large proportion of these sites did not relate well to the SCP data sets" and that 'difficult' sites "appear to be disturbed sites by the evidence of the species richness and the amount of weeds".

6.2 THREATENED ECOLOGICAL COMMUNITIES

All vegetation in the survey area is too degraded, floristically, and reduced in numbers of species to be confidently assigned by meaningful analysis to any floristic community type (SWAFCT). Prior to floristic degradation part of the Mhs vegetation unit might have been analysed as closest to SWAFCT26b, SWAFCT27, SWAFCT26a, or a combination of two or all of them, and the TXp vegetation probably would have been analysed as closest to SWAFCT25.

SWAFCT26a is a Threatened (Endangered) Ecological Community, and SWAFCT25 is a Priority 3 Ecological Community.

However, as shown by Griffin (2008, p. 8) for sites only a few hundred metres north of the Lot 1001 survey area, it was not possible to assign quadrat samples, even samples from quadrats with vegetation in much better condition than any in the Dawesville to Binningup Region, to SWAFCT26a, SWAFCT26b or SWAFCT27 with any confidence.

6.3 SIGNIFICANT FLORA

It is unlikely, though possible, that any Threatened or Priority flora, other than, possibly, the taxa yellow-highlighted in Table A, is in the survey area. ENV Australia (2009) found only one Threatened or Priority species in a similar habitat in the much larger area between Lot 1001 and Boundary Lake, due north of the survey area. It is *Eucalyptus argutifolia*, a Threatened mallee. Weston (2003) reported finding the same mallee, and also *Hibbertia spicata* subsp. *leptotheca* (Priority 3) and *Hakea oligoneura* (Priority 4), in the same area in 2002.

7.0 LIMITATIONS OF THE SURVEY

7.1 VEGETATION UNITS AND CONDITION

Delimiting units of vegetation and assigning names to them is much more arbitrary and subjective than identifying plants, because stands of vegetation often do not have clear boundaries or consistent features.

Assessing condition is also more arbitrary and subjective. The condition assessed may also be influenced by the season. For instance, a stand of wetland herbaceous vegetation that appears during winter and early spring to comprise largely small natives may in late spring and summer appear to be dominated by much larger alien grasses and other weeds.

7.2 FLORISTIC COMMUNITY TYPES

The paucity of species in a quadrat reduces the reliability of analysing quadrat samples using either a Full Gibson Analysis or a PATN analysis. When a group of species that would be in a quadrat, and sampled, is missing due to grazing or is not identifiable due to heavy browsing then analysis of a sample may yield a faulty result.

The sampling done for the original southern Swan Coastal Plains survey was in '. . . the least disturbed vegetation available . . .' (Gibson *et al.* 1994, p. 4).

Griffin (2008, pp. 2, 4) describes a number of problems in the interpretation of PATN analyses and with the system of Floristic Community Types, including the following.

> "It is very important in comparing different sets of floristic data that they are comparable in the application of names, in the intensity of the survey (i.e., the effort of searching resulting in similar proportion of the flora at sites being recorded) and in the size of the site recorded. If the data from different data sets is not comparable in these ways, it reduces the clarity of the results of the analyses carried out. If the discrepancy in the comparability of the data sets is large, the results may become meaningless."
>
> "It has been found in earlier projects that the addition of new sites to the SCP survey data set to produce a combined classification disrupts the original classification. The more data added, the higher the level of the disruption. This problem can make it difficult to assign Floristic Community Types to new sites using this method. Secondly, it is common for new data to group to their cohorts. In some cases this has proven to result from common deficiencies in the data, ie. whole groups of species missing. This absence tends to draw them together. The more sites in the added batch, the tighter they draw together."

Other problems described elsewhere by Griffin (2005) include:

> "The relevés had about a quarter the number of species recorded in the quadrats provided. Thus, an analysis with the relevés is unlikely to provide reliable interpretation. While preliminary scanning suggested that the quadrats appeared to have a reasonable number of species, an inspection of the Appendix suggested that there were probably a number of small generally annual species that may have been not recorded."

> "Because the size and shape of relevès are not standard, comparing relevès with each other or with quadrats will reduce the meaningfulness of the results."

7.3 FLORA

A number of species of plants that were not in flower at the times of the surveys could not be identified. Identification of species that are very similar when they are vegetative, e.g. several species of Iridaceae and Stylidiaceae, can be confirmed only when they are in flower, generally in early to mid-spring. Some herbaceous plants, such as many orchids, flower briefly, then disappear, and, furthermore, some do not appear every year.

Other taxa could be added to the list, especially if more field work were undertaken during August and September and, as was done, e.g. by Keighery, Keighery and Gibson (1995), during three flowering seasons in consecutive years.

7.4 SIGNIFICANT FLORA

Lists of Threatened and Priority Flora (e.g. Smith 2012) are updated more or less annually, with some taxa being added to the databases, others being deleted and some having their conservation codes changed. An example of a Priority Flora species that was deleted from listing is *Cartonema philydroides*. A poorly known and under-collected species when it was listed as Priority 3, (e.g. in Hopper *et al.* 1990), it was deleted from Priority listing presumably after more collections demonstrated that it is more common, better conserved or more widely distributed than previously thought.

8.0 CONCLUSIONS

Five provisional vegetation units were identified in the Lot 1001 survey area, mapped in Figure 1 and described in this report. They, their map unit symbols and their condition assessments are:

- Tuart Woodland, Peppermint Low Woodland & Balga Shrubland — TXp — CD(-D)
- Chenille Honeymyrtle (*Melaleuca huegelii*) – Mixed Closed Heath — Mhs — D-(CD)
- *Melaleuca systena* Open to Closed Heath — Ms — D-CD
- Summer-scented Wattle Heath to Closed Tall Scrub — Ar — CD-D
- Balga (*Xanthorrhoea preissii*) Shrubland — Xp — CD

All vegetation units in the survey area are too degraded, floristically, and too reduced in numbers of species to be confidently assigned by meaningful analysis to a floristic community type (SWAFCT), but if they were in much better condition at least part of the Txp unit might be analysed as closest to SWAFCT25 and the Mhs unit might be analysed as closest to SWAFCT26a, SWAFCT26b, SWAFCT27 or combinations of them. The Xp unit might have been analysed as closest to SWAFCT25, and the Ms unit might have been analysed as closest to SWAFCT26b, SWAFCT27 or both.

However, even Griffin (2008, p. 8) found it impossible to assign samples from quadrats in much better condition only a few hundred metres north of Lot 1001 to SWAFCT26a, or to any other SWAFCT, with any confidence.

No Threatened or Priority flora was found during the site inspections and it is unlikely that any is in the survey area.

But ENV Australia (2007 Figure 2; 2009 Figure 23; 2010 Figure 3) found *Eucalyptus argutifolia*, a Threatened species of mallee, in a similar habitat approximately two kilometres due north of the survey area and proposed excavation site. It, and other populations of the same species, is in the much larger area on the adjoining land, between Lot 1001 and Boundary Lake. Earlier, Weston (2003) reported finding the same Threatened mallee, and also *Hibbertia spicata* subsp. *leptotheca* (Priority 3) and *Hakea oligoneura* (Priority 4), in the same area.

9.0 ACKNOWLEDGEMENTS

The assistance of J. Leithead and C. Love in the field is gratefully appreciated. S. Beal provided maps, the plotting of coordinates and other help.

Access to the Western Australian Herbarium collections was essential for carrying out the survey and is also greatly appreciated.

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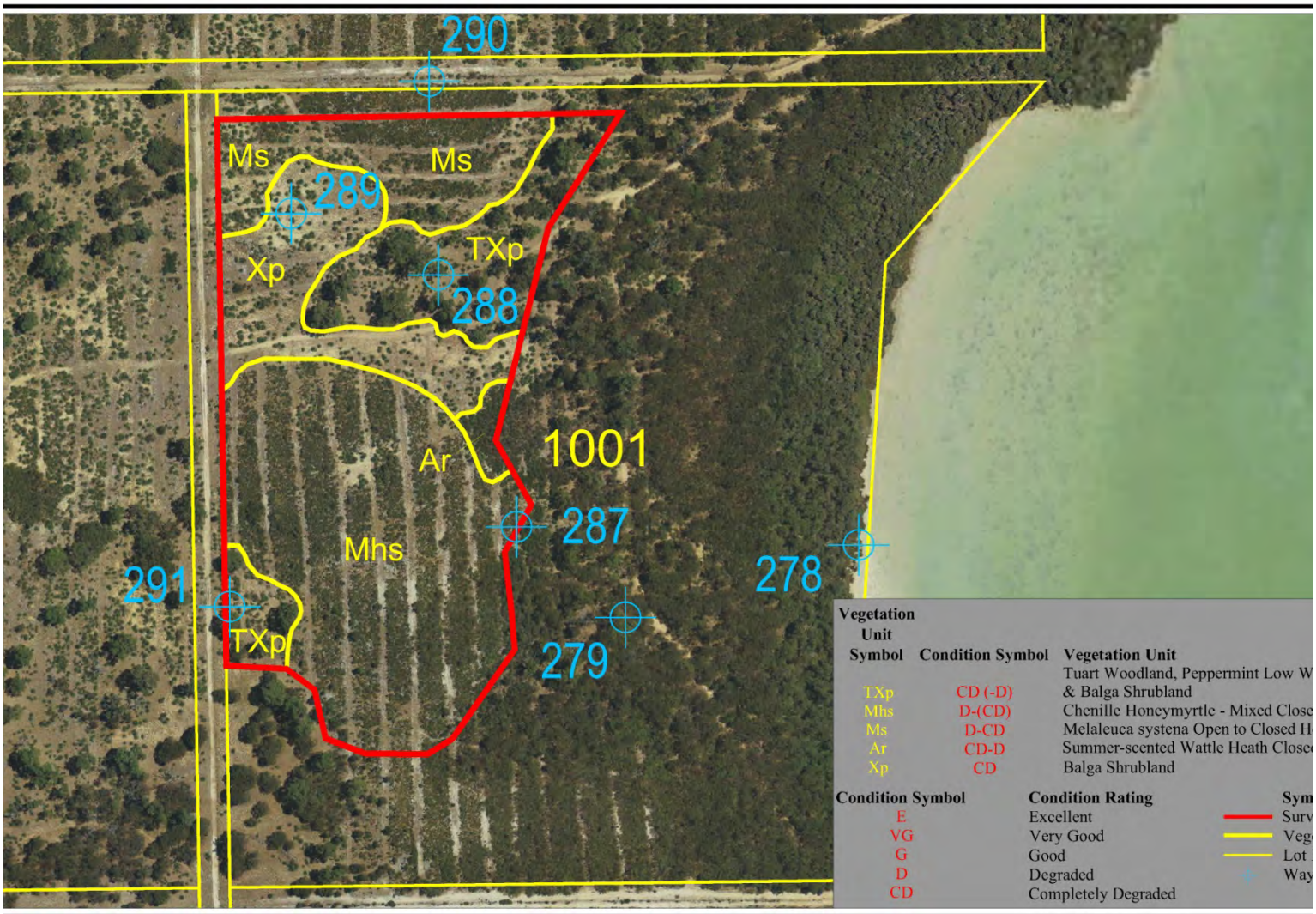


RE 1 - VEGETATION UNITS
RN) PT LOT 1001 PRESTON BEACH ROAD
N BEACH

N

SCALE 1:2500 @ A3

PLATES

PLATES

A. TXp Tuart Woodland and Balga (*Xanthorrhoea preissii*) Shrubland**.** Looking north from **Mhs** vegetation unit, with *Melaleuca systena* and *Hibbertia cuneiformis*, towards WP 288. **Xp** and **Ms** Units are in background. JL Photograph IMG_9018(50).

B. Xp Balga Shrubland and, in background, **Ms** *Melaleuca systena* Open to Closed Heath JL Photograph IMG_9024(50).

PLATE 1 Vegetation Units

A. Ms *Melaleuca systena* Open to Closed Heath and **Xp** Balga Shrubland in foreground.
Mhs Chenille Honeymyrtle – Mixed Closed Heath in centre.
*****_Gomphocarpus fruticosus_ in flower in lowe left corner JL Photograph IMG_9038(50).

B. Ar Summer-scented Wattle (*Acacia rostellifera*) Heath to Closed Tall Scrub, in centre.
Mhs Chenille Honeymyrtle – Mixed Closed Heath in Foreground.
Peppermint (*Agonis flexuosa*) Low Open Forest outside north side of survey area.
JL Photograph IMG_9007(50). NNW of WP 287.

PLATE 2 Vegetation Units

A. *Melaleuca rhaphiophylla* Swamp Paperbark Low Open Forest over *Baumea juncea, Juncus kraussii* and *Gahnia trifida* Sedgeland, with *Apium prostratum, Galium divaricatum, Lobelia anceps* and *Centella asiatica* herbaceous plants. In Lot 1001 between survey area and Lake Pollard.
West of WP 278. ASW Photograph DSC_9093(50).

B. *Melaleuca rhaphiophylla* Swamp Paperbark Low Open Forest over *Juncus kraussii* and *Baumea juncea* Sedgelands in Lake Pollard, with a few *Rhagodia baccata* shrubs at the bases of some *Melaleuca* trees and, possibly, *Sonchus hydrophilus.* In Lake Pollard.
WP 278. ASW Photograph DSC_9092(50).

PLATE 3 Two Vegetation Units between Survey Area and Lake Pollard

PLATE 4 Copied from Landform Research – Lot 1001 Mhs Vegetation Unit

APPENDICE S

APPENDIX A

Threatened and Priority Flora with Distributions and Habitats which may include the Lot 1001 Survey Area

(based mainly upon Keighery, Keighery and Longman (2009), Smith (2012) and FloraBase (2013) and upon EPBC Act Protected Matters Search Tool December 2013 search results)

1.0 TABLE A

Table A lists 23 taxa (species, subspecies and varieties) of flora and indicates which of them

- are the Threatened (T) and Priority (P1, P2, P3 and P4) Flora taxa in Keighery, Keighery and Longman (2009),
- are the Threatened (CR, EN, VU) flora taxa in the results of searches of federal databases with the EPBC Act Protected Matters Search Tool, and
- have the word 'Yalgorup' in the Distribution column in Smith (2012).

The taxa in Keighery, Keighery and Longman (2009) were recorded mainly within Yalgorup National Park, which more or less surrounds Lots 1001 and 1002. Six of the 10 EPBC CR, EN and VU taxa may have been recorded within 5 km of a point in the survey area with the coordinates -32.82°S and 115.65°E (32°49'10" S and 115°39'10" E). The other 4 species occur nowhere near Yalgorup; they are *Andersonia gracilis*, *Banksia nivea* subsp. *uliginosa*, *Darwinia foetida* and *Isopogon uncinatus.*

The taxa listed in Table A are the principal taxa searched for in 2013. The table also provides information, mainly from FloraBase (2013) and Smith (2012), about conservation codes, distributions, locality records, growth forms, habitats and flowering times for at least some of these taxa. The information about distributions, localities, growth forms, habitats and flowering times is not always comprehensive, but information about habitat is at least indicative and should help in assessing how likely species of rare flora are to occur in the survey area.

2.0 ATTACHMENT TO APPENDIX A

Extract from the 'Australian Government Department of Environment (DoE) EPBC Act Protected Matters Report PMST_2M785J' (for an area centred on 32°49'10" S – 115°39'10" E. [-32.8194 115.6528])

A report was generated by the Department of Environment EPBC Act Protected Matters Search Tool (http://www.environment.gov.au/arcgis-framework/apps/pmst/pmst-coordinate.jsf) for a 5 km wide area around a point in the survey area with the coordinates -32°49'10" S and 115°39'10" E. That report lists one threatened ecological community (Thrombolite (microbialite) Community of a Coastal Brackish Lake (L. Clifton)) and the 10 species of Threatened flora listed in Table A with Xs in Column 2.

3.0 CONSERVATION CODES DEFINITIONS (summary of definitions in Smith 2012)

T: **Threatened Flora** (Declared Rare Flora – Extant).Schedule 1 of the Wildlife Conservation (Rare Flora) Notice under the *Wildlife Conservation Act 1950.* [Gazetted]

X: **Presumed Extinct Flora** (Declared Rare Flora – Extinct). Schedule 2 of the Wildlife Conservation (Rare Flora) Notice under the *Wildlife Conservation Act 1950.* [Gazetted]

Threatened Flora (Schedule 1) are further ranked by the DPaW according to their level of threat using IUCN Red List criteria, which are the three EPBC Act Threatened Codes in this report's Appendix A's Table A and/or its Attachment:

CR: Critically Endangered – considered to be facing an extremely high risk of extinction in the wild.
EN: Endangered –considered to be facing a very high risk of extinction in the wild.
VU: Vulnerable – considered to be facing a high risk of extinction in the wild.

*Taxa = plural of taxon (a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies, variety or forma).

P1: **Priority One: Poorly-known taxa**

Taxa that are known from one or a few collections (generally less than five), all on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas,

P2**:** **Priority Two: Poorly-known taxa**
Taxa that are known from one or a few collections, some of which are on lands not under imminent threat of habitat destruction or degradation, e.g. national parks,

P3**:** **Priority Three: Poorly-known taxa**
Taxa that are known from collections from several localities not under imminent threat, or from few but widespread localities with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat.

P4**:** **Priority Four: Rare, Near Threatened and other taxa in need of monitoring**
(a) Rare. Taxa that are considered to have been adequately surveyed,
(b) Near Threatened. Taxa that are considered to have been adequately surveyed.
(c) Taxa that have been removed from the list of threatened taxa during the past five years for reasons other than taxonomy.

P5**:** **Priority Five: Conservation Dependent taxa**
Taxa that are not threatened but are subject to a specific conservation program, the cessation of which would result in the taxa becoming threatened within five years.

4.0 SIGNIFICANCR CODES DEFINITIONS
(from *Bush Forever* 2000, Volume 2, Table 13, pp. 51-55)

d = populations disjunct from their known geographic range;
e = taxa endemic to the Swan Coastal Plain;
p = considered to be poorly reserved (applies to all DRF and Priority taxa);
r = populations at the northern or southern limit of their known geographic range;
s = significant populations;
E = taxa endemic to the Swan Coastal Plain in the Perth Metropolitan Region;
X = taxa considered lost in the Perth Metropolitan Region

5.0 DEFINITION OF *

An asterisk (*) preceding an italicised two-word scientific name indicates that the name is of an established alien species, an environmental weed.

Table A

Threatened and Priority Flora Recorded in Yalgorup National Park or Nearby

/ on Keighery, Keighery and Longman (2009), Smith (2012) and FloraBase (2013) and on EPBC search results (PMST_2M785J) for circular a radius)

Taxon	Status & Rank	Fam-ily	Distribution / Localities	Flower period	Form	Plant Description and Habit
Anthotium junciforme	-	Good	Augusta-Margaret R – ThreeSprings LGAs	(Nov-)Jan-Mar	He	**FloraBase:** Formerly P4. Now "Not threatened, nor listed Open, erect to prostrate perennial, to 0.4 m high, leaves l purple. Sandy clay, clay. Winter-wet depressions, drainag
Blennospora doliiformis	P3	Aste	Yalgorup, Austin Bay, Kooljerrenup, Busselton	Oct-Nov	He	Erect annual, to 0.15 m high. Fl. yl Grey or red clay soils over ironstone. Seasonally-wet flats
Caladenia huegelii Grand Spider-orchid	T,CR	Orch	Perth-Capel	(Aug-) Sep-Oct	He	Lrge, few-flwered spider orch w large labellum that is drk rd (& are usually white & often divided at tip. Perennial, to 0.6 m high
Centrolepis caespitosa Matted Centrolepis	P4,EN	Cent	S Stirling, Pearce, Youngs Siding, Orange Grove	Oct-Dec (Nov)	He	Tufted annual, herb (forming a rounded cushion up to 25 White sand, clay. Salt flats, wet areas.
Conostylis pauciflora subsp. pauciflora	P4	Haem	Yarloop, Dawesville, Yalgorup NP	Aug-Oct	He	Rhizomatous, stoloniferous perennial, to 0.35 m high. Fl. Grey sand, limestone. Hillslopes, consolidated dunes.
Dielsia stenostachya	**e**[1]	Rest	Gingin-Pinjarra-Yalgorup	Feb-May	Se	[not listed in Keighery, Keighery and Longman (2009)] Sandy winter-wet depressions and flats & along watercou
Diuris micrantha	T, VU	Orch	Harvey, Kwinana, West Arthur, Williams LGAs	Sep-Oct	He	Perennial, to 0.6 m high. Fl. yellow & brown. Brown loamy clay. Winter-wet swamps, in shallow water
Diuris purdiei	T,EN	Orch	Perth-Waroona, Busselton	Sep-Oct	He	Slender donkey orchid with 5-10 narrow, spirally twisted leaves Seasonally wet, recently burnt sand over clay, shrublands, usual
Drakaea elastica	T,EN	Orch		Oct-Nov	He	Tuberous, perennial, herb, 0.12-0.3 m high. Fl. red & gre White or grey sand. Low-lying situations adjoining winte
Drakaea micrantha	T,VU	Orch	Perth, S Jarrah Forest, Warren IBRA Subregons	Sep-Oct	He	Perennial, to 0.3 m high. Fl. red & yellow. White-grey sand.
Eucalyptus argutifolia Wabling Hill Mallee	T	Myrt	Yanchep, Lancelin, Seabird, Jurien, Yalgorup	Mar-Apr	M	Mallee, to 4 m high, bark smooth. Buds angled; caps rour Shallow soils over limestone. Slopes or gullies of limesto
Galium leptogonium	P3	Rubi	Augusta-Margaret R, Dundas, Esperance, Waroona LGAs	Spring – Autumn	He	= Galium migrans. With sparse to dense slender hairs, or glabro mericarps ellipsoid to sub-globose, but flattened medially or 1a reticulately rugose. In forest, woodland and grassland, often in
Hakea oligoneura	P4	Prot	Yalgorup	Aug-Oct	S	=*H* sp. Yalgorup, = *H undulata* limestone variant. White-brown Mallee (*E. decipiens* & *E. petrensis*) over *Melaleuca acerosa, X*

[1] *Forever* (2000, Volume 2, Table 13) as an **e** species ('taxa endemic to the Swan Coastal Plain').

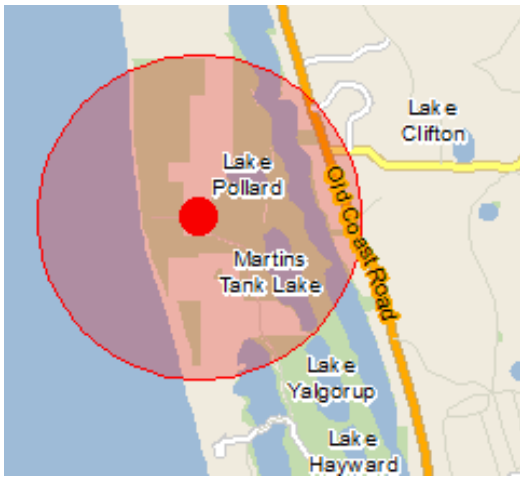
Taxon	Status & Rank	Fam-ily	Distribution / Localities	Flower period	Form	Plant Description and Habit
Haloragis aculeolata	P2	Halo	Yalgorup, Beermullah, (Toolbrunup,Cannington)	Sep or Dec	He	Slender, erect perennial, to 0.4 m high. Fl. green. Black sand or clay over limestone. Winter-wet areas.
Haloragis scoparia	P1	Halo	Canning & Harvey LGAs; Yalgorup	July	He	Perennial, to 0.3-0.6 m high.
Hibbertia spicata subsp. leptotheca	P3	Dill	Yalgorup, Lancelin, Burns Beach, Cataby	Jul-Oct	Sh	Erect or spreading, to 0.5 m high. Fl. yellow. Sand. Near-coastal limestone ridges, outcrops & cliffs.
Lasiopetalum membranaceum	P3	Malv	Yalgorup, Capel, Yanchep	Sep-Dec	Sh	Multi-stemmed, to 1 m high. Fl. pink-blue-purple. Sand o
Pimelea calcicola	P3	Thym	Yanchep-Yalgorup	Sep-Nov	Sh	Erect to spreading, to 1 m high. Fl. pink. Sand. Coastal li
Platysace ramosissima	P3	Apia	Yalgorup-Lancelin, Gingin	Oct-Nov	He	Perennial, herb, to 0.3 m high. Fl. white-cream. Sandy so
Pterostylis frenchii	P2	Orch	Yalgorup	Nov-Dec	He	To 0.35 m high, with rosette leaves. Calcareous sand with limestone, laterite. Flatlands and g
Sphaerolobium calcicola	P3	Faba	Yalgorup, Yanchep, Safety Bay, Denmark	Jun/Sep-Nov	ShSm	Slender, multi-stemmed, scandent or erect, to 1.5 m. Fl. orng-rd over limestone, black peaty sndy clay. Tall dnes, winter-wet flts
Stylidium longitubum	P3	Styl	Bullsbrook, Midland, Busselton, Arthur R	Oct-Dec	HeS	**Jumping jacks**. Erect annual (ephemeral), herb, 0.05-0.12 m hi Sandy clay, clay. Seasonal wetlands.
Stylidium maritimum	P3	Styl	Yalgorup – Breton Bay, Cervantes, Bold Park	Sep-Nov	He	Caespitose perennial, to 0.7 m high, Lves tufted, linear to narro mm wide, apex acute to mucronate, margin involute, glabrous. M of mature leaves. Scape glandular throughout. Inflorescence par Snd over lmestone. Dne slopes and flats. Coastal heath and shru
< **TOTALS = 21 T and P species + 1 e species (***Dielsia stenostachya*) **+ 1 delisted species (***Anthotium junciforme*)						

sed in table: **Column 4**: Taxon – Species, subspecies or variety. Yellow highlighting indicates taxon is more likely to occur in survey area; unhighlighted taxa re. **Column 5**: Status & Rank codes – CR, EN, VU – EPBC Act Threatened Flora; T – DPaW Threatened Flora; P1, P2, P3, P4 – DPaW Priority Flora. **Colu** he family names currently in use in the Western Australian Herbarium; e.g. Orch is Orchidaceae, Myrt=Myrtaceae. **Column 7**: Distribution / Localities – Not ı **8**: Flower period. **Column 9**: Form: He – herbaceous plant; Se – sedge; Sh – shrub. Height of shrubs: S – short; M – mid height (ca. 1-2 m); T – tall; V – vir

ATTACHMENT TO APPENDIX A

EPBC Act Protected Matters Report on Results of Database Searches for Threatened Flora and Threatened Ecological Communities recorded within 5 km of Point in Lot 1001 Survey Area (PMST_2M785J edited)

Database Search Area: Map (Area): Point Coordinates in decimal degrees: -32.82°, 115.65° (-32°49'10" S and 115°39'10" E) **Buffer:** 5 km **Area Searched:**



Matters of National Environmental Significance

Plants (10 Threatened Species; 6 of them are in Table A)	Status	Type of Presence
Andersonia gracilis Slender Andersonia	EN (DPaW T)	Species or species habitat may occur within area. Not in Table A **FloraBase:** Not recorded south of Gosnells LGA.
Banksia nivea subsp. *uliginosa* Swamp Honeypot	EN (DPaW T)	Species or species habitat may occur within area. Not in Table A. **FloraBase**: Recorded only in Augusta-Margaret River & Busselton LGAs
Caladenia huegelii Grand Spider-orchid	EN (DPaW T)	Species or species habitat likely to occur within area.
Centrolepis 3aespitose Matted Centrolepis	EN (DPaW T)	Species or species habitat likely to occur within area.
Darwinia foetida Muchea Bell	CR (DPaW T)	Species or species habitat may occur within area. Not in Table A. **FloraBase:** Recorded only in Chittering & Swan LGAs.
Diuris micrantha Dwarf Bee-orchid	VU (DPaW T)	Species or species habitat likely to occur within area.
Diuris purdiei Purdie's Donkey-orchid	EN (DPaW T)	Species or species habitat may occur within area.
Drakaea elastica Praying Virgin	EN (DPaW T)	Species or species habitat may occur within area. Glossy-leaved Hammer-orchid
Drakaea micrantha Dwarf Hammer-orchid	VU (DPaW T)	Species or species habitat likely to occur within area.
Isopogon uncinatus Hook-leaf Isopogon	EN (DPaW T)	Species or species habitat may occur within area. Not in Table A. **FloraBase:** Recorded only in Albany & Plantagenet LGAs.
Listed Threatened Ecological Communities:		
Thrombolite (microbialite) Community of a Coastal Brackish Lake (L. Clifton)	CR	Community known to occur within area

APPENDIX B

Vascular Flora recorded in the Lot 1001 Survey Area

Introduction

Table B lists native and established alien taxa (families, species, subspecies and varieties) of vascular plants recorded during botanical field work in the Lot 1001 survey area, Preston Beach Road, in November and December 2013.

The table lists the **20** taxa in two sets, each set in alphabetical order. The first set, of **17** taxa, is aliens assumed to be established, and the second set, of **20** taxa, is natives. The table was compiled using the Western Australian Herbarium database FloraBase (2013).

The taxa recorded in the Lot 1001 survey area and listed in Table B are estimated to constitute at least 60% of the flora there.

Other taxa could be added to the list, especially if more field work were undertaken during winter and early spring and, as was done, e.g. by Keighery, Keighery and Gibson (1995), during three flowering seasons in consecutive years.

Legend to Table B

Column 1 Taxon Name

A list of species, subspecies and varieties of vascular plants, in alphabetical order of taxon name of the weed (that is probably established).

Column 2 Fam (abbreviation of **Family**)

Four letter abbreviation of the name of the family to which the taxon in Column 1 belongs.

Column 3 X/C

Recorded and/or Collected

X – Recorded, **C –** Collected**, P –** Photographed **? –** ID uncertain **L** – recorded by Lindsay Stephens but not by Arthur Weston

Column 4 Notes

Names used previously (=) and other notes. An '=' precedes names that have been previously used for the listed taxon.

Table B
Vascular Flora recorded in the Lot 1001 Survey Area

Taxon Name	Fam	Mha	X/C	Notes
Aliens				
*Arctotheca calendula	ASTE		X	
*Crassula glomerata	CRAS		X	
*Euphorbia terracina	EUPH		X	
* Galium ?murale	RUBI		X	
*Geranium molle	GERA		C	
*Gomphocarpus fruticosus	APOC		X	
*Hypochaeris glabra	ASTE		C	
*Lolium ?perenne	POAC		C	
*Lotus ?angustissimus	FABA		C	
* Lysimachia arvensis	PRIM		X	= Anagallis arvensis
*Polycarpon tetraphyllum	POAC		C	
*Sonchus oleraceus	ASTE		X	
* Trachyandra divaricata	ASPH		X	
*Trifolium dubium	FABA		C	
*Trifolium campestre	FABA		C	
*Vulpia myuros	POAC		C	
*Wahlenbergia capensis	CAMP		C	
Aliens Totals (X's + C's)	**--**		**17**	
Natives				
Acacia cyclops	FABA		X	
Acacia rostellifera	FABA		X	
Agonis flexuosa	MYRT		X	
Anthocercis ilicifolia	SOLA		C	
Banksia sessilis	PROT		X	Herbaeous?; =Dryandra sessilis
Eucalyptus foecunda	MYRT		C	
Eucalyptus gomphocephala	MYRT		X	
Eucalyptus petrensis	MYRT		C	
Geranium solanderi	GERA		X	Herbaceous
Hakea prostrata	PROT		X?	
Hibbertia cuneiformis	DILL		C	
Hibbertia ?racemosa	DILL		C	
Leucopogon parviflorus	ERIC		X	
Lobelia tenuior	CAMP		C	Herbaceous
Melaleuca huegelii	MYRT		X	
Melaleuca systena	MYRT		X	
Phyllanthus calycinus	PHYL		X	
Pimelea rosea	THYM		C	
Poranthera microphylla	PHYL		C	Herbaceous; formerly in Euphorbiaceae
Templetonia retusa	FABA		X	
Xanthorrhoea preissii	XANT		X	
Natives Totals (X's + C's)	**--**		**21**	**--**
Totals (Aliens + Natives)	**--**		**38**	**--**

ASW 29 January 2014

APPENDIX C

WAYPOINTS AND PHOTOGRAPH LOCATIONS

Locations (GDA94 Datum) of Lot 1001 Preston Beach Rd
Waypoints and Photographs (WP: accuracy +/- 6-8 m)

WP/Photo	Position: Lat. Long.	Location ⊗ Photo	Photo By	Date
DSC_9092 WP 278	32°49'12.6" S, 115°39''22.7" E	**Plate 3A.** *Melaleuca rhaphiophylla* Swamp Paperbark Low Open Forest over *Baumea juncea, Juncus kraussii* and *Gahnia trifida* Sedgeland, with *Apium prostratum, Galium divaricatum, Lobelia anceps* and *Centella asiatica* herbaceous plants. In Lot 1001 between survey area and Lake Pollard	**AW**	01/11/2013
DSC_9093 Between 278 & 279	--	**Plate 3B**. *Melaleuca rhaphiophylla* Swamp Paperbark Low Open Forest over *Baumea juncea, Juncus kraussii* and *Gahnia trifida* Sedgeland, with *Apium prostratum, Galium divaricatum, Lobelia anceps* and *Centella asiatica* herbaceous plants. In Lot 1001 between survey area and Lake Pollard	**AW**	01/11/2013
DSC_9094 WP 279	32°49'14.1" S, 115°39''16.9" E	*Agonis flexuosa* Open Low Forest over *Xanthorrhoea preissii* Open Heath to Shrubland, with *Macrozamia riedlei, Hibbertia cuneiformis* and a few other species of shrubs and a few scattered Tuart trees.	**AW**	01/11/2013
DSC_9095	Mhs vegetation unit	Title Page: **Proposed Site for Limestone Pit**	**AW**	01/11/2013
DSC_9096	near DSC_9095	Mhs vegetation unit	**AW**	01/11/2013
WP 287	32°49'12.2" S, 115°39''14.2" E	*Melaleuca huegelii* location	**AW**	3/12/2013
WP 288	32°49'06.8" S, 115°39''14.2" E	Looking east from lower, eastern part of Mhs unit.	**AW**	3/12/2013
WP 289	32°49'05.4" S, 115°39''08.6" E		**AW**	3/12/2013
WP 290	32°49'02.7" S, 115°39''12.1" E		**AW**	3/12/2013
WP 291	32°49'13.8" S, 115°39''06.7" E	Txp vegetation unit	**AW**	3/12/2013
IMG_9018	--	**Plate 1A. TXp** and **Mhs** vegetation units. **Xp** and **Ms** units are in background.	**JL**	3/12/2013
IMG_9024	--	**Plate 1B. Ms** and **Xp** vegetation units.	**JL**	3/12/2013
IMG_9037	--	= IMG_9038	**JL**	3/12/2013
IMG_9038	--	**Plate 2A. Ms** and **Xp** in foreground. **Mhs** in centre.	**JL**	3/12/2013
IMG_9007	Near WP 287 32°49'12.2" S, 115°39''14.2" E	**Plate 2B. Ar** in centre. **Mhs** in Foreground. Peppermint (*Agonis flexuosa*) Low Open Forest.	**JL**	3/12/2013
IMG_8991 – IMG_9050 Photographs of Lake Pollard, Lot 1001 and nearby			**JL**	3/12/2013

APPENDIX D

VEGETATION STRUCTURE CLASSES AND CONDITION SCALE TABLES

Vegetation Structure Classes (Layers)

These vegetation structure classes are rationalisations of the ones defined by Keighery (1994) and used in *Bush Forever* (2000, Volume 2, Table 11 and p. 493) to describe vegetation in Bush Forever sites, except that [1] a bracketed name refers to a dominant that has fewer plants and provides significantly less cover than others, and that [2] 'scattered' refers to trees, low trees, tall shrubs and low shrubs that have <2% cover). 'Sedges' are in Table 11 but not on p. 493. The rationalisation is that, in the name, density always precedes height, for example 'Open Low Forest' instead of 'Low Open Forest'.

Life Form/ Height Class	**Canopy Cover (percentage)**			
	100% - 70%	**70% - 30%**	**30% - 10%**	**10% - 2%**
Trees 10-30m Trees < 10m	Closed Forest Closed Low Forest	Open Forest Open Low Forest	Woodland Low Woodland	Open Woodland Open Low Woodland
Shrub Mallee	Closed Shrub Mallee	Shrub Mallee	Open Shrub Mallee	Very Open Shrub Mallee
Shrubs > 2m Shrubs 1-2m Shrubs <1m	Closed Tall Scrub Closed Heath Closed Low Heath	Open Tall Scrub Open Heath Open Low Heath	Tall Shrubland Shrubland Low Shrubland	Open Tall Shrubland Open Shrubland Open Low 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

Vegetation Condition Scale

This condition scale is the one used in *Bush Forever* (2000, Volume 2, Table 12 and p. 494) to describe condition of vegetation in Bush Forever sites, but with the addition of the last category, Completely Cleared. Assessment of condition is at least as much of understorey strata as of overstorey.

---	Pristine	Pristine or nearly so; no obvious signs of disturbance.
E	Excellent	Vegetation structure intact; disturbance affecting individual species [plants?]; weeds are non-aggressive species.
VG	Very Good	Vegetation structure altered; obvious signs of disturbance.
G	Good	Vegetation structure significantly altered by very obvious signs of multiple disturbance (e.g. disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds, partial clearing, dieback and grazing). Has basic vegetation structure or ability to regenerate it.
D	Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management (e.g. removing aggressive weeds).
CD	Completely Degraded	Vegetation structure not intact, and the area is completely or almost completely without native species ('parkland cleared', with isolated native trees or shrubs).

ASW 15/04/11

APPENDIX E

Quadrat Descriptions

(* indicates that the SWAFCT number is inferred from data, not determined by analysis)

FCT (SWAFCT) 25, 26a, 26b and 27 Samples Listed in Freeman *et al.* (2009, Appendix2)

11 Quadrats, 5 Relevés

Quadrat (Q)/ Relevé (R)	SWA FCT	Page	No. Taxa Na, We	Location	Date(s) Sampled
Q YALG-7	25	144	45, 9	YNP Heathlands Walk	1993, 25/08/2007
R4 YLCB-4	*25	145	- -	32 48.8033 115 40.8717 (WGS84)	26/08/2007
R11 YLCN04-2	*25	145	- -	Nightingale Road	26/08/2007
R12 YLCN04-3	*25	146	- -	Nightingale Road	26/08/2007
Q WHILL-3	27	146	**27 0**	White Hill Road	13/10/&17/11/1993
Q WHILL-4	27	147	**41 0**	White Hill Road	13/10/&17/11/1993
Q WHILL-5	26b	147	**41 15**	White Hill Road	13/10/&17/11/1993
Q YALG-1	26b	147	**49 11**	YNP Heathlands Walk	9/09/&13/10.1993
Q YALG-2	26b	148	**52 2**	YNP Heathlands Walk	1993, 25/08/2007
Q YALG-3	27	148	**37 2**	YNP Heathlands Walk	1993, 25/08/2007
Q YALG-4	27	148	**30 3**	YNP Heathlands Walk	1993, 25/08/2007
Q YALG-5	27	149	**42 0**	YNP Heathlands Walk	1993, 25/08/2007
Q YALG-6	26b	149	**38 2**	YNP Heathlands Walk	1993, 25/08/2007
Q YALG-8	27	150	**41 5**	YNP Heathlands Walk	1993, 25/08/2007
R13 YLCN04-4a	*26a	151	- -	Nightingale Road	26/08/2007
R13 YLCN04-4b	*26a	151	- -	Nightingale Road	26/08/2007

Note: the R11, R12 and R13 releves are near 32°51'00" S, 115°41'57" E

FCT (SWAFCT) Quadrats 5&10 (of Quadrats 1 through 22 between L Pollard and Boundary L)

(ENV Australia 2009a, Table 10 Floristic Community Type Determination, pp. 56-57 and Griffin 2008, Table 2 Summary of results, p. 8)

ENV Quadrat	PATN analysis NNB FCT	ENV Australia (2009a, p. 57) Comments
5	??24/28	ENV believes that both quadrats have a close affiliation with FCT 26a, through communication with the DEC, the community in known to occur on Cottesloe and Karrakatta units which are situated within the Spearwood Dune geomorphologic system which the two quadrats are situated on.
10	?29a/30a	

Note: ENV Australia (2009, 56-57) inferred FCT 26a for Quadrats 5 and 10 and for none of their other 22 and stated on page 57 that "Western (2003) also inferred FCT 26a as being present on site."

APPENDIX F

› use in distinguishing FCTs (SWAFCTs) 26a, 26b and 27 from each other and other FCTs (based upon Appendix A's Table A in Westo
›son *et al.* 1994, Table 12 (pp. 31, 35, 36), pp. 43-46 and Appendix 1; Note: this information may have been updated, though not printed or available, s

TAXON NAME	Species Group	Family	Form	Taxa Frequencies in Plots of FCTs						Number of (and referred to in Gi
				26a	26b	27	29a	29b	other highest	
carpa var. *lasiocarpa*	A	163	Sh vs	82	16	57	22	85	**30c**: 67	+ 8 other FCTs (incl. **1**
:ata	A	163	Sh s	36	-	86	-	15	**24**: 8	in no other FCT
›us preissii	A	054C	He p	-	16	-	78	85	**30b**: 75	+ 5 other FCTs
›icrocalyx	A	288	Sh vs	36	16	100	-	8	-	in no other FCT
:ompressa	Q	031	Gr p	55	42	-	-	-	**20c**: 78	+ 11 other FCTs
flavescens	A	031	Gr p	91	42	-	78	92	**30b**: 63	+ 9 other FCTs;
andicans	A	055	He p	18	37	-	22	62	**30c**: 33	+ 3 other FCTs
s flexuosus	Q	039	He p (gr)	100	79	100	44	92	**24**: 72	+ 16 other FCTs
oluta	A	054E	He p	-	32	14	11	8	**30c**: 100	+ 14 other FCTs
yandra) sessilis	A	090	Sh t	91	42	29	11	-	**30c**: 67	+ 3 other FCTs
eissii	A	090	Sh vs	100	32	100	22	-	**24**: 40	+ 2 other FCTs
icata subsp. *leptotheca*	A	226	Sh vs	9	-	71	11	15	**24**: 12	in no other FCT
parviflorus	A	288	Sh m	64	37	86	67	62	**18**: 100	+ 8 other FCTs
aritima	A	054C	He p (gr)	45	37	86	44	92	**24**: 64	+ 3 other FCTs
uegelii	A	273	Sh m-t	82	11	29	44	-	**30a**: 14	+ 1 other FCT: **24**: 12
ystena	A	273	Sh s-m	82	68	100	22	92	**24**: 52	+ 8 other FCTs
calycinus	A	185	Sh vs	45	47	-	-	62	**25**: 82	+ 10 other FCTs
lobulosum	A	215	Sh m-t	9	16	29	78	46	**30**: >85	**30a**: 86, **30b**: 100, **30c**:
aritimum	A	343	He p (gr)	73	5	-	-	8	-	in no other FCT
retusa	A	165	Sh m	64	16	86	33	8	**30c**: 67	+ 5 other FCTs
a divaricata	A	054G	He	-	5	-	22	-	**30b**: 63	+ 3 other FCTs
edifolium var. *ledifolium*	A	215	Sh s-m	91	11	71	22	8	**30a**: 14	+ 2 other FCTs (**24**: 4;
os	Q	031	Gr a	100	47	-	44	-	**18**: 50	+ 18 other FCTs

ass), He (herb), Sh (shrub). a (annual), p (perennial), gr (graminoid). vs (very small: <0.5m), s (small: 0.5-1m), m (medium: 1-2m), t (tall: 2-4m), vt (very tall:

leuca huegelii – M. acerosa shrublands of limestone ridges (Spearwood) **FCT 26b** Woodlands and mallees on limestone (Spearwood: Co

ies poor mallees and shrublands on limestone (mainly Yalgorup area) (Spearwood) **FCT 24** 'heaths' Northern Spearwood shrublands (with *Dryand*

tal shrublands on shallow sands (over limestone: Quindalup) **FCT 29b** *Acacia* shrublands on taller dunes (Quindalup)

tris preissii (or *Melaleuca lanceolata*) forests and woodlands (Perth, Quindalup) **FCT 30b** Quindalup [southern] tuart and / or peppermint woodl

r mallees and scrubs (Quindalup-Spearwood) (on Spearwood dunes: only three plots [one *Eucalyptus argutifolia* plot and two *Dryandra sessilis* plots], near Sw

FLORA AND VEGETATION SURVEY IN SOUTHERN PART OF LOT 1002 PRESTON BEACH ROAD NORTH, PRESTON BEACH (SOUTH-WEST OF LAKE POLLARD)

SHIRE OF WAROONA

Proposed Site for Sand Pit, the vegetation of which is **Trachyandra divaricata* Herbland to Closed Herbland. The only native species found in the site were Balga (*Xanthorrhoea preissii*) and *Hibbertia cuneiformis* shrubs. There were fewer than 10 browsed plants of the former species and one of the latter; the *Hibbertia* was only on the stump beyond Jeremy's right shoulder. Tuart and Peppermint trees are outside the perimetre of the site. Photograph: ASW Pentax IMGP3326(50), 03/12/2013. Looking northeast over site.

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7 January 2014

SUMMARY

The original objectives of this flora and vegetation survey were to:

- describe the vegetation unit(s) of the survey area and assess its, or their, condition vis a vis native natural vegetation,
- determine, if possible, which Floristic Community Types (FCTs, SCPs) the floras represent,
- search for rare flora, and
- discuss and list flora recorded.

The only vegetation unit in the survey area is Completely Degraded Dune Onion Weed (**Trachyandra divaricata*) Herbland to Closed Herbland, with a species of Pygmyweed (**Crassula glomerata*) and an unidentified moss in some of the relatively small open areas.

The Floristic Community Type (FCT) of the survey area prior to clearing was most likely to have been either FCT 25 (Southern *Eucalyptus gomphocephala – Agonis flexuosa* Woodlands) or FCT 30b (Quindalup *Eucalyptus gomphocephala* and/or *Agonis flexuosa* woodlands). This inference is based upon the substrate of the survey area being sandy, upon the presence nearby of *Eucalyptus gomphocephala* and *Agonis flexuosa* trees and upon the previous identification of both FCTs in Yalgorup National Park (Freeman *et al.* 2009, pp. 68).

No rare flora plants were found. The only native species found in the survey area are *Xanthorrhoea preissii* and *Hibbertia cuneiformis*. Only a few plants of the former and one of the latter were found. Neither species is rare or uncommon.

TABLE OF CONTENTS

FLORA AND VEGETATION SURVEY IN SOUTHERN PART OF LOT 1002 PRESTON BEACH ROAD NORTH, PRESTON BEACH (SOUTH-WEST OF LAKE POLLARD)

1.0 INTRODUCTION

This report describes the flora and vegetation in an area of approximately 4 ha proposed for sand mining, the survey area. That area is shown in Figure 1 and on the title page. It is in the south central part of Lot 1002. It is south-west of Lake Pollard and approximately west of the north end of Martins Tank Lake.

2.0 OBJECTIVES

The original objectives of this flora and vegetation survey were to:

- describe the vegetation unit(s) of the survey area and assess its, or their, condition vis a vis native natural vegetation,
- determine, if possible, which Floristic Community Types (FCTs, SCPs) the floras represent,
- search for rare flora, and
- discuss and list flora recorded.

However, as the native vegetation of the site had been cleared, except for a few shrubs of two species, it was impossible to determine which Floristic Community Type the pre-clearing flora represented. The paucity of species reduces the reliability of analysing samples using either a Full Gibson Analysis or a PATN analysis.

3.0 METHODS

Prior to field work a list of Threatened and Priority species, and other taxa (varieties, subspecies), to search for was compiled as Table A, in Appendix A. The listed taxa

- are the Threatened (T) and Priority (P1, P2, P3 and P4) Flora taxa in the Keighery, Keighery and Longman (2009) report, *A Preliminary List of the Flora and Significant Flora of the Yalgorup National Park,*
- are the Threatened (CR, EN, VU) flora taxa in the results of searches of federal databases with the EPBC Act Protected Matters Search Tool, or
- have the word 'Yalgorup' in the Distribution column in Smith (2012).

They are the principal rare taxa searched for.

Table A also gives information about statuses and ranks of the Threatened and Priority Flora listed and their distributions, localities, growth forms, habitats and flowering times. The information in the table is mainly from Smith (2012) and FloraBase (2013), but other references, Western Australian Herbarium (WAH) herbarium specimens and personal observations were also sources.

Field work in the survey area was on 3 December 2013, with assistant Jeremy Leithead. Rare flora plants were searched for, and plants found were identified and recorded. Keighery, Keighery and Longman (2009) was used as a check-list. The dominant species and assessed

condition of vegetation were recorded; the vegetation structure categories and condition assessment scale used are outlined in Appendix B.

After the recorded plants were identified and prior to and during report preparation the names assigned to them were checked against FloraBase for currency and conservation status.

4.0 RESULTS

The Title Page plate and Figure 1 show the survey area and neighbouring areas and their vegetation. The Title Page plate and Plate 1 also show the only two native plant species recorded in the survey area, Balga (*Xanthorrhoea preissii* – fewer than 10 plants) and Cutleaf Hibbertia (*Hibbertia cuneiformis* – 1 plant). Neither species is rare.

The vegetation of the survey area is all Dune Onion Weed (**Trachyandra divaricata*) Herbland to Closed Herbland, with a species of Pygmyweed (**Crassula glomerata*) and an unidentified moss in some of the relatively small open areas. Both weed species are native to South Africa (Randall 2002).

The survey area is mapped by Freeman *et al.* (2009, p. 109, Map 6, based on Heddle, Loneragan and Havel 1978) as Yoongarillup Vegetation Complex (**56**). The Churchward and McArthur (1978) landforms and soils counterpart of Vegetation Complex **56** is **Yo** (Yoongarillup, Marine Deposits). Vegetation Complex **52** and Landform and Soils Unit **Cl** are adjacent to **56** and **Yo**. Complex **52** comprises heaths on limestone outcrops and Tuart-dominated woodlands and open forests on deeper sands, and the Landforms and Soils unit **Cl** comprises shallow yellow-brown sands and exposed limestone.

5.0 DISCUSSION

The eleven Floristic Community Types (FCTs) identified by Freeman *et al.* (2009, p. 22, 25, 68) in their Dawesville to Binninngup Region (mainly Yalgorup National Park) are 17, 18, 19b, 21a, 25, 26a, 26b, 27, 29a, 29b and 30b. Of these, the FCT of the survey area prior to clearing was most likely to have been either FCT 25 (Southern *Eucalyptus gomphocephala – Agonis flexuosa* Woodlands) or FCT30b (Quindalup *Eucalyptus gomphocephala* and/or *Agonis flexuosa* woodlands). Both FCTs are Priority 3 Ecological Communities. This statement is based upon the substrate of the survey area being sandy, upon the presence nearby of *Eucalyptus gomphocephala* and *Agonis flexuosa* trees and upon the previous identification of both FCTs in Yalgorup National Park (Freeman *et al.* 2009, pp. 22, 25, 68).

6.0 CONCLUSIONS

The vegetation unit of the survey area is **Trachyandra divaricata* Herbland to Closed Herbland, with **Crassula glomerata* and an unidentified moss in some of the relatively small open areas.

No rare flora plants were found. The only native plants found in the survey area are *Xanthorrhoea preissii* and *Hibbertia cuneiformis.* Neither species is rare or uncommon.

7.0 LIMITATIONS

The condition of the vegetation in the survey area was too degraded to produce samples of adequate size and quality for meaningful analysis. When a group of species that would be in a quadrat and sampled is missing due, for example, to grazing or is not identifiable due to browsing, as is the case in Lot 1002, then analysis of a sample would yield a faulty result.

The unnatural paucity of species in a quadrat reduces the reliability of analysing samples using either a Full Gibson Analysis or a PATN analysis.

Furthermore, many, if not most, herbaceous plants recorded in November are unidentifiable. However, at least in the case of the Lot 2002 survey area, most of these unidentifiable plants are alien weeds.

The sampling done for the original southern Swan Coastal Plains survey was in '. . . the least disturbed vegetation available . . .' (Gibson *et al.* 1994, p. 4). Because the Lot 1002 survey area vegetation has been heavily disturbed, the samples (species lists) would differ significantly from any of the Gibson *et al.* (1994) SCP FCTs.

Griffin (2005) describes a number of problems in the interpretation of PATN analyses and with the system of Floristic Community Types. He describes some of the problems in the first paragraph of his Section 1.4 Data Provided on his report's Page 2:

> "It is very important in comparing different sets of floristic data that they are comparable in the application of names, in the intensity of the survey (i.e., the effort of searching resulting in similar proportion of the flora at sites being recorded) and in the size of the site recorded. If the data from different data sets is not comparable in these ways, it reduces the clarity of the results of the analyses carried out. If the discrepancy in the comparability of the data sets is large, the results may become meaningless."

8.0 ACKNOWLEDGEMENTS

Access to the Western Australian Herbarium Reference Herbarium collections was essential for carrying out the study and is greatly appreciated.

The assistance of Jeremy Leithead in the field work is also appreciated, as is Lindsay Stephens' provision of aerial photography, maps, information and advice. Elaine Marchetti provided access to the survey area and useful information about it.

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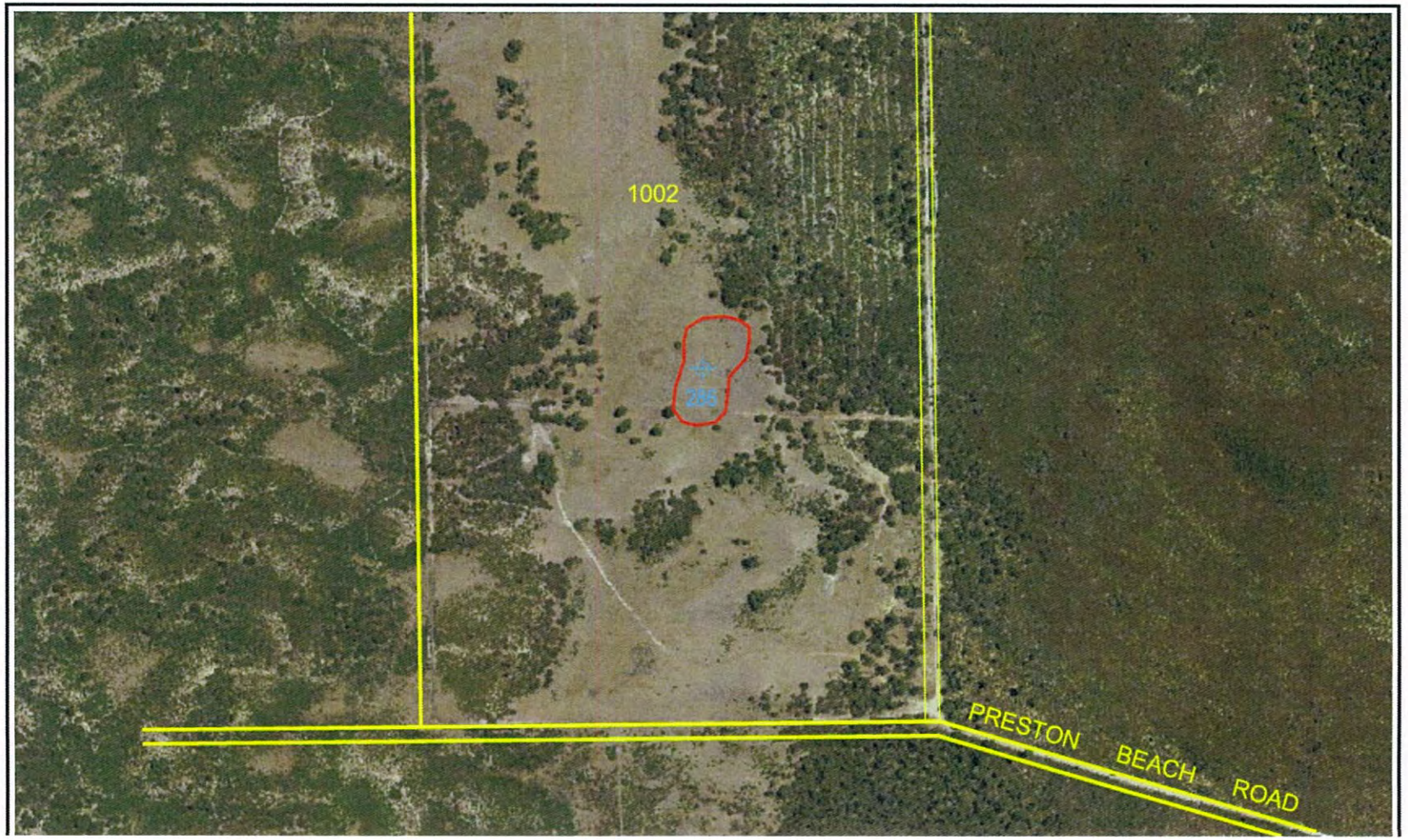

1002
285
PRESTON BEACH ROAD

PLATES

A. *Hibbertia cuneiformis* and **Trachyandra divaricata* on stump in survey area. Photograph: J Leithead IMG_8984(50), 03/12/2013.

B. **Crassula glomerata* and **Trachyandra divaricata,* weeds, the most common species in the survey area. Photograph: J Leithead IMG_8990(50), 03/12/2013.

PLATE 1

APPENDIX A

Threatened and Priority Flora and other Significant Flora with Distributions and Habitats which may include the Lot 1002 Survey Area

(based mainly upon Keighery, Keighery and Longman (2009), Smith (2012) and FloraBase (2013) and upon EPBC Act Protected Matters Search Tool December 2013 search results)

1.0 TABLE A

Table A lists 23 taxa (species, subspecies and varieties) of flora and indicates which of them

- are the Threatened (T) and Priority (P1, P2, P3 and P4) Flora taxa in Keighery, Keighery and Longman (2009),
- are the Threatened (CR, EN, VU) flora taxa in the results of searches of federal databases with the EPBC Act Protected Matters Search Tool, and
- have the word 'Yalgorup' in the Distribution column in Smith (2012).

The taxa in Keighery, Keighery and Longman (2009) were recorded within Yalgorup National Park, which more or less surrounds Lots 1001 and 1002. The EPBC CR, EN and VU taxa were recorded within 5 km of a point in the survey area with the coordinates --32.83°S and 115.64833°E (32°49'48" S and 115°38'54" E).

The taxa listed in Table A are the principal taxa searched for in 2013. The table also provides information, mainly from FloraBase (2013) and Smith (2012), about conservation codes, distributions, locality records, growth forms, habitats and flowering times for at least some of these taxa. The information about distributions, localities, growth forms, habitats and flowering times is not always comprehensive, but information about habitat is at least indicative and should help in assessing how likely species of rare flora are to occur in the survey area.

2.0 ATTACHMENT TO APPENDIX A

Extract from the 'Australian Government Department of Environment (DoE) EPBC Act Protected Matters Report' for an area centred on Lat. -32°49'48" S and 115°38'54" E. (--32.83 115.64833)

A report was generated by the Department of Environment EPBC Act Protected Matters Search Tool (http://www.environment.gov.au/arcgis-framework/apps/pmst/pmst-coordinate.jsf) for a 5 km wide area around a point in the survey area with the coordinates -32°49'48" S and 115°38'54" E. That report lists one threatened ecological community (Thrombolite (microbialite) Community of a Coastal Brackish Lake (L. Clifton)) and the 6 species of Threatened flora listed in Table A with Xs in Column 3.

3.0 CONSERVATION CODES DEFINITIONS (summary of definitions in Smith 2012)

T: **Threatened Flora** (Declared Rare Flora – Extant).Schedule 1 of the Wildlife Conservation (Rare Flora) Notice under the *Wildlife Conservation Act 1950.* [Gazetted]

X: **Presumed Extinct Flora** (Declared Rare Flora – Extinct). Schedule 2 of the Wildlife Conservation (Rare Flora) Notice under the *Wildlife Conservation Act 1950.* [Gazetted]

Threatened Flora (Schedule 1) are further ranked by the DPaW according to their level of threat using IUCN Red List criteria, which are the three EPBC Act Threatened Codes in this report's Appendix A's Table A and/or its Attachment:

CR: Critically Endangered – considered to be facing an extremely high risk of extinction in the wild.
EN: Endangered –considered to be facing a very high risk of extinction in the wild.
VU: Vulnerable – considered to be facing a high risk of extinction in the wild.

*Taxa = plural of taxon (a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies, variety or forma).

P1: **Priority One: Poorly-known taxa**
Taxa that are known from one or a few collections (generally less than five), all on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas,

P2: **Priority Two: Poorly-known taxa**

Taxa that are known from one or a few collections, some of which are on lands not under imminent threat of habitat destruction or degradation, e.g. national parks,

P3: **Priority Three: Poorly-known taxa**
Taxa that are known from collections from several localities not under imminent threat, or from few but widespread localities with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat.

P4: **Priority Four: Rare, Near Threatened and other taxa in need of monitoring**
(a) Rare. Taxa that are considered to have been adequately surveyed,
(b) Near Threatened. Taxa that are considered to have been adequately surveyed.
(c) Taxa that have been removed from the list of threatened taxa during the past five years for reasons other than taxonomy.

P5: **Priority Five: Conservation Dependent taxa**
Taxa that are not threatened but are subject to a specific conservation program, the cessation of which would result in the taxa becoming threatened within five years.

4.0 SIGNIFICANCE CODES DEFINITIONS

(from *Bush Forever* 2000, Volume 2, Table 13, pp. 51-55)

d = populations disjunct from their known geographic range;
e = taxa endemic to the Swan Coastal Plain;
p = considered to be poorly reserved (applies to all DRF and Priority taxa);
r = populations at the northern or southern limit of their known geographic range;
s = significant populations;
E = taxa endemic to the Swan Coastal Plain in the Perth Metropolitan Region;
X = taxa considered lost in the Perth Metropolitan Region

5.0 DEFINITION OF *

An asterisk (*) preceding an italicised two-word scientific name indicates that the name is of an established alien species, an environmental weed.

Table A

Threatened and Priority Flora Recorded in Yalgorup National Park

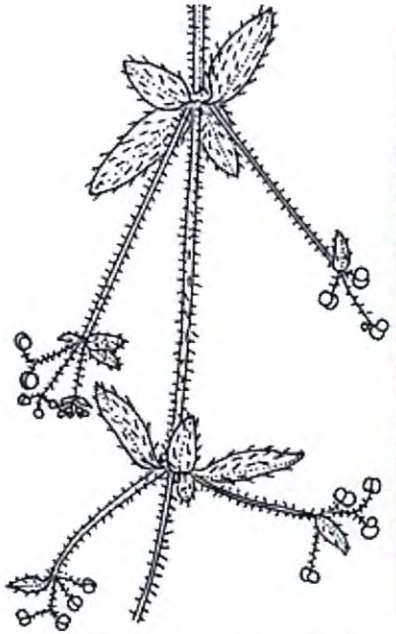
(based mainly on Keighery, Keighery and Longman (2009), Smith (2012) and FloraBase (2013) and on EPBC search results (PMST_OUKBWS) for circular area with 5 km radius)

K *et al.*	EPBC	Smith '12	Taxon	Status & Rank	Family	Distribution / Localities	Flower period	Form	Plant Description and Habitats
X	-	-	Anthotium junciforme	-	Good	Augusta-Margaret R – ThreeSprings LGAs	(Nov-)Jan-Mar	He	Formerly P4. Open, erect to prostrate perennial, to 0.4 m high, leaves linear to terete. Fl. blue-violet-purple. Sandy clay, clay. Winter-wet depressions, drainage lines.
X	-	X	Blennospora doliiformis	P3	Astc	Yalgorup, Austin Bay, Kooljerrenup, Busselton	Oct-Nov	He	Erect annual, to 0.15 m high. Fl. yl Grey or red clay soils over ironstone. Seasonally-wet flats.
-	X	-	Caladenia huegelii Grand Spider-orchid	T,CR	Orch	Perth-Capel	(Aug-) Sep-Oct	He	Lrge, few-flwered spider orch w large labellum that is drk rd (& wh) & has lng fringing hairs that are usually white & often divided at tip. Perennial, to 0.6 m high. Grey or brown sand, clay loam.
-	X	-	Centrolepis caespitosa Matted Centrolepis	T.P4	Cent	S Stirling, Pearce, Youngs Siding, Orange Grove	Oct-Dec (Nov)	He	Tufted annual, herb (forming a rounded cushion up to 25 mm across). White sand, clay. Salt flats, wet areas.
X	-	X	Conostylis pauciflora subsp. pauciflora	P4	Haem	Yarloop, Dawesville, Yalgorup NP	Aug-Oct	He	Rhizomatous, stoloniferous perennial, to 0.35 m high. Fl. yellow. Grey sand, limestone. Hillslopes, consolidated dunes.
-	-	-	Dielsia stenostachya	e[1]	Rest	Gingin-Pinjarra-Yalgorup	Feb-May	Se	[not listed in Keighery, Keighery and Longman (2009)] Rhizomes rufous furry. Sandy winter-wet depressions and flats & along watercourses.
-	X	-	Diuris micrantha	T, VU	Orch	Harvey, Kwinana, West Arthur, Williams LGAs	Sep-Oct	He	Perennial, to 0.6 m high. Fl. yellow & brown. Brown loamy clay. Winter-wet swamps, in shallow water.
-	X	-	Diuris purdiei	T,EN	Orch	Perth-Waroona, Busselton	Sep-Oct	He	Slender donkey orchid with 5-10 narrow, spirally twisted leaves. Seasonally wet, recently burnt sand over clay, shrublands, usually of *Regelia* and *Pericalymma*.
-	X	-	Drakaea micrantha	T	Orch	Perth, S Jarrah Forest, Warren IBRA Subregons	Sep-Oct	He	Perennial, to 0.3 m high. Fl. red & yellow. White-grey sand.
X	-	X	Eucalyptus argutifolia Wabling Hill Mallee	T	Myrt	Yanchep, Lancelin, Seabird, Jurien, Yalgorup	Mar-Apr	M	Mallee, to 4 m high, bark smooth. Buds angled; caps rounded. Fl. white. Shallow soils over limestone. Slopes or gullies of limestone ridges, outcrops.
X	-	-	Galium leptogonium	P3	Rubi	Augsta-Margt R, Dundas, Esper., Waroona LGAs	Spring - Autumn	He	= Galium migrans. With sparse to dense slender hairs, or glabrous. Fruit dull and smooth; mericarps ellipsoid to sub-globose, but flattened medially or reniform, dark reddish brown, reticulately rugose. In forest, woodland and grassland, often in rock crevices.
X	-	X	Hakea oligoneura	P4	Prot	Yalgorup	Aug-Oct	S	=*H* sp. Yalgorup, =*H undulata* limestone variant. White-brown sand on limestone ridges in open Mallee (*E. decipiens* & *E. petrensis*) over *Melaleuca acerosa*, *Xanthorrhoea* and *Hibbertia*
X	-	X	Haloragis aculeolata	P2	Halo	Yalgorup, Beermullah, (Toolbrunup,Cannington)	Sep or Dec	He	Slender, erect perennial, to 0.4 m high. Fl. green. Black sand or clay over limestone. Winter-wet areas.
X	-	X	Haloragis scoparia	P1	Halo	Canning & Harvey LGAs; Yalgorup	July	He	Perennial, to 0.3-0.6 m high.
-	X	X	Hibbertia spicata subsp. leptotheca	P3	Dill	Yalgorup, Lancelin, Burns Beach, Cataby	Jul-Oct	Sh	Erect or spreading, to 0.5 m high. Fl. yellow. Sand. Near-coastal limestone ridges, outcrops & cliffs.
-	X	-	Isopogon uncinatus	T, EN	Prot	Albany, Plantagenet LGAs	Oct-Nov	ShSm	Tufted spreading or prostrate, to 0.4 m high. Fl. yellow/cream. Loam or sand on granite, peaty sand. Swampy depressions, hillslopes
X	-	X`	Lasiopetalum membranaceum	P3	Malv	Yalgorup, Capel, Yanchep	Sep-Dec	Sh	Multi-stemmed, to 1 m high. Fl. pink-blue-purple. Sand over limestone.

[1] Listed in *Bush Forever* (2000, Volume 2, Table 13) as an e species ('taxa endemic to the Swan Coastal Plain').

K *et al.*	EP BC	Smith '12	Taxon	Status & Rank	Fam-ily	Distribution / Localities	Flower period	Form	Plant Description and Habitats
-	-	X	Pimelea calcicola	P3	Thym	Yanchep-Yalgorup	Sep-Nov	Sh	Erect to spreading, to 1 m high. Fl. pink. Sand. Coastal limestone ridges.
-	-	X	Platysace ramosissima	P3	Apia	Yalgorup-Lancelin, Gingin	Oct-Nov	He	Perennial, herb, to 0.3 m high. Fl. white-cream. Sandy soils.
-	X	X	Pterostylis frenchii	P2	Orch	Yalgorup	Nov-Dec	He	To 0.35 m high, with rosette leaves. Calcareous sand with limestone, laterite. Flatlands and gentle slopes.
-	-	X	Sphaerolobium calcicola	P3	Faba	Yalgorup, Yanchep, Safety Bay, Denmark	Jun/Sep-Nov	ShSm	Slender, multi-stemmed, scandent or erect, to 1.5 m. Fl. orng-rd. Wh-grey-brwn snd, sndy clay over limestone, black peaty sndy clay. Tall dnes, winter-wet flts, interdnal swmps, low areas.
X	-		Stylidium longitubum	P3	Styl	Bullsbrook, Midland, Busselton, Arthur R	Oct-Dec	HeS	**Jumping jacks**. erect annual (ephemeral), herb, 0.05-0.12 m high. fl. pink. sandy clay, clay. seasonal wetlands.
X	-	X	Stylidium maritimum	P3	Styl	Yalgorup - Breton Bay, Cervantes, Bold Park	Sep-Nov	He	Caespitose perennial, to 0.7 m high, Lves tufted, linear to narrowly oblanc, 10-40 cm long, 1-5.5 mm wide, apex acute to mucronate, margin involute, glabrous. Membraneous scale lves at base of mature leaves. Scape glandular throughout. Inflorescence paniculate. Fl. white/purple. Snd over lmestone. Dne slopes and flats. Coastal heath and shrubland, open Banksia wdland.
11	**6**	**13**	**< TOTALS = 21 T and P species + 1 e species + 1 delisted species**						

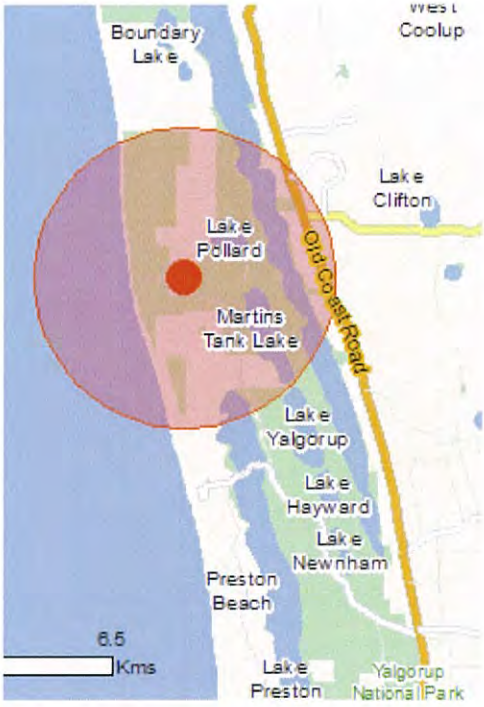
Abbreviations used in table: **Column 4**: Taxon – Species, subspecies or variety. **Column 5**: Status & Rank codes - CR, EN, VU – EPBC Act Threatened Flora; T – DPaW Threatened Flora; P1, P2, P3, P4 – DPaW Priority Flora. **Column 6**: Family – abbreviations of the family names currently in use in the Western Australian Herbarium; e.g. Orch is Orchidaceae, Myrt=Myrtaceae. **Column 7**: Distribution / Localities – Not complete listings. **Column 8**: Flower period. **Column 9**: Form [of plant]: He – herbaceous plant; Se – sedge; Sh – shrub. Height of shrubs: S – short; M – mid height (ca. 1-2 m); T – tall; V – vine.. Sm - small



http://plantnet.rbgsyd.nsw.gov.au/cgi-bin/NSWfl.pl?page=nswfl&photo=28&file=47/925/Galium_leptogonium_flower_620.jpg

ATTACHMENT TO APPENDIX A

EPBC Act Protected Matters Report on Results of Database Searches for Threatened Flora and Threatened Ecological Communities (TECs) recorded within 5 km of Point (PMST_OUKBWS edited)
Database Search Area: Map (Area): Point Coordinates in decimal degrees: -32.83°, 115.64833° (-32°49'48" S, 115°38'54" E) **Buffer:** 5 km **Area Searched:**



Matters of National Environmental Significance

Plants (6 Threatened Species):	Status	Type of Presence
Caladenia huegelii Grand Spider-orchid	EN (DEC T)	Species or species habitat likely to occur within area.
Centrolepis caespitosa Matted Centrolepis	EN (DEC T)	Species or species habitat likely to occur within area.
Diuris micrantha Dwarf Bee-orchid	VU (DEC T)	Species or species habitat likely to occur within area.
Diuris purdiei Purdie's Donkey-orchid	EN (DEC T)	Species or species habitat may occur within area.
Drakaea micrantha Dwarf Hammer-orchid	VU (DEC T)	Species or species habitat likely to occur within area.
Isopogon uncinatus Hook-leaf Isopogon	EN (DEC T)	Species or species habitat may occur within area. Only Albany area; south coast
Listed Threatened Ecological Communities:		
Thrombolite (microbialite) Community of a Coastal Brackish Lake (L. Clifton)	CE	Community known to occur within area

APPENDIX B

Vegetation Structure Categories and Condition Assessment Scale

The classification system used for describing vegetation structure and the six-point scale used for assessing vegetation condition are based upon those in *Bush Forever* (2000, Vol. 2, pp. 493-494).

The vegetation classification system is, basically, as set out below (note that the term for density precedes the term for height; in *Bush Forever* the term for height sometimes precedes the term for density):

Canopy cover / Form, height	100% - 70%	70% - 30%	30% - 10%	10% - 2%
Trees > 30m	Closed Tall Forest	Open Tall Forest	Tall Woodland	Open Tall Woodland
Trees 10-30m	Closed Forest	Open Forest	Woodland	Open Woodland
Trees < 10m	Closed Low Forest	Open Low Forest	Low Woodland	Open Low Woodland
Shrubs > 2m	Closed Tall Scrub	Open Tall Scrub	Tall Shrubland	Open Tall Shrubland
Shrubs 1-2m	Closed Heath	Open Heath	Shrubland	Open Shrubland
Shrubs < 1m	Closed Low Heath	Open Low Heath	Low Shrubland	Open Low Shrubland
Grasses	Closed Grassland	Grassland	Open Grassland	Very Open Grassland
Herbs	Closed Herbland	Herbland	Open Herbland	Very Open Herbland
Also Sedges: Sedgelands. Rushes: Rushlands. Etc.				

The six-point condition scale is, basically:

P	Pristine	No obvious signs of disturbance,
E	Excellent	Vegetation structure intact, disturbance affecting individual species, and weeds are non-aggressive species,
VG	Very Good	Vegetation structure altered, obvious signs of disturbance,
G	Good	Vegetation structure significantly altered by very obvious signs of multiple disturbance; basic vegetation structure or ability to regenerate it is retained,
D	Degraded	Basic vegetation structure severely impacted by disturbance; scope for regeneration but not to a state approaching good condition without intensive management, and
CD	Completely Degraded	Vegetation structure not intact; the area completely or almost completely without native species ('parkland cleared').

Appendix 2

MEMO TO : LANDFORM

ATTN: LINDSAY STEPHENS

FROM : MICHAEL KEANE

DATE : 25 JUNE 2014

REF : DOYLES LIME SERVICE
PRESTON BEACH ROAD NORTH

Lindsay,
Further to your request, I have inspected Preston Beach Road (PBR) North from Preston Beach Road turn-off through to the gate marking the end of the public road – total 5.7 kms long.
PBR North is a local road vested in the Shire of Waroona. Much of the road is located within Yalgorup National Park and the road provides access to the Martin's Tank Campground operated by Dept of Parks and Wildlife (DPaW). See Appendix 1, Location Map.

1.0 BACKGROUND

The Proponent seeks to develop a lime sand pit located at the top end of PBR North.
When operational, the proponent will cart approx. 50,000 tonnes of lime sand per annum through to Forrest Highway via PBR North and Preston Beach Road. This carting operation will be limited to the period of agricultural demand - December through to April (5 months).

The Shire has expressed some reservations about granting pit approval based on concerns re truck traffic on PBR North. Those concerns include the following;

1. Keeping the road safe for traffic associated with Martins Tank Campground (Yalgorup NP), especially during busy holiday periods.
2. Short Sight Distances on some sections of PBR North.
3. Durability of the existing road structure
4. Increased truck traffic on Preston Beach Road, especially during busy holiday periods

Being a public road, there should be no restriction on 19m semi-trailer trucks using PBR North.
However, the Shire has already erected a sign stating that this road is "Closed to all vehicles Class 3 and over, i.e. single axle rigid trucks not greater than 3.2m long"
Refer Appendix 2, Shire of Waroona Bye-Law No…….
At time of writing , Shire of Waroona has not responded to my request to provide evidence of this bye-law.

2.0 ROAD ASSESSMENT

Refer Appendix 3, photos.
Generally the road consists of a cleared track, flat-bladed in sandy material.
There is little or no constructed road formation to assist simple drainage – but being in sand, drainage may not be a significant problem.
There is some evidence of limestone sheeting on top of the sand but it is sparse and not representative.
Road width varies from minimum observed 5.4m at SLK 4.6 to 7.0m plus at SLK 1.9 and 4.1.
Sight distances along the route vary from minimum approx. 60m to maximum approx. 200m.
Sight distance is compromised throughout by vegetation overhanging the road but particularly on curves.
The road is thus best described as Road Type Class 1 Unformed.

The road inspection indicates that the Shire's concerns are valid and warrant due consideration.

If the bye-law restriction was lifted, then the Proponent could expect to use "as-of-right" 19m long semi-trailer combinations with approx. 30 t payload. In which case 50,000 tonnes per season equates to total 1563 semi-trailer loads.
If the trucking operation is spread evenly over 5 months, the truck traffic would equate to approx. 10 loads per day, i.e. 20 truck movements per day, or 2 truck movements per hour.

The current road structure will not, in my opinion, support this level of truck activity.

The road structure would need to be formed up into a crowned cross-section and sheeted with a suitable wearing course. For safety reasons, the best wearing course would be one which generates the least dust in summertime.

In bringing the road up to Type 3 paved road, a standard minimum road width of 6.4m could be established and all overhanging vegetation cut back to improve sight distances.
There is one particular location at SLK 2.4 (access to Martins Tank farm) where the road width is restricted by a property boundary peg on one side of the road and a large tree on the other side. The maximum road width available here is approx. 5.6m and this location would need additional advisory signage.

Notwithstanding the pavement improvements, those locations with limited sight distance due to crests and / or curves would also need advisory signage. Refer Appendix 4.

The right-turn into the Martin's Tank campground is located within a curve and the sight distance to a stalled vehicle for vehicles approaching from the south may be no more than 60m.
The best approach to addressing this and other such safety concerns is to install the most appropriate advisory signage, per Appendix 4.

The PBR North approach to the intersection is now notable for it's short-radius bend. The options for improving this tight bend are constrained by a power pole on the inside of the curve. At present, the curve is somewhat ill-defined.
Refer Appendix 5, intersection plan with turning templates for 19m long semi-trailers. The turning templates indicate that there is only enough road width to accommodate one vehicle at a time, i.e. whenever a semi-trailer is negotiating the intersection, any and all other vehicles will have to wait outside the intersection.

There is potential for widening the intersection to overcome this problem but it looks like the intersection has been modified previously to ensure that vehicles entering and exiting PBR North do give way to through-traffic on Preston Beach Road.
If the road is to accommodate trucks and light traffic, then the intersection should be improved by either road widening to accommodate two-way traffic or undertaking such clearing works as are required to provide clear visibility and safe waiting bays for vehicles exiting PBR North.
This work would require a combination of structured pavement with advance signage on the approach straight, and curve delineation using hazard boards.

The intersection with Preston Beach Road is located within a designated 70 kph speed limit.
The distance for vehicles approaching the intersection to sight trucks waiting to turn right is approx. 170m which satisfies the Austroads Sight Distance requirements within a 70 kph zone.

There is no restriction on as-of-right vehicles using Preston Beach Road.

3.0 TRAFFIC CONSIDERATIONS

As noted above, the period of demand for lime sand is December through to April – approx. 150 days. Appendix 6 provides details from traffic counts undertaken by Shire of Waroona on Preston Beach Road and PBR North. Unfortunately, the counts provided refer only to peak holiday periods at Christmas and Easter.

For Preston Beach Road, the Avg Peak Daily Traffic (ADT) is 700 vpd
The holiday traffic data generally indicates 100% compliance with the current RAV restriction (19m semi-trailer) on this road.

For PBR North, the Avg Peak Daily Traffic (ADT) is 75 vpd
The holiday traffic data generally indicates 100% compliance with the truck restriction.

Given the Shire's concerns about trucks using the road during peak holiday periods, it makes sense to limit trucking to non-peak periods. To this end, the Proponent may need to establish a stockpile area adjacent to Forrest Hwy to cater for customer demand during holiday periods.

If the proponent sees fit to establish a stockpile area, then he may consider structuring his operations so that all lime sand supply goes through the stockpile. This means that trucking on PBR North could be organized not only to completely avoid holiday periods but also to operate on a campaign basis where the road is prepared annually to cater for a short intensive trucking campaign, maintained during the campaign and reinstated after the campaign.

In an ideal world, if PBR North could be closed to the public for 3 weeks in Oct/Nov, and the shire permitted 27.5m pocket road trains, the proponent could organize 3 units to cart the whole 50,000 tonnes to stockpile in one operation thus negating all of the shire's concerns.
This level of activity would equate to 5 truck movements per hour in each direction, 6 days per week by 3 weeks.

Note any application to run 19m semi's can be approved by the Shire.
Any application to run pocket road trains needs the approval of both Shire and Main Roads WA.

4.0 Summary of Options considered over a 5-year operating period.

Option 1A, maintain existing formed track over 5-month period
The cost of basic maintenance grading will be approx $ 500 /km, total $ 3,000 per visit.
Allow at least monthly visits, sub-total $ 15,000 per season. Shire may or may not contribute.
Add for one-off signage – approx $ 3,000
Add for one-off intersection works $ 30,000
Total $ 33,000 + $ 15,000 x 5 = $ 108,000 over 5 years (250,000 tonnes) = $ 0.39 / tonne

Option 1B, maintain existing formed track over 1-month period
The cost of basic maintenance grading will be approx $ 500 /km, total $ 3,000 per visit.
Allow three grades sub-total $ 9,000 per season. Shire unlikely to contribute.
Add for one-off signage – approx $ 3,000
Add for one-off intersection works $ 30,000
Add for cost of stockpile arrangement, nominal one-off $ 20,000
Total $ 53,000 + $ 9,000 x 5 = $ 88,000 over 5 years (250,000 tonnes) = $ 0.35 / tonne

Option2A, upgrade to formed and sheeted standard, truck over 5 months
The cost of bringing the road to formed and sheeted standard will be at least $ 25,000 per km, total $ 150,000. Allow to maintain the road once per month - $ 15,000 over 5 months.
Add for one-off signage – approx $ 3,000
Add for one-off intersection works - included.
Total $ 153,000 + $ 15,000 x 5 = $ 228,000 over 5 years (250,000 tonnes) = $ 0.91 / tonne

Option2B, upgrade to formed and sheeted standard, truck over 1 month
The cost of bringing the road to formed and sheeted standard will be at least $ 25,000 per km, total $ 150,000. Allow two grades to maintain the road - $ 6,000.
Add for one-off signage – approx $ 3,000
Add for one-off intersection works - included.
Add for cost of stockpile arrangement, nominal one-off $ 20,000
Total $ 173,000 + $ 6,000 x 5 = $ 203,000 over 5 years (250,000 tonnes) = $ 0.81 / tonne

CONCLUSION

There are significant factors feeding into the assessment of PBR North for approval of proposed trucking and it will most likely require good faith between all parties to arrive at an acceptable solution. In my view, the best outcome for all may be that which will allow the Shire to close the road to the public for a short period annually, to facilitate a concerted trucking campaign by the proponent – Option 1B, Option 2B.
I expect that Option 2B will be more attractive to the Shire and DPaW.

This report is provided by way of general guidance. The cost figures used for comparative purposes are indicative only and should be tested in the market.

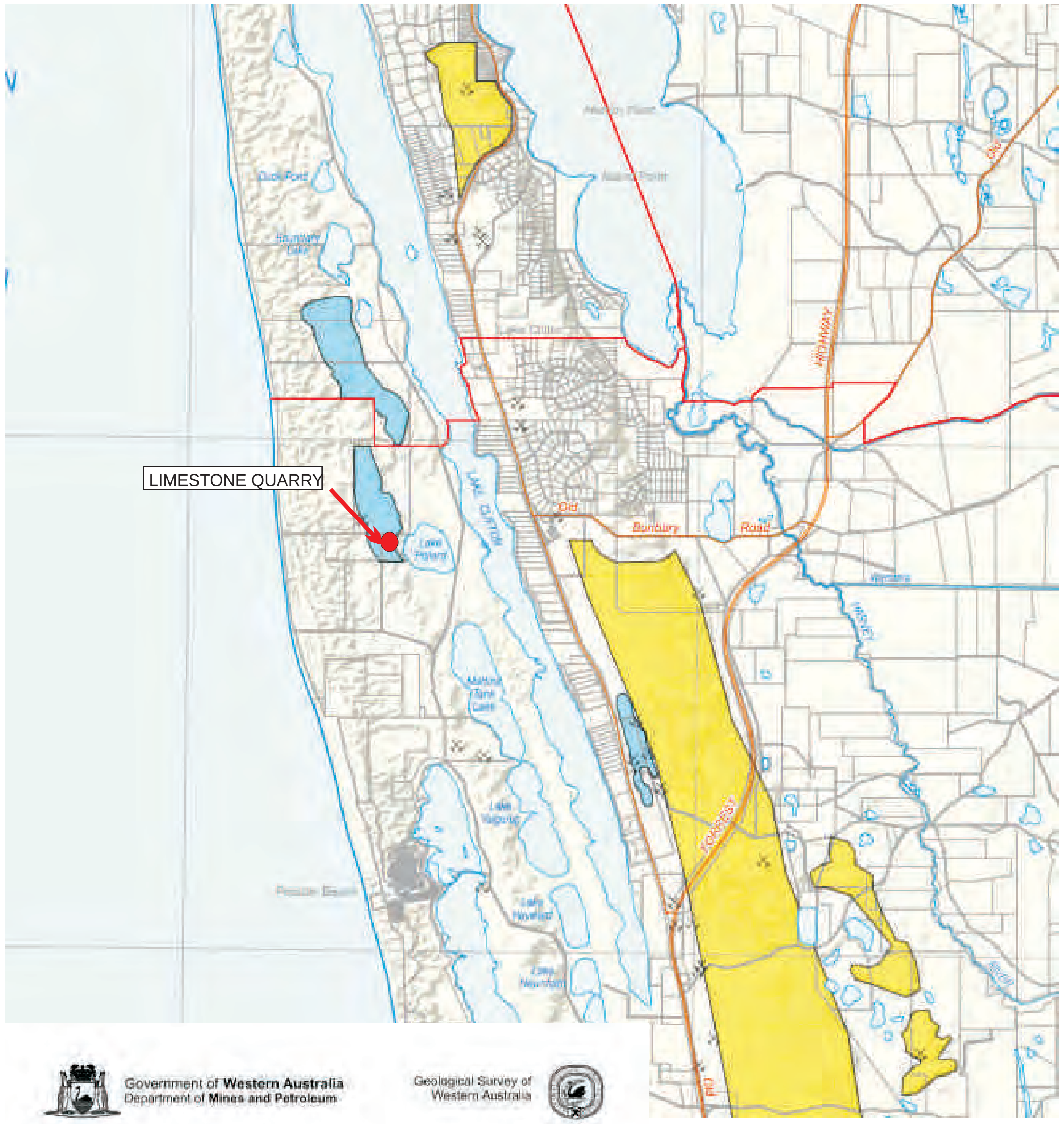
Regards

Michael Keane

LIST OF APPENDICES

Appendix 1 Location Map
Appendix 2 Shire Bye- Law
Appendix 3 Photos
Appendix 4 Advisory Signage
Appendix 5 Intersection Templates
Appendix 6 Traffic Data

Appendix 1 Location Map



Government of Western Australia
Department of Mines and Petroleum

Geological Survey of Western Australia

GDA

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

RESOURCE POTENTIAL FOR LAND USE PLANNING

REGIONALLY SIGNIFICANT BASIC RAW MATERIALS

PINJARRA

SHEET 2032 FIRST EDITION 2012

Figure 1

DOYLES LIME SERVICE – PRESTON PIT	
LOCATION	
Landform Research	May 2013
Source NEARMAP	Scale See Plan

Appendix 2 Shire Bye- Law

Appendix 3 Photos

Preston Beach Road, approaching PBR North intersection.
Intersection location determined by maximising sight distance on curve.

PBR North – Heavy Vehicle restriction

PBR North, SLK 0.05, unformed sandy track.
Note power pole at edge.

PBR North, SLK 1.4, typical 6.5m wide track, overhanging vegetation

PBR North SLK 1.7 typical 7.0m wide track

PBR North, SLK 2.4

PBR North, SLK 2.4, track narrows abruptly at pinch point between fence and tree

PBR North SLK 3.3, track narrows to 6.0m width

PBR North, SLK 3.9, vegetation overhanging road, obscuring sight distance

PBR North, SLK 4.3 blind crest on curve just south of campground turn-off.

PBR North SLK 4.6, looking south towards the campground turn-off

PBR North, SLK 4.8, poor sight distance on crest curve

PBR North SLK 5.0, looking north

PBR North 5.7, looking south

APPENDIX 4 SIGNAGE

TYPICAL SIGNAGE REQUIRED;

W1-3A CURVE

W1-5A WINDING ROAD

W2-3A TERMINATING ROAD

W2-4A SIDE ROAD JUNCTION

W4-3A ROAD NARROWS

W5-11A CREST

W5-73 GRAVEL ROADS

D4-6A CHEVRON

WARNING SIGNS

WARNING SIGNS ARE USED TO WARN TRAFFIC OF POTENTIALLY HAZARDOUS CONDITIONS ON OR ADJACENT TO THE ROAD. WARNING SIGNS ADVISE OF CONDITIONS WHICH REQUIRE CAUTION ON THE PART OF THE DRIVER AND MAY CALL FOR A REDUCTION IN SPEED IN THE INTEREST OF THE SAFETY OF THE DRIVER AND OF OTHER ROAD USERS.

In general, warning signs are diamond shaped (square with one diagonal vertical) with a black legend or symbol, or both, and a black border on a yellow reflectorised background.

The W8 series signs are used in conjunction with other signs in the Warning Series to supplement and clarify the message conveyed and are generally rectangular.

SIGN CLASSIFICATIONS

The sub-classifications and the prefix and series number relevant to each individual warning signs are as follows:

SERIES No.	CLASSIFICATION
W1	Alignment series
W2	Intersection and junction series
W3	Advance warning of traffic control device series
W4	Road width, low and narrow clearance signs
W5	Road obstacle series
W6	Pedestrian, bicycle and school series
W7	Railway level crossing series
W8	Supplementary plate series
W9	Modified intersection series

WARNING SIGNS

All signs are available in Hi Intensity **(H)**, Diamond Grade **(DG),** Fluoro Yellow/Green **(FYG)** materials

SIZE	DIMENSIONS (mm)
A	600 x 600
B	750 x 750
C	900 x 900
D	1200 x 1200

TURN
W1-1A
W1-1B
W1-1C
(L or R)

REVERSE TURN
W1-2A
W1-2B
W1-2C
(L or R)

CURVE
W1-3A
W1-3B
W1-3C
(L or R)

REVERSE CURVE
W1-4A
W1-4B
W1-4C
(L or R)

WINDING ROAD
W1-5A
W1-5B
W1-5C

HAIRPIN BEND
W1-7A
W1-7B
W1-7C
(L or R)

TILTING TRUCK
W1-8B 1500 x 3000
(L or R)

CROSS ROAD
W2-1A
W2-1B
W2-1C

T JUCTION
W2-3A
W2-3B
W2-3C

SIDE ROAD JUNCTION
W2-4A
W2-4B
W2-4C
(L or R)

ROUNDABOUT
W2-7A
W2-7B
W2-7C

STAGGERED SIDE ROAD JUNCTION
W2-8A
W2-8B
W2-8C
(L or R)

WARNING SIGNS

All signs are available in Hi Intensity **(H)**, Diamond Grade **(DG)**, Fluoro Yellow/Green **(FYG)** materials

SIDE ROAD JUNCTION ON A CURVE

W2-9A
W2-9B
W2-9C
(L or R)

SIDE ROAD JUNCTION ON A CURVE

W2-10A
W2-10B
W2-10C
(L or R)

SUCCESSIVE SIDE ROAD JUNCTION

W2-11A
W2-11B
W2-11C
(L or R)

SUCCESSIVE SIDE ROAD JUNCTION

W2-12A
W2-12B
W2-12C
(L or R)

SUCCESSIVE SIDE ROAD

W2-13A
W2-13B
W2-13C

T-JUNCTION BEYOND

W2-14A
W2-14B
W2-14C
(L or R)

STOP SIGN AHEAD

W3-1A
W3-1B
W3-1C
W3-1D

GIVE WAY SIGN AHEAD

W3-2A
W3-2B
W3-2C
W3-2D

SIGNALS AHEAD

W3-3A
W3-3B
W3-3C
W3-3D

ROAD HUMPS AHEAD

W3-4A
W3-4B
W3-4C

NARROW BRIDGE

W4-1A
W4-1B
W4-1C

ROAD NARROWS

W4-3A
W4-3B
W4-3C

DIVIDED ROAD

W4-4A
W4-4B
W4-4C

ISLAND

W4-5A
W4-5B
W4-5C
W4-5D

LOW CLEARANCE ...m (AHEAD)

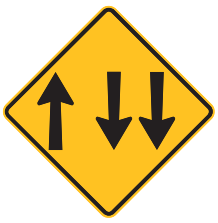
W4-8B
W4-8C

LEFT LANE ENDS

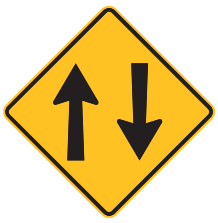
W4-9B
W4-9C

WARNING SIGNS

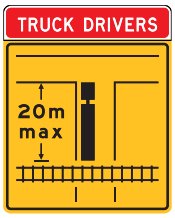
All signs are available in Hi Intensity **(H)**, Diamond Grade **(DG),** Fluoro Yellow/Green **(FYG)** materials



LANE ALLOCATION
W4-10B
W4-10C



TWO WAY TRAFFIC
W4-11A
W4-11B
W4-11C
W4-11D



VIC ONLY
W4-V103

LOW TREE BRANCHES
VIC ONLY
W4-V106A
W4-V106B
W4-V106C

FERRY
W5-1A
W5-1B
W5-1C

OPENING BRIDGE
W5-2A
W5-2B
W5-2C

FORD
W5-6A
W5-6B
W5-6C

FLOODWAY
W5-7A
W5-7B
W5-7C

LOW LEVEL BRIDGE
W5-8A
W5-8B
W5-8C

DIP
W5-9A
W5-9B
W5-9C

ROAD HUMP
W5-10A
W5-10B
W5-10C

CREST
W5-11A
W5-11B
W5-11C

STEEP DESCENT
W5-12A
W5-12B
W5-12C

STEEP CLIMB
W5-13A
W5-13B
W5-13C

GATE
W5-14A
W5-14B
W5-14C

GRID
W5-16A
W5-16B
W5-16C

WARNING SIGNS

All signs are available in Hi Intensity **(H)**, Diamond Grade **(DG)**, Fluoro Yellow/Green **(FYG)** materials

PREPARE TO STOP
W8-27B 750 x 375
W8-27C 900 x 450
W8-27D 1200 x 600

VIC ONLY
W8-V113A 600 x 480
W8-V113B 750 x 600
W8-V113C 900 x 720

VIC ONLY
W8-V115-1 600 x 600

VIC ONLY
W8-V115-2 900 x 600

W9-1A
W9-1B
W9-1C
(L or R)

W9-2A
W9-2B
W9-2C
(L or R)

W9-3A
W9-3B
W9-3C
(L or R)

W9-4A
W9-4B
W9-4C
(L or R)

SCHOOL
QLD ONLY
TC1192A 750 x 750
TC1192B 900 x 900
TC1192C 1200 x 1200

CHILDREN
QLD ONLY
TC1193A 750 x 750
TC1193B 900 x 900
TC1193C 1200 x 1200

SCHOOL CROSSING AHEAD
QLD ONLY
TC1194A 750 x 750
TC1194B 900 x 900
TC1194C 1200 x 1200

WA ONLY
MR-WDAD-2

WA ONLY
MR-WDAD-3

W5-73 900 x 1200

CHEVRON ALIGNMENT MARKER

D4-6A 600 x 750
D4-6B 750 x 900
D4-6C 900 x 1125

Appendix 5 Intersection Templates

INTERSECTION PBR NORTH AND PRESTON BEACH ROAD

DESIGN VEHICLE 19M SEMI-TRAILER
PLAN SHOWING TEMPLATES FOR
RIGHT TURN-IN
LEFT TURN-OUT

INTERSECTION PBR NORTH AND PRESTON BEACH ROAD

DESIGN VEHICLE 19M SEMI-TRAILER
PLAN SHOWING TEMPLATES FOR

LEFT TURN-OUT only

INTERSECTION PBR NORTH AND PRESTON BEACH ROAD

DESIGN VEHICLE 19M SEMI-TRAILER
PLAN SHOWING TEMPLATES FOR
RIGHT TURN-IN
LEFT TURN-OUT

INTERSECTION PBR NORTH AND PRESTON BEACH ROAD

DESIGN VEHICLE 19M SEMI-TRAILER
PLAN SHOWING CONFLICT
BETWEEN 19M SEMI'S TURNING-IN
AND TURNING-OUT

Appendix 6 Traffic Data

Class Speed Matrix

ClassMatrix-41
Site: 209_000031_000500.0.0EW
Description: **Preston Beach Road - 500m from Old Coast Road**
Filter time: **12:00 Wednesday, 18 December 2013 => 14:39 Wednesday, 8 January 2014**
Scheme: Vehicle classification (AustRoads94)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12) Dir(NESW) Sp(10,160) Headway(>0)

Speed (km/h)	Class 1	2	3	4	5	6	7	8	9	10	11	12	Speed Totals	
10 - 20	2	.	.	.	.	.	.	.	.	.	.	.	2	0.0%
20 - 30	13	.	.	.	.	.	.	.	.	.	.	.	13	0.1%
30 - 40	22	.	.	.	.	.	.	.	.	.	.	.	22	0.1%
40 - 50	57	3	.	.	.	1	.	.	.	.	.	.	61	0.4%
50 - 60	258	18	17	2	.	1	2	1	.	.	.	.	299	1.7%
60 - 70	1543	85	86	21	4	2	6	.	2	.	.	.	1749	10.2%
70 - 80	5504	248	279	92	11	7	13	4	2	.	.	.	6160	35.9%
80 - 90	5961	158	309	125	6	11	12	5	2	.	.	.	6589	38.4%
90 - 100	1722	35	110	27	2	3	3	1	.	.	.	.	1903	11.1%
100 - 110	266	1	23	1	.	.	1	.	.	.	.	.	292	1.7%
110 - 120	43	.	5	1	.	.	.	.	.	.	.	.	49	0.3%
120 - 130	5	.	.	.	.	.	.	.	.	.	.	.	5	0.0%
130 - 140	2	.	.	.	.	.	.	.	.	.	.	.	2	0.0%
140 - 150	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
150 - 160	1	.	.	.	.	.	.	.	.	.	.	.	1	0.0%
	15399	548	829	269	23	25	37	11	6	0	0	0	17147	
	89.8%	3.2%	4.8%	1.6%	0.1%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%		

Class Totals

Class Speed Matrix

ClassMatrix-44
Site: 209_000032_000100.0.0WE
Description: **Preston Beach Road North - 100m from Preston Beach Rd**
Filter time: **12:00 Wednesday, 18 December 2013 => 14:48 Wednesday, 8 January 2014**
Scheme: Vehicle classification (AustRoads94)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12) Dir(NESW) Sp(10,160) Headway(>0)

Speed (km/h)	Class 1	2	3	4	5	6	7	8	9	10	11	12	Speed Totals	
10 - 20	72	.	15	.	.	.	.	.	.	.	.	.	87	5.2%
20 - 30	181	2	19	.	1	.	.	.	.	.	.	.	203	12.0%
30 - 40	347	18	16	.	1	.	.	.	.	.	.	.	382	22.7%
40 - 50	377	19	25	.	.	.	.	.	.	.	.	.	421	25.0%
50 - 60	319	12	41	.	.	1	.	.	.	.	.	.	373	22.1%
60 - 70	152	5	18	.	.	1	.	.	.	.	.	.	176	10.4%
70 - 80	36	.	3	.	.	.	.	.	.	.	.	.	39	2.3%
80 - 90	2	.	2	.	.	.	.	.	.	.	.	.	4	0.2%
90 - 100	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
100 - 110	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
110 - 120	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
120 - 130	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
130 - 140	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
140 - 150	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
150 - 160	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
	1486	56	139	0	2	2	0	0	0	0	0	0	1685	
	88.2%	3.3%	8.2%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		

Class Totals

Class Speed Matrix

ClassMatrix-42
Site: 209_000031_000500.0.0WE
Description: **Preston Beach Rd - 500m from Old Coast Road**
Filter time: **11:00 Wednesday, 9 April 2014 => 15:18 Wednesday, 30 April 2014**
Scheme: Vehicle classification (AustRoads94)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12) Dir(NESW) Sp(10,160) Headway(>0)

Speed (km/h)	Class 1	2	3	4	5	6	7	8	9	10	11	12	Speed Totals	
10 - 20	9	.	.	.	1	.	.	.	.	.	.	.	10	0.1%
20 - 30	13	.	1	1	.	.	.	.	.	.	.	.	15	0.1%
30 - 40	18	.	2	.	.	.	1	.	.	.	.	.	21	0.1%
40 - 50	35	1	1	.	.	.	.	.	.	.	.	.	37	0.3%
50 - 60	208	19	13	1	.	.	.	.	.	.	.	.	241	1.7%
60 - 70	1445	127	88	17	3	4	4	.	3	.	.	.	1691	11.6%
70 - 80	4805	258	260	22	5	13	10	1	4	.	.	.	5378	36.9%
80 - 90	4956	156	250	7	2	8	8	.	1	.	.	.	5388	36.9%
90 - 100	1374	55	93	3	.	2	.	.	.	.	.	.	1527	10.5%
100 - 110	221	6	14	.	.	.	.	.	.	.	.	.	241	1.7%
110 - 120	35	.	1	.	.	.	.	.	.	.	.	.	36	0.2%
120 - 130	4	.	.	.	.	.	.	.	.	.	.	.	4	0.0%
130 - 140	5	.	.	.	.	.	.	.	.	.	.	.	5	0.0%
140 - 150	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
150 - 160	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
	13128	622	723	51	11	27	23	1	8	0	0	0	14594	
	90.0%	4.3%	5.0%	0.3%	0.1%	0.2%	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%		
	Class Totals													

Class Speed Matrix

ClassMatrix-45
Site: 209_000032_000200.0.0NS
Description: **Preston Beach Rd North - 200m from Preston Beach Rd**
Filter time: **11:00 Wednesday, 9 April 2014 => 15:10 Wednesday, 30 April 2014**
Scheme: Vehicle classification (AustRoads94)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12) Dir(NESW) Sp(10,160) Headway(>0)

Speed (km/h)	Class 1	2	3	4	5	6	7	8	9	10	11	12	Speed Totals	
10 - 20	48	.	4	.	.	.	.	.	.	.	.	.	52	3.3%
20 - 30	115	4	7	.	.	.	.	.	.	.	.	.	126	8.0%
30 - 40	266	23	9	.	.	.	.	.	.	.	.	.	298	18.9%
40 - 50	446	34	13	.	.	1	1	.	.	.	.	.	495	31.3%
50 - 60	384	16	15	.	.	1	.	.	.	.	.	.	416	26.3%
60 - 70	123	5	15	.	.	1	.	.	.	.	.	.	144	9.1%
70 - 80	35	2	2	.	.	.	.	.	.	.	.	.	39	2.5%
80 - 90	6	1	1	.	.	.	.	.	.	.	.	.	8	0.5%
90 - 100	1	.	.	.	.	.	.	.	.	.	.	.	1	0.1%
100 - 110	1	.	.	.	.	.	.	.	.	.	.	.	1	0.1%
110 - 120	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
120 - 130	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
130 - 140	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
140 - 150	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
150 - 160	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0%
	1425	85	66	0	0	3	1	0	0	0	0	0	1580	
	90.2%	5.4%	4.2%	0.0%	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%		

Class Totals

Appendix 3

Landform Research
Land Systems - Quarries - Environment
ABN 29 841 445 694

20 May 2014

Potential for Karst on Lot 1001
Potential for cavities from Stygofauna and Troglofauna

1.0 Stygofauna and Troglofauna

EPA Guidance 54, concentrates on Stygofauna, which occur in caves and "are aquatic subterranean animals, found in a variety of groundwater systems".

Environmental Protection Authority, 2013, *Consideration of subterranean fauna in environmental impact assessment in Western Australia* relates to the level of survey.

The limestone ridge is not an isolated habitat, but joins similar limestone regolith north and south. The main change will be modification of the two ends of the ridge at an existing swale. Limestone will remain to depth at the end of excavation.

"Troglofauna occur in air chambers in underground caves or smaller voids".

The issues of these organisms is best addressed on a risks basis, because the water table is not proposed to be impacted on.

Stygofauna relate particularly to Root Mat Communities, which are listed as Endangered Communities. Root mat communities occur in locations where groundwater flows quickly and where Tuart Trees are present because their roots can access the water table. No Tuarts occur on the resource area of Lot 1001. The base of the excavation at 11 to 14 metres AHD is over 10 metres above the highest known water table. The low lying swales between the ridges on Lot 1001 and 1002 drop down to 3 – 4 metres AHD well below the proposed floor of the pit.

Root Mat Communities are briefly considered in conjunction with the Flora Assessment in Appendix 1 under Endangered Communities on page 11 of that report. None of the risk factors listed in Guidance 54 are likely to occur. The limestone is too young for cave development and even if they did occur under this site they will not be impacted on.

For Troglofauna, which may occur in air chambers in underground caves or smaller voids, it will be difficult to undertake any meaningful sampling of these. Any crevices or fissures in the adjoining quarries will probably have been contaminated by surface or near surface invertebrate fauna. The existing soils are sands with occasional limestone pinnacles and not rocky outcrops.

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2.0 Assessment Methods

A reconnaissance survey of the limestone ridge and surrounding area was completed by Lindsay Stephens of Landform Research during the site inspection of 23 May 2013. Lake Clifton area has been studied for potential limestone resources and potential subdivisions for a number of projects, predominantly on the eastern side of Lake Clifton. Lindsay Stephens has significant experience working with coastal limestone in Western Australia.

Published and unpublished data was also considered, in addition to the assessments of Lex Bastian for the WA Limestone Lake Clifton extractive industry on Lot 5 Old Coast Road which is attached.

The geology and geomorphology was considered, in addition to the vegetation and hydrogeology provided in published work and the documentation prepared by Cape Bouvard Investments, 2009, *Rural Subdivision, Lots 1000, 2240, 2275, 2675 and 3045 Preston Beach Road, Lake Clifton*, Unpublished Report, prepared for EPA Assessment 1440.

3.0 Location

The limestone ridge is joined to the north and south of Lot 1001 and is therefore not an isolated feature. Any troglofauna are therefore likely to inhabit the whole ridge and are unlikely to be locally rare. South of Lot 1001, and west and east of the ridge extension to the north, the limestone ridge lies within the Yalgorup National park and is therefore afforded protection.

4.0 Definitions of karst

Karst is solution structures developed on a rock usually calcium carbonate based, by the dissolution and precipitation of minerals. The most common form of karst is associated with limestones.

Karst can be surface features such as rills and sharp edges, small cavities or caves.

If the karst features are significant, caves, collapse structures, structurally “weak ground” and other related features could develop.

For karst to form, the limestone must be of high grade. If a rock does not have sufficient amounts of calcium carbonate, when the calcium carbonate dissolves, the non soluble materials will fill any void and significant karst structures may not develop.

Karst can develop on rocks that are already consolidated such as on the old hard limestones in the Eastern States.

On the other hand karst can develop on calcareous sediments and sands as the sands are becoming lithified. This is called Syngenetic Karst or “soft rock” karst.

In Australia syngenetic karst is most commonly associated with the coastal limestones that occur along the western and southern Australian coasts from Shark Bay to Mt Gambier.

On the Swan Coastal Plan karst only develops in the coastal or Tamala Limestones.

A summary of the formation of karst is contained in the report by *Grimes K G, 2006 Syngenetic karst in Australia: a review, Helictite 39 (2) 2006*.

In order to gain an understanding of the potential for karst a brief consideration of the origin and form of the Tamala limestone is required.

5.0 Notes on the Origin, Location and Form of Tamala Limestone

- **Location and Origin**

From the very late Tertiary to today a series of coastal sand dunes formed along the south western coast of Western Australia. These formed from beach sands and dunes that accumulated along the coast and moved inland, draping over the existing regolith (weathered rocks and soils), similar to the Lancelin dunes.

The location of the coast varied across the landscape a number of times during the last (Pleistocene) Ice Age as sea levels changed significantly. This enabled sequences of coastal and near coastal dunes to form. Locally these resulted in limestone dunes along the eastern side of Lake Clifton, which are the oldest with repeated dunes between Lake Preston and Lake Clifton and younger coastal dunes.

The intervening dune swales restricted drainage leading to the formation of the coastal lakes.

The earliest dunes are the Bassendean Dunes in which almost all the calcium carbonate has been removed. These occur on the eastern side of the Swan Coastal Plain as white sands.

Another set of dunes formed closer to the coast. These are the yellow sands of the Spearwood Dune System with which the Tamala Limestone is an integral part. These occur east of Laker Clifton with a younger set of dunes and is probably the limestone on Lot 1001 and 1002.

Finally a third set of dunes (Quindalup) formed closer to the coast, as the current coastal dunes that occur along the coast forming the unconsolidated coastal dunes to the west.

The Tamala dunes are generally more lithified and harder, with the older dunes having had the calcium carbonate removed and precipitated, and the new dunes not enough time for the dunes to consolidate.

Within each dune sequence, including the Tamala Dunes, there are a number of sequences of dunes overlying each other and running over the older Bassendean Dunes on the inland side of the coast.

The other significant factor in dune formation is the availability of coastal sands.

Coastal sands are predominantly composed of variable amounts of quartz grains and calcium carbonate as shell fragments and foraminifer skeletons. Also present are small amounts of feldspar and heavy minerals.

By far the greatest proportion of the dune is quartz and calcium carbonate fragments.

The variation in coastal sand at the time of formation depends on the undersea near shore contours and the potential environment for the organisms with calcium carbonate skeletons.

When excess sand accumulates it forms large individual dunes that normally migrate north east but collectively form a line of dunes parallel to but inland from the coast.

All of these parameters change over geological time as the coast and sea levels change.

Vegetation growing in the soil can lead to the development of solution pipes and fissures within the limestone.

All the various parameters are very important in determining the origin and history of the Tamala Limestone at particular sites such as Lots 1001 and 1002 and provide valuable insight into the potential for presence, or, formation, of karst features.

- **Weathering and Lithification**

Once the dune is stabilised, the dune starts to lithify, erode and calcify.

Over time the calcium carbonate dissolves and reprecipitates to cement the sand grains together.

This process can lead to the formation of “capstone” which is very hard recrystallised limestone with the highest grade or percentage of calcium carbonate. Capstone develops on most of the best quality limestone ridges and indicates a high grade of limestone and an older age to the limestone.

The heavy minerals weather, with the iron forming goethite, which stains the sand grains yellow and gives the limestone a cream colour.

The surface sand becomes more yellow, and on limestone red, due to the presence of iron oxide, in the form of coatings of the quartz sand grains; yellow being goethite and red being hematite. The source of the iron oxide is the weathering of heavy minerals. This process has been studied by *Bastian L, 1996, Residual soil mineralogy and dune subdivision, Swan Coastal Plain Western Australia, Australian Journal of Earth Sciences 1996, (43) 31 – 44.*

The feldspar weathers to kaolin clay and adds a small amount of clay to sand and limestone, making it “earthy”. The earthy sand is found at depths of 1 plus metres onwards.

Finally the calcium carbonate dissolves as calcium hydrogen carbonate only to be deposited in situations where the water evaporates. On evaporation, the water deposits the calcium carbonate, cementing the sand and when in excess forms karst.

Any limestone so formed is also subject to karst development.

This process is repeated often.

Where limestone is degrading, the soils become deeper, and pinnacles of weathering limestone can often be found.

On Lots 1001 and 1002 the ridge has higher calcium carbonate and has become lithified and remains more resistant. The sand soils in other locations result from lower calcium carbonate and form low swales. The limestone ridge represents the leading edge of a calcareous dune structure. The outline of the leading edge of the dunes can be seen on the aerial photography.

6.0 Formation of Karst

- **Factors in Formation**

Where limestone encounters acidic water there is potential for dissolution, karst and cave formation. Once the water enters limestone the acidity is rapidly neutralised and loses its capacity to dissolve limestone.

The other critical factor is the amount of water available and the elevation of the water table. As the climate has changed in the past so has the elevation of the water table and the amount of water available to dissolve the calcium carbonate.

Limestone that has a high proportion of calcium carbonate on dissolution will form voids that may enlarge to cavities and caves in areas where large water flows and longer time periods are involved. High grade limestone is much stronger and provides good support across cavities and voids.

On the other hand sandy limestone will form sand on dissolution and that sand will fill cavities and support ground above.

Finally time is a factor. The longer the time the greater the amount of total potential karst activity that can occur.

- **Acidity of the Water**

With cave development and dissolution, the acidity of the water is significant. The source of the acidity is almost totally from organic acids from the breakdown of vegetation and acid rainwater. There is potential for acids to originate from the breakdown of sulphides, but these do not occur within the local geology, with the exception of sulphides formed under reducing conditions in the sediments of lakes and wetlands. This could be associated with Lake Pollard or the wet peaty soils east of the lake.

There is no surface drainage on Lots 1001 and 1002 due to the porosity and permeability of the limestone and sand, with precipitation draining to the water table. It has been estimated that perhaps <10 - 20 % of the rainfall will reach the water table.

The site lies 200 metres west from Lake Pollard. However shallow groundwater on the site is fresh, sitting as a layer overlying the saline ground water. The groundwater is exposed in a sump in the south western corner of Lot 1002.

From evidence of the soils, the sump and vegetation, the water table lies at about 1 metre AHD. See Figure 3 in Deeney (undated).

The site lies at the southern end of the Cape Bouvard Investments Land which was once owned by the landholder of Lots 1001 and 1002. As part of the studies for proposed developments, Cape Bouvard Investments (2009) completed extensive hydrogeological studies of the southern portion of their land which abuts Lot 1001 and of the local hydrogeology, including Lake Pollard.

A line of drill holes was placed along the boundary of Lot 1000 and the Cape Bouvard Investments land and is very relevant to the subject site (Cape Bouvard Investments MWS1, MWS2, MWS3, MWs4, MWS 5 and MWS6). See Figure 3 of the Main Report.

Lake Pollard is brackish as confirmed by (Figure 8 of Cape Bouvard Investments 2009). A fresh water lens overlays the subject land with water flow both to the east to Lake Pollard and west towards the coast. There is also a suggestion that there could be a connection in water flow between Lake Pollard and Lake Clifton because of the large surface area of Lake Clifton causing a small draw from Lake Pollard.

Cape Bouvard Investments 2009 found that the water elevation in Lake Pollard ranged from -0.4 metres AHD in February 2008 to +0.5 m AHD in July – September 2008 (Cape Bouvard Investments 2009 Figure 9).

They also found that the ground water along the northern boundary of Lot 1001 was slightly elevated at between 0.2 – 0.3 m AHD with a groundwater divide near the western boundary of Lot 1001. The divide was around 100 metres west of the boundary in February 2008 and around 200 metres east of the western boundary in September 2008. The variation being due to seasonal factors, most likely winter precipitation, evapotranspiration from vegetation and evaporation from Lake Pollard/Lake Clifton (Cape Bouvard Investments 2009 Figure 10).

The groundwater salinity was found by Cape Bouvard Investments, on Monitoring Bores MWS5 and MWS6 located near the western edge of the northern boundary of Lot 1001, to be fresh down to – 7.0 metres AHD where the interface of the saline groundwater occurred with some reductions in salinity due to mixing from winter precipitation. At MWS1 located east of the eastern end of the northern boundary of Lot 1001 the salt water interface varied from -7.0 - -8.0 mAHD (Cape Bouvard Investments 2009 Figures 14 and 15). This indicates fresh water flows to lake Pollard.

- **Acidic Groundwater**

Acid groundwater moving through sand can intersect limestone. At the point of intersection the acidity begins to dissolve the limestone. Once neutralised the groundwater has no power to dissolve further limestone. Therefore the greatest dissolution occurs at the interface between the sand and the limestone or wetland and limestone, with progressively less development in a short distance westwards. See Grimes 2006 and Gozzard (undated).

This is the situation that has led to the formation of the Yanchep caves.

Borelogs from Cape Bouvard Investments 2009 show that the site, including the northern boundary of Lot 1001 consists of limestone to depth with the limestone being intersected to depths of 18 – 25 metres and not bottomed. That would indicate some 10 metres at least of limestone beneath the site.

The water in Lake Pollard is alkaline at between pH 8 and 10 (Cape Bouvard Investments 2009).

That demonstrates that the groundwater flow to Lake Pollard, is alkaline and flowing through limestone. It therefore has little erosive power and is unlikely to have formed significant cavities at depth.

- **Flow Rate of Groundwater**

There is more potential for dissolution to occur and extend further when groundwater flows are faster. Steep slopes on the groundwater contours indicate more rapid flows.

Again this situation occurs at Yanchep and is a factor in the cave development there but not locally on Lots 1001 and 1002.

The groundwater is very flat and therefore relatively slow flowing reducing its potential erosive and dissolution power.

- **Elevation of Groundwater**

The elevation of groundwater is discussed above at around 0 m AHD. Any cavities formed as a result of groundwater dissolution would be located at that elevation some 10 metres below the base of the proposed quarry.

Water added to the groundwater from the soil profile is generally the source of acidity. Therefore voids and dissolution normally occur above the water table or at the interface and not at depth. See Grimes 2006 and Gozzard (undated).

On this site the limestone is comparatively young and the precipitation falling on the limestone itself will be quickly neutralised reducing its potential erosive power. The same conclusion was reached by Bastian 2007, for WA Limestone Clifton Quarry.

- **Basement**

As noted above the site is underlain by limestone to depth. There can be no impermeable basement which confines the groundwater and leads to concentrated dissolution such as at Leeuwin – Naturaliste area and no sandy basement as occurs at Yanchep.

- **Location of Swamps and Lakes**

Ground or surface water, especially on the western edge of a wetland or swamp, and acidic subsurface water lead to dissolution of limestone and the formation of caves. This is most

pronounced where westerly flowing groundwater had a hydraulic gradient and was more mobile such as on the western side of the lake or wetland.

This produces steepening of the slopes with voids underneath. On Lots 1001 and 1002 there is no evidence of notching or other features and none would be expected as the water in Lake Pollard is alkaline and groundwater flow is fresh to the lake and not away from it.

7.0 Types of Karst

Karst is generally of two main forms, soil based and void based.

- **Soil Based Karst**

Soil based karst forms on or near the surface of the land where limestone outcrops are subject to dissolution and precipitation. This forms sharp solution type edges, rills, cavities, depressions and a number of other features. It also forms a hard capstone or rock that caps the higher grade limestone ridges. Figure 9. See Grimes 2006 and Gozzard (undated).

Dissolution and precipitation can be directed to depth along roots and structural features such as cracks, joints or fissures in the rock. Rhyzomorphs form in this manner. The organic matter associated with root breakdown assists dissolution locally adjacent to the root.

If this process continues for a long period of time then pinnacles of limestone may be left sitting proud of the limestone basement and completely surrounded by sand. Such pinnacles are not normally associated with cavities in the limestone and any that do develop are filled over time with sand flowing in from above. This does not occur on site to any extent.

This form of karst is normally filled with sand from the soils above and from minor surface dissolution of the limestone. Any such cavities on site will be sand filled. Bastian 2007 also mentioned the infilling by sand.

- **Void Based Karst**

Karst formed as a result of subsurface dissolution forms voids that are always joined in some way following the path of the groundwater.

The voids may enlarge, collapse, and form spongework and form precipitation structures such as stalagmites and stalactites, flowstone, and a number of other features if there is high erosive power in the water. This is not the case on site as also noted by Bastian 2007 for the nearby limestones east of Lake Clifton.

The voids may also collapse with the roof either protected by hard capstone or in more sandy locations the roof may fall in to leave depressions, sink holes, blind valleys, surface voids and other surface features. See Grimes 2006 and Gozzard (undated). As there is little erosive power of the groundwater on Lot 1001 and Lot 1002 the limestones are young these features are unlikely to have formed and none are evident from surface examination or aerial photography.

When voids are present large Tuart trees may locally grow. There are no large Tuarts associated with the limestone. Tuart trees readily germinate and grow in local conditions and therefore trees other than older mature trees are not indicators of cavities.

As discussed above this occurs in older limestones where there is significant flow of Acidic groundwater along steeper gradients. None of these conditions occur on site. Bastian 2007 did not record any signs or voids in the faces of the older limestone at WA Limestone Lake Clifton Quarry. There are also no signs of voids in excavations in the Hull or Tyler Limestone Quarries east of Lake Clifton or limestones operated by Doyles and B and J Catalano west of Lake Preston at Myalup to the south.

8.0 Proposed Excavation

The excavation proposes to make only a relatively small excavation in comparison to the overall limestone that occurs along this belt.

The base of the excavation will be bottomed at around 5 metres AHD some 4 metres above the current water table and providing significant separation and potential for any voids to be protected

9.0 Conclusions

There is no evidence of cavities or karst which could lead to the development of stygofauna or troglofauna and there is no evidence of significant potential for voids and cavities which favour these organisms to development.

Stygofauna would occur at the water table if any cavities occurred at that location. The excavation is proposed to have a 4 metre vertical buffer to the water table.

The limestone is not isolated but represents a very small portion of the total limestone locally. The potential for short range endemics and troglofauna will not be significantly impacted if any occur and will be able to re-establish at the end of excavation.

In addition ten metres thickness of limestone is proposed to be retained beneath excavation, which will be deep ripped and revegetated with local native species and pasture.

The remaining resource in the floor of the pit which extends to depth, will enable limestone to continue to be present for significant future geological time.

Therefore there is no evidence of cavities or voids that may provide habitat for stygofauna or troglofauna.

Limestone showing the sandy soils that fill any voids on the lower and mid slopes

Limestone on the upper slopes shown the lack of voids

Limestone on the upper slopes, broken out by bulldozer, showing thesoft limestone with a lack of karst and voids.

Lindsay Stephens

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>
> Moore River – Cape Leschenault Urban Geology (1997).

COPY

45 Nautical Grove
BELDON 6027
19th February 2007
(ph 9401 7158)

WA Limestone
41 Spearwood Avenue
BIBRA LAKE WA 6163
Attention: Denis Hill

KARST EXAMINATION OF PROPERTIES

Quarries belonging to WA Limestone at Lake Clifton and Dawesville were examined by the writer on 15th February.
The quarries which at present are not being worked, are understood to be earmarked for a resumption of activity. In both cases the quarries are developed in dune limestone of the Tamala Limestone formation.

Aim of Examination:

The aim of the examination was to ascertain whether there are any surface indications of subsurface karstic activity in areas adjacent to the existing quarry. Features sought included:

(i) actual cave entrances,
(ii) deep solution pipes or groups of pipes from which soil has been removed,
(iii) dolines or any smaller irregular hollows which break the general profile of the rolling topography which exists on the property,
(iv) fissure alignments or at least aligned breaks in elevation,
(v) or finally any marked tuart tree alignments, as distinct from scattered trees.

Further note: all limestone pinnacles stand "proud" from the general soil level to some extent, but in the case of (ii) we are here looking at localised areas where they project much farther than the general soil level, indicating that soil has been undermined, running into a hidden cavity. Dolines – more or less circular closed depressions in the topography – are a certain indication of cave activity. Fissure alignments – which are not not closed depressions, but linear breaks in the topography – are less obvious than dolines but show that cave formation has been active, leading to rupture of the limestone caprock, even though the feature may be more or less soil covered. Grouped tuart trees are an excellent indication of caves, as they are known to develop along stretches of broken rock giving easy access to a water table.

Examination of properties:

Each property was traversed on foot.

Lake Clifton:

In the case of Lake Clifton it was found that the terrain is characterised for the most part by a gently rolling topography of limestone hillocks with extensive pinnacles which project a little above the adjacent soil, never as much as one metre. A broad shallow valley runs north-south along the eastern flank of the hillocks, with more limestone hills rising to the east of this, which however are beyond the area in question. The sand pit developed in one spot in this valley suggests it has deep sand throughout, probably being accumulated residual sand from dissolution of the limestone,

which is understood to be low grade – and hence very sandy.

The terrain south of the existing quarry was examined first, then northwards to the northern limit of proposed excavation. None of the above karstic indications were observed on the limestone hillocks. Pinnacles were found to project uniformly almost throughout, with no evidence of fissures or linear breaks in elevation. In one or two spots they stood slightly more proud of the soil, although this is most likely due to soil eroding off a minor rise into an adjacent dip. The vegetation consists mainly of peppermints with more or less evenly distributed tuarts. No tuart groupings were found which could suggest cave development beneath.

The only surface irregularity seen which could in any way resemble a karstic feature is a shallow roughly circular depression about 150metres west-south-west of the southwest corner of the existing quarry. This could be interpreted as a collapsed cave fissure – which however, judging by the shallowness of the depression could only have been very small.

The quarry walls were also examined and found to be totally free of any fissures or other types of rupture, such as tiny cavities.

Dawesville:

The terrain at this site is higher than at Lake Clifton, being more or less at the high point of the ridge west of the inlet. The ground in question lies to the south of the existing quarry. A cave (Morfitts Cave) is situated close to the inlet southeast of the quarry.

Apart from the immediate vicinity of the quarry, the southern end of which which seems to be at a high point on the north-south profile, the ground has a consistent slope to the south. Tuarts are less prominent in this area, which has plentiful jarrah. There is for the most part limited outcrop; the most outcrop being where the southerly slope steepens a little.

This east-west strip of outcrop was examined more closely for karstic features of the types described above, but none were found. It was found that the pinnacles are generally somewhat more massive than those at Lake Clifton, but still project very little above the surrounding soil. Beyond this as the ground continues to slope southwards limestone outcrops disappear altogether. The quarry itself again lacks signs of subsurface karstic activity, such as fissures or small cavities.

Discussion:

Although there is no evidence of subsurface karstic activity, it is pertinent to discuss further the possibility of hidden caves. Firstly it needs to be noted that the main cave belt in the Yanchep-Wanneroo area lies on the western slope of the Gnangara Mound, and cave solution has been facilitated by the abundant supply of water flowing therefrom.

Both sites however lie to the west of the north-south arm of Peel Inlet, which limits the groundwater to what actually rains directly onto it. It therefore does not have a large water resource comparable to the Gnangara Mound feeding beneath the limestone. In the Dawesville area the groundwater emerges as springs along the inlet frontage, and has been able to carve a series of small caves in close proximity to the inlet. It is not known how far west of the inlet this karstic activity occurs, but appears from the quarry examination to not reach as far west as that.

A second factor in this regard is the depth to water table. Because caves in dune limestone are formed by water table contact with the limestone base, they tend to be most abundant in low terrain, with relatively few being encountered on the higher hills. Thus in the Lake Clifton property if there

were any caves at all they should be expected to breach the surface. The total absence of karstic features suggests that despite that groundwater would doubtless run towards the adjacent lake, it does not appear to have carved out cave passages, at least not of significant size.

A further factor is the age of the limestone, as the dune limestone ridge upon which the Lake Clifton quarry has been developed is considered to be geologically younger than that at Dawesville. Dune limestone is formed from the lithification of beach dunes, which have been building up westwards across the Swan coastal plain. Thus as a general rule, the more westerly the ridge, the younger it is geologically. It is concluded that there has simply been much less time at Lake Clifton than on the Dawesville ridge for solution activity to have occurred.

Conclusion:

It is concluded that neither property has significant cave development, and that the limestone resource will in each case prove to be intact.

Yours faithfully

Lex Bastian
(L V Bastian, B.Sc, OAM)

Appendix 4

Government of Western Australia
Department of Parks and Wildlife

Your ref: TP1576/EI 32
Our ref: 34814
Enquiries: Lyndon Mutter
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Mr Greg Delahunty
Town Planner
Shire of Waroona
Post Office Box 20
WAROONA WA 6125

Dear Sir

PROPOSED EXTRACTIVE INDUSTRY – LOT 1001 AND 1002 PRESTON BEACH ROAD NORTH, PRESTON BEACH

With reference to your correspondence dated 26 July 2013 and the proposed Excavation and Rehabilitation Management Plan for Lots 1001 and 1002, the Department of Parks and Wildlife (DPaW) provides the following advice.

Advice has been sought from DPaW's Wetlands Section and Threatened Ecological Communities Section.

Background information

The proposal is to excavate limestone from the eastern portion of Lot 1001 and excavate sand from an area in the south of Lot 1002.

The proposed excavation on lot 1001 is located approximately 60-70 metres from the wetland boundary of Lake Pollard as delineated in the *Geomorphic Wetlands Swan Coastal Plain* dataset (the dataset) (Figure 1). Landform Research (2013) appear to have incorrectly measured the wetland buffer from the waterbody of Lake Pollard and not the wetland boundary displayed in the dataset.

It is understood that the limestone ridge will be lowered by up to 14 metres and that excavation activities will be undertaken for up to 20 years.

Wetland values

Lake Pollard is located within the internationally significant Peel-Yalgorup System Ramsar site and the nationally recognised Yalgorup Lakes System listed under the *Directory of Important Wetlands in Australia*. Lake Pollard is identified in the dataset as a Conservation category lake (UFI 3100), and is listed under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* as an environmentally sensitive area under the *Environment Protection (Clearing of Native Vegetation) Regulations 2004*.

The vegetation within and surrounding Lake Pollard is identified as regionally significant (Environmental Protection Authority 2010a) and a regional ecological linkage is located immediately east of Lake Pollard (Molloy et al. 2009). The vegetation at Lake Pollard is described as:

Lake Pollard Wetland Mosaic: Between Lake Pollard and Martins Tank Lake, a series of integrating wetland communities are found. These communities are dominated by Tuart, Peppermint, *Banksia litoralis*, *Melaleuca cuticularis* and *M. rhaphiophylla* and combinations of these. Understorey species include the shrubs *Templetonia retusa*, *Acacia cyclops* and *Spyridium globulosum* and the sedges *Gahnia trifida*, *Juncus kraussii* subsp. *australiensis* and *Baumea juncea* (Freeman et al. 2009).

The flora and vegetation survey of the Dawesville to Binningup Region included two quadrats at Lake Pollard that were located in the south of the lake. The vegetation condition within both quadrats was described as Pristine-Excellent (Freeman et al. 2009).

Preliminary information collected during a study into the food chain dynamics and ecology of wading and shorebird prey at lakes within Yalgorup National Park has been submitted to DPaW in accordance with *Wildlife Conservation Act 1950 Regulation 17*. This information indicates that the vegetation of the western shoreline of Lake Pollard is dominated by *Melaleuca rhaphiophylla* and *Baumea juncea* and the eastern shoreline comprises *Melaleuca cuticularis* with scattered *Juncus kraussii* and *Gahnia trifida*. *Melaleuca rhaphiophylla* is less adapted to saline conditions than *Melaleuca cuticularis* (Powell 1990), indicating that the western shoreline of Lake Pollard maintains fresher conditions than the eastern shoreline. The information provided to DPaW suggests that the limestone ridge along the western shore of Lake Pollard (including the proposal site) stores rainwater which slowly seeps into the lake and reduces salinity along the western shoreline. The freshwater seepage has been linked to high productivity including, invertebrates, vegetation and shorebirds.

Lake Pollard is the only lake within the Ramsar site to support extensive areas of the aquatic plant *Lamprothamnium papulosum* (Hale and Butcher 2007). This aquatic plant provides a valuable food source and supports large numbers of grazing waterbirds during spring and summer – up to 5,000 Australian Shelduck (*Tadorna tadornoides*) and 3,000 Black Swans (*Cygnus atratus*) have been recorded (Hale and Butcher 2007). Lake Pollard also provides nesting habitat for Black Swans (Hale and Butcher 2007). Little information is known on the extent and condition of *Lamprothamnium papulosum* and this has been raised as a knowledge gap of concern (Hale and Butcher 2007).

Six waterbird species listed as migratory under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* have been recorded at Lake Pollard (NatureMap 2013). In addition, various other flora and fauna species of conservation significance have been recorded within a one kilometre radius of the centre of Lake Pollard (e.g. Wambenger, Quenda) (NatureMap 2013).

Lake Pollard contains relic microbialite structures and develops algal mats of cyanobacteria (Environmental Protection Authority 2010b).

Potential impacts

The Environmental Protection Authority (EPA) in it's 2010, *Strategic Environmental Advice on the Dawesville to Binningup Area* states that 'It is the EPA's view that subdivision and development, particularly adjacent to the Yalgorup lakes pose a significant risk and unacceptable threat to the ecological character of the Yalgorup lakes' and '...excavation for mining may adversely impact the lake ecosystems through changes to groundwater quality and quantity'.

The EPA's Strategic Advice states 'Comprehensive site specific information is expected to be provided by proponents as part of an environmental impact assessment process'. The proponent has provided limited ecological and hydrological information and has largely dismissed the

potential impacts from the proposal. In particular, the potential impacts to Lake Pollard, approximately 60-70 metres from the proposal site, have not been investigated.

Of greatest concern, is the potential for the proposal to alter the hydrology and water quality of Lake Pollard. The EPA has recognised that the hydrogeology of the Dawesville to Binningup area is extremely complex. The proposal will result in a significant change to the landform and the immediate catchment of Lake Pollard. The proponent has stated that there is no surface drainage from the limestone ridge; however, it is understood that the limestone ridge is infiltrating freshwater to Lake Pollard via seepage flows. Further, in large rain events there would be expected to be some surface flows from the ridge. Any change to freshwater input will adversely impact the water quality of Lake Pollard. Any impact to the hydrology and water quality of Lake Pollard will directly impact the vegetation, invertebrates, avifauna and subsequently the ecological character of an internationally significant wetland.

The potential impacts from limestone dust moving through the air or via surface flows into Lake Pollard have not been addressed. The proponent refers to a 200 metre buffer to Lake Pollard; however, this is the distance to the waterbody of Lake Pollard and not the wetland boundary delineated by DPaW. The proponent has not acknowledged that the wetland vegetation on the western shoreline of Lake Pollard is within the wetland boundary. As such, the excavation site is only 60-70 metres from the wetland boundary of Lake Pollard.

The report states that Lake Clifton is some 2 km up groundwater gradient from the proposed excavation and that Lot 1001lies outside the Lake Clifton catchment, (EPA Guidance No 28, Protection of the Lake Clifton Catchment 1998). Lake Clifton is located approximately 1.5 km from the proposal, not 2km as stated. The consideration of potential risk to Lake Clifton is inadequate and no supporting hydrological data or assessment is provided. Lake Clifton supports a Threatened Ecological Community (Stromatolite like freshwater microbialite community of coastal brackish lakes (Lake Clifton)) which is listed as Endangered in WA and as Critically Endangered under the Commonwealth's Environmental Protection and Biodiversity Conservation Act 1999.

The proposal should be accompanied by more comprehensive hydrological data and assessment to demonstrate the proposal will not impact Lake Pollard and Lake Clifton.

Flora and Vegetation

It appears that Landform Research did not undertake a formal flora and vegetation survey of Lots 1001 and 1002 and that the recommended guidelines for vegetation survey methods and analysis to determine floristic community types for a new site on the southern Swan Coastal Plain has not been followed. A vegetation condition map was provided for the limestone pit area, but no vegetation mapping was provided. As a consequence it is unclear the areas covered by the survey. The flora and vegetation was "reviewed" by Lindsay Stephens, using historical reports and by traversing the site.

No Declared Rare or Priority flora species and no Threatened or Priority ecological community were identified within the survey area.

Landform Research described the remnant vegetation present on the limestone ridge as heath with *Melaleuca system*, *Banksia sessile*, *Templetonia retusa*, and *Hibbertia cuneiforms* over weeds. A total of 10 native flora and 19 weed species were recorded on one day in May 2013. Recommended timing of survey of the Swan Coastal Plain floristic

communities is twice: usually early and late spring to capture the suite of species likely to be present. Comparisons were made of the raw data with Gibson *et al.* 1994 flora lists. Statistical methods were not used. Landform Research concluded the extant floristic community "best related" to type 26b Woodlands and mallees on limestone, not listed as threatened.

Historical data of earlier surveys was used as guidance in identifying the likely floristic community types present. The majority of the site was described as degraded, due to past land practices including "strip cleared, intensively grazed and part seeded with pasture species" with native flora species diversity low, and the presence of a weed, *Trachyandra divaricata,* dominating the site.

The report identified Eucalyptus decipiens occurs "around the edges" and on the southern boundary with *Agonis flexuosa* on the lower slopes. It is not clear the location of these trees due to the absence of vegetation mapping. The EPA's *Swan Bioplan – Peel Regionally Significant Natural Areas*, Environmental Protection Bulletin No. 12, (2010) identified the extant vegetation east of the limestone pit, fringing Lake Pollard as regionally significant. It is possible that the floristic community type present aligns with type 25 Southern *Eucalyptus gomphocephala – Agonis flexuosa* woodland, which is a Priority 3 ecological community. The vegetation is likely to act as a buffer for Lake Pollard and should be retained.

Although the flora and vegetation survey undertaken by Landform Research is inadequate and did not follow the recommended guidelines for vegetation survey methods and analysis to determine floristic community types on the Swan Coastal Plain, the combination of the degraded site, high number and abundance of weeds species and low number and diversity of native flora species present, indicates it is unlikely an extant threatened or priority ecological community is present within the survey area.

Road Traffic Issues and Impacts on Yalgorup National Park Users

DPaW has significant concerns about potential impacts on Yalgorup National Park visitors and recreational users; and on the Martins Tank Campsite.

Road access requirements and the impact of heavy vehicle transport have not been adequately addressed. Consideration of the capacity of Preston Beach Road north to accommodate the required heavy vehicular traffic; road safety issues; and impacts on Yalgorup National Park recreational users who use the road to access Martin's tank campsite is required.

The upgrade of the Martins Tank Campsite will accommodate some camper vans and caravans and these vehicles will traffic Preston Beach Road North.

The proposal will impact on the safety of walkers in the Park who currently use sections of the Preston Beach road north alignment.

The intersection of Preston Beach Road and Preston Beach Road North is likely to be unsafe for heavy vehicle traffic.

Consideration of the potential noise impacts and visual impacts (including dust emissions) on the amenity of Martin's Tank campsite is required.

Recommendations

The EPA has identified the region between Dawesville to Binningup (including Lake Pollard) as maintaining 'important international, national and regional environmental values'. Lake Pollard is internationally significant and maintains a variety of important values that contribute to the ecological character of the entire Peel-Yalgorup System Ramsar site. The proponent has provided limited hydrological and ecological information and has dismissed the potential impacts, which are considered by DPaW to be significant. The proponent has not demonstrated that the excavation will not impact Lake Pollard or the wider Ramsar site including Lake Clifton. Recent information suggests that the limestone ridge is critical in maintaining the values of Lake Pollard.

The proposal is likely to have a significant impact on Yalgorup National Park visitors and recreational users, and the Martins Tank Campsite.

DPaW recommends the proposal be refused, in consideration of the significant potential impacts to Lake Pollard and the ecological character of the Peel-Yalgorup System Ramsar site. Alternatively, the proposal should be referred to the Commonwealth Department of Sustainability, Environment, Water, Population and Communities and the Western Australian Environmental Protection Authority. The proponent will be required to provide comprehensive site specific information for an environmental impact assessment.

Yours faithfully

Mike Meinema
ACTING REGIONAL MANAGER

4 September 2013

Appendix 5

Landform Research
Land Systems - Quarries - Environment
ABN 29 841 445 694

DUST MANAGEMENT PLAN
SAND AND LIMESTONE EXCAVATION
LOTS 1001 AND 1002, PRESTON BEACH ROAD NORTH

MAY 2016

1.0 Environmental Dust

1.1 Dust Risk

Excessive dust has the potential to impact on both the workers and the adjoining land.

Dust can originate from a number of operations and may impact on onsite workers, or travel offsite. Potential dust impacts are addressed by reducing the dust generated from the quarrying, processing and transport operations.

The main risk from dust is not the sand, but rather the fine organic particles that are generated during land clearing and reinstatement, and most importantly the fine particles generated by transport along limestone access roads and traffic areas.

Dust from some materials such as ground limestone can form smaller particles that are capable of blowing further or even becoming so fine that they become invisible. On this site most of the excavation will be sand with limited limestone. The access roads will utilise the existing forestry roads and temporary roads formed on the floor of the pit constructed from limestone.

1. Mining (predominantly coal) has been shown *by NSW Health* to have the characteristics listed below. These values are not necessarily applicable to sand and limestone extraction because of the high amounts of clay within the shales associated with coal and the fine particles that can be generated by the coal itself. Sand and limestone extraction will have less of the fine particles.

    - PM <2.5 microns as 2 – 5% of emissions
    - PM 2.5 – PM10 microns as 15 – 45%
    - PM>10 microns as 50 – 70%.

    (One micron is 1 / 1000 of 1 mm).

2. PM< 2.5 are invisible and called “fine particles”. They are the main health issue and are caused by vehicle emissions whether they are along roads or on private land. Vehicle emissions will not occur at night or at other times when the site is not active.

3. Modern vehicles are increasingly designed to minimise the fine particulates of carbon through the use of fuel efficiencies, particulate fixtures and hybrid technologies where electrical motors are used to assist operation of the plant from recovered energy.

    These particles are also diluted by surrounding air mass and, in a situation such as this with little nearby activity, dilution factors are significant.

4. PM 10 are invisible and called “coarse particles”. They can be breathed in, but are removed by alveoli and mucous. *(NSW Health).* This dust may be generated when land is cleared and topsoil disturbed or the site is subject to traffic in summer. For limestone extraction this can include calcium carbonate which is innocuous to health and is the main component of antacid treatments.

5. PM>10 is visible dust and will, based on the resource, be the vast majority of the particles.

6. Sand particles are normally >50 microns. DEC 2011 (below) lists particle sizes of >50 um as not normally becoming airborne. That is the sand grains which move by saltation (bouncing) and are retained by the wall of the pit. The sand grains within the limestonde are bound and are not known to below significantly.

As all sizes of dust are likely to be generated together, there will be visible dust being generated when invisible dust is being formed. Therefore any visible dust present is a good sign and early indicator of a dust risk.

The main risk is therefore from the fine organic matter in the topsoil, any clay within the sand and limestone or calcium carbonate that is broken down through tyre impacts or disturbance. There is also the risk from the crushing and tipping processes of dry products.

Dust has the potential to be generated during some phases of the sand quarrying and crushing operation, particularly during summer. In winter the frequent rains greatly reduce the potential dust emissions. The main and generally only risk is from transport along the limestone access roads and hardstand.

As noted below sand stays moist and, as shown in all operating sand pits, generates no dust during excavation apart from clearing topsoils, trafficing dry areas and moving sand around so that it can dry out. Extraction directly from the face does not produce dust.

Limestone is formed from sand grains bound together by grains of calcium carbonate held together by calcium carbonate cement.

Being softer than the sand grains the calcium carbonate is readily ground very fine from disturbance particularly in dry conditions from actions such as vehicle movements. The sand grains within the limestone are hard and are not normally reduced in size even by traffic movements.

When dry there is some minor dust from the wheels and associated ground calcium carbonate of the limestone and tiny amounts of clay with the dark yellow sands.

Calcium carbonate is an innocuous material that is a major component of bones and is required by all living organisms for their health and growth.

What makes calcium carbonate unique is that it is readily dissolved to calcium hydrogen carbonate by weak acids in rainfall and water applied to the site. Once dissolved, the calcium hydrogen carbonate readily precipitates to calcium carbonate as the water is evaporated. The calcium carbonate deposits on the surface of the land and any exposed limestone, readily forming a crust that stabilizes the surface and is not liable to any dust lift off unless disturbed by vehicle movements. Limestone which has been left even for a week or so becomes crusted and stabilised, with the crust thickening over time. This process can even occur from dew.

Limestone also stays moist as noted below, and the main dust risk is also traffic on roads and hardstand. When excavating using a bulldozer there is very little dust even in summer.

1.2 Climate and Soil Conditions

Through the winter months of May to September inclusive, there is little dust risk because rainfall exceeds evaporation. The rainfall is sufficient to wet the whole limestone profile to depth, with excess water reaching the water table.

In summer, when evaporation exceeds rainfall, the limestone roads dry when exposed to the sunlight and atmosphere and are susceptible to crushing and grinding by vehicles.

Limestone prior to excavation retains its moisture if there are no tree roots to extract moisture from depth. Without tree roots the moisture in the limestone can only be lost by capillary action and so stays moist to below 0.5 and 1 metre depth right through summer. The same applies to sand.

On active areas such as roads and hardstand that dry out, the dust can readily be generated. Normal practice is to treat this with water, which maintains the moisture content of the soil and limestone and mitigates dust generation.

1.3 Wind directions

The most comparable wind data is taken from Fremantle. These show that the prevailing wind is from the north east and east at 9.00 am and the south west at 3.00 pm.

For the summer months, where February is a typical month, the wind directions are more variable at 9.00 am ranging from east through south. At 3.00 pm in February the winds are almost solely from the south west. The morning data shows that on some days the south westerly sea breeze is blowing at 9.00 am in February.

In July the predominant winter wind direction at 9.00 am is from the north east with 3.00 pm winds more variable and spread from north through south west.

The wind roses for Fremantle are included in this attachment.

These winds predominantly blow away from the closest premises at 400 metres to the south west but becoming increasingly further away as excavation progresses.

Proposed perimeter bunds and vegetation, such as the pines and vegetation to the west of the resource, provide effective wind breaks and wind screening. Winds crossing the site are slowed by any nearby trees. This reduces the speed of the winds across the floor of the pit.

When winds exit the pit or cross out of the pit they have to travel across a vegetated buffer that slows the speed of the wind and allows the coarser particles to drop from suspension.

1.4 Assessment of Dust Risk

Dust management has been an integral part of the extraction and processing of limestone. Facilities and procedures are updated as better technology becomes available.

Dust emissions fall under the *Guidance for the Assessment of Environmental Factors, EPA, March 2000*. Assessments of the potential dust risk are normally made using the Land development sites and impacts on air quality, *Department of Environmental Protection and Conservation Guidelines, November 1996.* These are still in place but are incorporated into the *DEC 2011 Guideline for Managing the Impacts of Dust and Associated Contaminants from Land Development Sites, Contaminated Sites Remediation and other Related Activities.*

The *DEC (DER) in 2008* released a *draft Guideline for the Development and Implementation of a Dust Management Plan.*

The key Environmental Objectives for the operations are;

- Manage the potential for the generation of dust.
- Visually monitor dust levels and take steps to reduce the potential impact of dust on occupational and environmental aspects of the operation and local area.

The category of dust risk is included in *DER 2011 Guideline for Managing the Impacts of Dust and Associated Contaminants from Land Development Sites, Contaminated Sites Remediation and other Related Activities.* This document is not really applicable to mining because it is to be used to assess the mitigation required based on no mitigation.

When making the assessments using the DEC (DER) Guideline there are four key points;

The prevailing winds blow from the south west to south on summer afternoons and from the east on summer mornings.

- Dust risk is generally only in the dry summer months
- The limestone readily crusts and is stabilised. It is only trafficked areas of limestone that develop fine dust from the grinding of wheels.
- The perimeter bunds and vegetation provide effective wind breaks and wind screening.
- Effective water treatment of the limestone is used to wet down and manage dust risk.

Dust mitigation measures are maintained on a regular basis and updated as necessary.

The management of environmental and occupational dust requires the same techniques and actions. If occupational dust is managed, then there will be minimal risk of dust impacting on the external or onsite environment.

2.0 Dust

Environmental Dust

Dust has the potential to be generated during most phases of the quarrying and crushing operation, particularly during summer. In winter the frequent rains greatly reduce the potential dust emissions. The main risk is from the crushing and tipping processes and from vehicle movements. Occasional one off dust is produced from blasting approximately once per month.

Dust may impact on onsite workers. Dust also has the potential to be visually intrusive and travel to adjoining properties if not managed.

Dust management has been an integral part of the extraction and processing of limestone. Facilities and procedures are updated as better technology becomes available.

Dust emissions fall under the *Guidance for the Assessment of Environmental Factors, EPA, March 2000*.

Assessments of the potential dust risk are normally made using the Land development sites and impacts on air quality, *Department of Environment Regulation Guidelines, November 1996.* These are still in place but are incorporated into the *DEC 2011 Guideline for Managing the Impacts of Dust and Associated Contaminants from Land Development Sites, Contaminated Sites Remediation and other Related Activities.*

The aim of dust management is to;

- Manage the potential for the generation of dust.
- Continually visually assess dust levels and take steps to reduce the potential impact of dust on occupational and environmental aspects of the operation and local area.

The site is 2.8 km from any sensitive premises negating any dust impacts on the closest sensitive premises.

The category of dust risk is included in *DER 2011 Guideline for Managing the Impacts of Dust and Associated Contaminants from Land Development Sites, Contaminated Sites Remediation and other Related Activities.* This document is not really applicable to mining because it is to be used to assess the mitigation required based on no mitigation.

However the document can also be used to determine the risk of potential dust impacts of earthworks such as clearing and the removal of overburden and rehabilitation which, only occurs about once per year. The document does not apply or take account of separation distances as great as available on site.

Yalgorup National Park

It is impossible to think that dust will travel over 2 km and have any significant or noticeable impact on any sensitive premises or Lake Clifton. With a buffer of 200 metres with intervening vegetation it is also considered most unlikely that any dust will impact on Lake Pollard.

Limestone is predominantly calcium carbonate with some sand grains. It is an integral part of the local environment. Calcium carbonate is an integral substance in the waters and sediments of Lake Clifton and Lake Pollard and is essential for the development of most life within those systems, including the Thrombolites which incorporate it into their structures. (Figures 2, 8 and 11) of the main report).

Cape Bouvard Investments 2009 found that the water elevation in Lake Pollard ranged from -0.4 metres AHD in February 2008 to +0.5 m AHD in July – September 2008 (Cape Bouvard Investments 2009 Figure 9). The lake was alkaline at pH 8 to 10 and in summer the high pH leads to precipitation of calcium carbonate making the water more turbid.

Therefore even in the unlikely event that dust will travel to the lake it will not impact on the lake as the lake is already subject to precipitation of calcium carbonate in summer when excavation will take place.

The Guidelines, which include the Department of Health guidelines for spray drift, and studies conducted at Emerald in Queensland that are used by the Department of Health, all suggest that a tree buffer of 20 metres width will provide an effective buffer for fine particulates. The site has a 200 metre tree buffer to Lake Pollard. (*Department of Health, 2012, Guidelines for Separation of Agricultural and Residential Land uses*).

Primary Industries Standing Committee 2002, *Spray Drift Management*, SCARM, Report 82, whilst the studies involves droplets and not particulates, the size of the particles and their density show similarities and indicates the effectiveness of vegetation and windbreaks. The study forms the basis of the Department of Health Dust Guidelines.

Wind breaks are well researched and contained in many documents, for example DAFWA Farmnote 35/96, 67/2002, 38/2000/2005, 21/2994/2005 and 48/1986 all available from the DAFWA website.

A 20 metre buffer of vegetation is to be retained to the north and south of the excavation area to the adjoining land of Yalgorup National Park in the south. Any dust falling on vegetation will have minimal impact. Any dust is readily washed from leaves by even very small amounts of rainfall. The potential impacts are minimal, and, adjacent to gravel roads, there is almost always no discernible impacts on the growth and success of native vegetation.

The potential for dust to deposit on the adjoining vegetation is less than for a gravel road because the on site activities will be set back further than the vegetation which can be as close as 3 metres along a roadside.

The information in the summary table below also operates in a similar manner by determining the risk of dust without, and then with, management procedures in place.

Activity	Calculated Score	Allocated Risk of Dust
Land clearing and excavation, when effective dust management is used (For Lake Pollard).	98	Negligible

Occupational Dust

Occupational dust associated with the quarrying processes falls under the *Mines Safety and Inspection Act 1994 and Regulations 1995* overseen by the Department of Mines and Petroleum.

Limestone is predominantly calcium carbonate with some sand grains. There are no known health impacts from calcium carbonate and the material is the major component of bones and is essential for human health. It is also an integral part of the local environment. The sand grains are too large to cause a health issue if ingested.

A personal (occupational) dust monitoring program will be used as per Department of Mines and Petroleum specifications.

3.0 Dust Management

3.1 Issues and Management

There are a number of management actions that can be taken in quarries to minimise dust generation or travel and these are used wherever possible. The general management actions are summarised in the tables below, together with the potential dust issues that relate to this site. The actions are used where applicable and as the opportunity presents to minimise dust on this site.

On this site, with Negligible Dust Risk with normal dust management, many of the operational procedures will not be required.

A dedicated water truck is to be retained on site for the wetting down of roads and other dust suppression activities. In addition the access road is sealed and maintained.

Loads on trucks that have the potential to generate dust are required to be covered or wetted down.

Dust generated from earthworks is closely monitored and managed.

Actions that can be used to prevent or mitigate dust are standard quarry best practice. Some methods are taken from the DER 2011 Appendix 2 and others from quarry best practice.

Methods that are available, and will be selected from, are listed below. The most effective by far is the use of water management from a water truck, sprinklers, water canon or other such mechanism.

DESIGN AND SITE

1. Minimising the amount of ground open.
2. Minimising the amount of ground being subject to traffic.
3. Locating access roads away from sensitive premises.
4. Design of the pit to reduce wind speed and potential dust lift off.
5. Maintaining effective setbacks.
6. Constructing perimeter bunds to reduce wind speed.
7. Maintaining tree buffers such as pines and their replanting.
8. Providing wind break fencing generally and on top of bunds as required.
9. Maintaining a secure, fenced site, to prevent illegal access.

10. Rehabilitate and stabilise all completed areas as soon as practicable.
11. Clearing and replacing topsoil and overburden during wetter times; April to October.

OPERATIONS

12. Locate active areas away from windy locations.
13. Locate active areas away from sensitive premises.
14. Working on the floor of the pit.
15. Operate some parts of the pit only when conditions are suitable.
16. Locating mobile plant and stockpiles in sheltered areas.
17. Design staging to minimise dust risk.
18. Conduct higher dust risk operations such as topsoil clearing and placement during more favourable conditions.
19. Shut down equipment that is not required.

ACCESS AND HARDSTAND

20. Constructing the access roads from hard materials that resist dust generation.
21. Maintaining a water truck on site for road and other wetting down.
22. Using a sealant such as a polymer, chemical or emulsified oil or bitumen on the access road to reduce water use.
23. Using sprinklers and water canon on roads, traffic areas and stockpiles.

PROCESSING

24. Applying water sprays and additives to crushing and screening cycles.
25. Providing screening and shielding of mobile plant.
26. Use and maintain filters on all suitable plant.
27. Ensure regular appropriate emptying of filter collection devices.
28. Face hoppers away from prevailing winds.
29. Maintain reduced pressure in plant, hoppers and bins to prevent loss of dusty air.

STOCKPILES

30. Minimise the number of stockpiles.
31. Maintain stockpiles in sheltered areas.
32. Reduce the elevation of stockpiles.
33. Limit the drop height to stockpiles and loading.
34. Locate finer products inside or screened by stockpiles of coarse materials.

TRANSPORT

35. Cover all loads.
36. Ensure all trucks are dust free and not carrying pebbles and other materials outside the tray.
37. Choose the best transport routes.
38. Wet down or sweep the cross over and access roads.

HEALTH AND COMMUNITY

39. Maintain air conditioned cabins on all vehicles.
40. Provide a readily auditable trigger of no visible dust to cross the property boundary in line with DER Licence and best practice in WA.
41. Conduct effective site induction and awareness training for all staff.
42. Training should include observation and mitigation where possible of all dust emissions.
43. Providing a complaints investigation, mitigation and recording procedure.
44. Liaising with the owners/operators of nearby sensitive premises.
45. Ceasing operations when conditions are not favourable or when visible dust is crossing the boundary.
46. Obtain the latest weather conditions to increase the awareness of dust risk.
47. Cease operations during adverse weather conditions.
48. Operate during wetter months or when the soils are moist.

Normally the stripping of overburden and topsoil and their subsequent use in rehabilitation will be undertaken during the wetter months to reduce the generation of dust.

Completed sections of the quarry are to be stabilised and not subject to traffic as soon as practical to reduce the area of open ground and help reduce wind speed.

In the event of dust management not being able to be achieved, and to minimise impact on adjoining land holders, the dust generating activities will be stopped until conditions improve.

A record of all dust complaints will be retained together with the mitigation measures used to reduce the dust impacts.

3.2 Tree Belt - Buffers

Dust is readily stopped by tree belts and distance with which the site complies with, *Planning Guidelines Separating Agricultural and Residential Land Uses, Department of Natural Resources Queensland 1997(Pages 65 – 111) and Department of Health WA, 2012, Guidelines for Separation of Agricultural and Residential Land Uses which uses the same criteria (Pages 112 – 118).*

The Queensland Guidelines predominantly relate to agricultural spray drift, but, based on particle size, also relate to dust.

The Guidelines provide for a buffer of 300 metres for open agricultural land, dropping down to 40 metres where an effective tree belt is in place. The Western Australian Department of Health also uses the same guidelines.

The distance, with vegetation, to the lake will provide significant dust management as will the operations working behind the eastern face. See Figure 5 of the main report.

A tree belt is proposed to be planted along the eastern edge of the proposed pit as shown in Figure 3, 5 and 11 of the main report.

The Guidelines are based on field studies and demonstrate the effectiveness of tree belts in providing screening against particulate travel.

The proposed excavation has adequate buffers and design that will minimise any potential dust impacts.

3.3 Dust Management Actions

ACTIVITY	POSSIBLE RISK SEVERITY and FREQUENCY	IDEAL OPERATIONAL PROCEDURES	COMMITMENTS ON ACTIVITIES CONDUCTED ON SITE	RISK AFTER MANAGEMENT
GENERAL				
Legislation	----	• Comply with the provisions of the Mines *Safety and Inspection Act 1994 and Regulations 1995*.	• Doyles Limes Service will comply with the Act and Regulations and the other Conditions.	----
Buffers	----	• Maintain adequate buffers to sensitive premises.	• The buffers to the nearest residences are 2.8 km and not anticipated to change within the next 20 years.	----
Landform	----	• Locate activities behind natural barriers, landform and vegetation.	• The design of the pit and staging has been selected to provide the best screening. That is excavation from west to east. • Excavation will be conducted below the land surface. • The processing and stockpile facilities are to be located on the pit floor to the west of the excavation.	----
Landform	----	• Work below natural ground level.	• This is proposed.	----
		• Push overburden and interburden dumps into positions where they can form screening barriers.	• This is to be used where overburden is available in combination with the adjoining vegetation.	----
Staging	----	• Design operational procedures and staging, to maximise the separation to sensitive premises.	• There are no dwellings within 1000 metres of the operations.	----
Pit design	----	• Design the excavation to provide enhanced landform and constructed dust screening.	• See above.	----
Screening/ Vegetation	----	• Use landscape screening, wind breaks and tree belts.	• The perimeter vegetation assists in dust mitigation and complies with the Department of Health Guidelines on the use of tree belts in the *DOH 2012 Separation of Agricultural and Residential Land Uses* which has some relevance to dust on sites such as this.	----
MANAGEMENT				
Occupation	----	• Provide air conditioned closed cabins on plant	• These are used at all sites for operational mobile plant.	----
Monitoring	----	• Provide monitoring and supervision of	• A monitoring system is proposed. see below “Trigger	----

		the processing and other practices on site.	Conditions".	
Trigger conditions	----	• Trigger conditions are used to determine when additional dust management is required.	• Most dust generated from processing and vehicle movements has a very large visible component. Lesser risks emanate from excavation and land clearing. • The trigger for dust management is the generation of visual dust. • The quarry manager and leading hands are ultimately responsible for site supervision of dust. • They will travel around the operations and pit frequently and be in two way radio contact with all mobile plant. • All operators on site will be instructed to be vigilant to dust generation and management and report any excessive dust or potential dust management issues. • When trigger conditions are detected and/or alerted, relevant action is to be taken. This can include additional water suppression, modification of procedure, delay until more favourable conditions are present, use of alternative equipment etc.	----
Adverse weather	Moderate - Uncommon	• When winds are sufficiently strong, or other weather conditions are unacceptable, to negate the effects of dust management, operations will cease until conditions improve and compliance can be achieved.	• Rare adverse conditions are more likely to occur on summer mornings and sometimes on summer afternoons with strong sea breezes. In winter, stronger winds are normally associated with rain and therefore carry a reduced dust risk. • This policy will be used to minimise impact on adjoining land, particularly the Yalgorup National Park. • Limestone is predominantly calcium carbonate with some sand grains. There are no known health impacts from calcium carbonate and the material is the major component of bones and is essential for human health. It is also an integral part of the local environment.	Low
Equipment failure	Low - Uncommon	• In the event of dust management not being able to be achieved through equipment failure operations will cease	• This will be used on site and is committed to.	Low

		until full capability is restored.		
Training	----	• Conduct training programs on dust minimisation practices.	• Doyles Lime Service uses on site induction and training to inform all personnel of the dust risk and management.	----
Complaints	----	• Provide a complaints recording, investigation, action and reporting procedure such as Appendix 3 of Land development sites and impacts on air quality, Department of Environmental Protection Guidelines, November 1996.	• A record of all dust complaints is to be maintained together with the mitigation measures to be used to reduce the dust impacts. • All complaints relating to dust are to be investigated immediately.	
Monitoring	----	• Provide a Monitoring procedure to minimise dust generation.	• Visual dust monitoring is to be conducted on site at all times by all operators and the quarry manager. This response is instantaneous and does not rely on monitoring equipment which normally has time delays associated with it. • The amount and source of dust is observed before any dust monitoring could trigger. Treatment is therefore more effective and targeted. • When a significant source of dust is noticed it will be dealt with by temporary or permanent changes to procedures and equipment or treatment using water.	----
EARTHWORKS				
Land Clearing	Low - Once	• Schedule activities such as vegetation removal or topsoil stripping on exposed ridgelines at times when the materials are less likely to blow or during suitable wind conditions.	• Normally the stripping of overburden and topsoil and their subsequent use in rehabilitation is undertaken in the drier months when the soils are still moist enough to suppress dust but not wet. • Completed sections of the quarry are to be rehabilitated as soon as practical to reduce the area of open ground. • No clearing will take place unless a Clearing Permit is in place.	Low
Overburden removal	Low - Once	• Schedule activities such as overburden stripping on exposed ridgelines at times when the materials are less likely to blow or during suitable wind conditions.	• See above.	Low
Land	Low	• Schedule activities	• See Land Clearing above.	Low

restoration	- Once per year	such as ripping, overburden and topsoil spreading on exposed ridgelines at times when the materials are less likely to blow or during suitable wind conditions.		
EXCAVATION				
Excavation	Low - Low level campaign activity	• Excavate from the face using techniques that minimise the crushing of dry matter.	• The floor of the pit will be formed on limestone that crusts in winter but is broken by traffic in summer. • The application of water will be used as required to wet down the loading and traffic areas.	Low
Loading at Face	Low - Low level campaign activity	• Ensure that products to be loaded are moist and that the hardstand on which the loading occurs is wetted down or moist.	• This will be conducted concurrently with excavation using a loader. • The limestone will then be carried by the loader to the mobile crusher.	Low
Haulage	Moderate - Medium level campaign activity	• Maintain haul road and hardstand surfaces in good condition (free of potholes, rills and product spillages) and with suitable grades.	• No internal haul roads are proposed. • The application of water will be used as required to wet down the loading and traffic areas.	Low
		• Reduce the length of the internal roads by maximising internal servicing efficiency.	• The operations are to be designed to mitigate the use of haul roads by locating the stockpiles and crusher close to each other.	
		• Providing speed management on hardstand and the road network.	• This is to be used for pit traffic.	
		• Provide air conditioned closed cabins on plant.	• All vehicles are to be air conditioned.	
		• Treat access roads, hardstand and stockpile transport and loading areas with dust suppression sealant, water or seal coat.	• Methods of water based dust suppression are to be maintained on site during the summer months, such as road watering facilities.	
PLANT - PROCESSING				
Hardstand traffic	Low - Medium in campaigns	• Maintain hardstand surfaces in good condition (free of potholes, rills and product spillages) and with suitable grades	• Hard stand areas will be limited in area and able to be watered by the dedicated truck as required.	Low

Processing	Moderate - Campaigns	• Treat processing areas with water sprays, shields and dust extraction.	• Crushing operations are to be watered as required to suppress dust. • Dust covers and equipment shields are to be maintained on all static plant. • Continuous visual monitoring of dust will be used. • Regular emptying of any dust collection devices and the renewal of any filter devices will be programmed.	Low
Mobile and static plant Operation	Moderate - Campaigns	• Maintain all plant in good condition.	• Doyles Lime Service uses well maintained equipment that includes where possible dust minimisation measures. • Faults are repaired promptly.	Low
		• Ensure mobile and static plant is provided with dust extraction, shielding or filtration systems or wetting down as appropriate.	• Operators will be instructed to visually monitor dust, report and treat any visible dust. • Regular emptying of any dust collection devices and the renewal of any filter devices is programmed. • Dust management and monitoring forms part of the site induction programs. • See Processing above.	
Loading and Stockpile Creation	Moderate - Continuous	• Shut down equipment when not in use.	• Doyles Lime Service uses this policy to save fuel and maintenance costs in addition to noise minimisation.	Low
		• Limit drop heights from conveyors and dump trucks.	• This is to be used. It is a good safety and site management procedure. • Fixed and mobile stackers are to be used. The use of stackers will minimise road traffic.	
TRANSPORT				
Road condition	Low - Medium transport risk in campaigns	• Maintain access roads in good condition (free of potholes, rills and product spillages).	• The access road will be maintained to repair impacts caused by trucks. • Doyles Lime Service will work with the Shire of Waroona to upgrade the road network and form it to limestone in consultation with DPaW. • Doyles Lime Service will provide grading of the road in conjunction with the Shire of Waroona. See Appendix 2. • Doyles Lime Service maintains speed restrictions for safety and site management on all their access roads.	Low
		• Water and/or treat access roads and paved areas using a water tanker or sprinkler system.	• See above. • Where possible management will be used to minimise dust such as maintenance and the use of water when dust lift off is a potential hazard.	

Road Transport	Low - Medium transport risk in campaigns	• Wet down or cover loads on trucks that are likely to blow during transport.	• Trucks will be covered or wetted down prior to exiting the site when product is likely to blow.	Low
		• Implement a site code outlining requirements for operators and drivers.	• A site code and induction system is to be used.	
		• Maintain road trucks in a clean condition.	• Doyles Lime Service has a policy of encouraging transport operators to maintain their vehicles in a clean condition.	
		• Avoid spillages on roads and clean up promptly.	• Trucks will be covered or wetted down prior to exiting the site when product is likely to blow.	Low
		• Ensure that during loading, product does not become lodged on the sides of trucks from where it can fall off during transport.	• This forms part of proposed normal operational procedures.	
		• Drivers are to inspect trucks prior to leaving site. Any product not correctly located and secured is to be removed prior to exit from the site.	• This forms part of proposed normal operational procedures.	
STOCKPILES				
Stockpiles	Moderate - Frequent during campaigns	• Wet down stockpiles using water canon or sprinklers as required.	• Limestone is normally moist when stacked and readily crusts after rain. Where possible stockpiles are low in elevation and less than 2 metres in height.	Low
		• Locate stockpiles behind bunds/ windbreaks or other screening barriers	• The stockpiles will be located on the floor of the pit to provide better site screening. • The stockpile area has some windbreak protection from trees and bunding from strong winds.	
		• Reduce the height of stockpiles. Low flat stockpiles are less likely to be disturbed by wind than high conical ones.	• The height of stockpiles will be maintained at manageable levels that remain sheltered from the prevailing winds. Normally stockpiles are maintained at less then 2 metres in elevation.	
		• Locate coarser products around fine materials to assist wind protection of the finer products that are more likely to blow or contain greater amounts of dust.	• This will be undertaken when required but is not normally necessary. • Limestone is normally moist when stacked and readily crusts after rain.	
		• Provide bunding, fencing and windbreaks around stockpiles and along the tops of bunds.	• This is not normally required because of the landscape screening. Tree belts and bunds will be used around the western edge of the pit to reduce wind and provide visual screening.	

4.0 Dust Monitoring

The most effective dust monitoring is the generation of visible dust.

The auditable condition is visible dust crossing the boundary of the premises; the lot boundary. This is the condition used on Department of Environment Regulation Licences and all other sand, limestone and hard rock quarries in Western Australia.

It is also the method used by the Department of Mines and Petroleum to rapidly assess occupational dust on site.

Normal DER Licences state;

> *The licensee shall use all reasonable and practical measures to prevent and, where that is not practicable, to minimise dust emissions from the Premises.*
>
> *The Licensee shall ensure that no visible dust generated by the activities of the Premises crosses the boundary of the Premises.*

As invisible dust can be generated with the visible dust, recognising and dealing with visible dust is a very effective instantaneous method of recognizing excessive dust.

There are no nearby dwellings.

The potential risk of external dust impacts is regarded as very low. If any risk was generated from dust there would be an on site occupational situation that would have to be treated. Such treatment would normally mitigate any external dust risk.

- **Visual Dust Monitoring**

Most dust generated from processing and vehicle movements has a very large visible component. Lesser risks emanate from excavation and land clearing.

The trigger for dust management is the generation of visual dust. The quarry manager and leading hand are ultimately responsible for site supervision of dust. This is the method required by the DER in the licence applying to the operations.

They will travel around the operations and pit frequently and be in two way radio contact with all mobile plant.

All operators on site will be instructed to be vigilant to dust generation and management and report any excessive dust or potential dust management issues.

When trigger conditions are detected and/or alerted, relevant action will be taken. This can include additional water suppression, modification of procedure, delay until more favourable conditions are present, use of alternative equipment etc.

Human monitoring can detect potential dust risks prior, and take action prior, to the dust being generated. They also notice dust immediately such as from tyres, whereas machine monitoring has to rely on significant dust being generated, travelling to the boundaries of the premises and triggering an alarm. The operators would be negligent if they let the dust get to that level of impact prior to taking action.

Visual monitoring is even more effective when complemented by an extensive reporting and complaints process.

The photographs attached show how monitoring of visual dust is more effective than mechanical monitors located at the boundaries of a site.

Dust can be seen immediately it is generated, even if it is only a small amount. At that time it can be treated before it becomes a problem.

For dust to be detected by a mechanical monitor on the boundary, then there will have been large amounts of dust generated within the pit.

Notice how much dust would have to be generated for it to escape from the pits shown.

The attached photograph presents some examples of the likely excavation methods and pit form. See also Figure 6 of the main report.

Typical Limestone processing. Notice that any dust will be detected visually long before it escapes the pit. Once noticed water treatment can be applied before dust becomes an issue.

COMPLAINTS MECHANISM

The following complaints mechanism is proposed.

1. A complaints book will be provided and maintained by the operator.

2. Upon receipt of a complaint Doyles Lime Service will investigate and action the complaint.

3. When a complaint is found to be legitimate, Doyles Lime Service will, where possible, undertake any reasonable actions to mitigate the cause of the complaint and where possible, take reasonable steps to prevent a reccurrence of the situation in the future.

4. Details of any complaints, the date and time, means by which the complaint was made, the nature of the complaint, the complainant, investigations and any resulting actions and the reasons, will be recorded in the Complaints Book.

5. The Shire of Waroona will be informed of any complaint or any other report provided to a Government Department within 3 working days.

6. The complaints book will be made available for viewing or requested details made available to the Shire of Waroona or any other official upon request.

Greenhouse Gas

The development of the Peel Region and agriculture in the south west of Western Australia Region has generated the need for limestone products.

There are no alternative resources as discussed in Western Australian Planning Commission in *WAPC 2012, Basic Raw Materials Demand and Supply Study for the Bunbury - Busselton Region.*

Over the years trucks have become more efficient with respect to greenhouse gas emissions, particularly with the use of truck and trailer and road train configurations.

Doyles Lime Service continues to seek ways to reduce the amount of fossil fuels used, and has obtained more efficient mobile plant and equipment when this has become economically available.

The internal design of the operations attempts to minimise the haulage route to save energy use and potential impacts.

Dust Management - Applicable Legislation / Policies

- *Guidance for the Assessment of Environmental Factors, EPA, March 2000.*
- *Land development sites and impacts on air quality, DEP, 1996.*
- Department of Environmental Protection Guidelines, November 1996 and *DEC 2008, A guideline for the development and implementation of a dust management plan*

Commitments to Dust Management

- Doyles Lime Service will take the necessary steps to manage and contain dust by implementing and maintaining the Dust Management Plan.
- Doyles Lime Service will upgrade the road network as outlined in Option 2B in Greenfields Technical Services Traffic Management Plan attached at Appendix 2.

Appendix 6

Landform Research
Land Systems - Quarries - Environment
ABN 29 841 445 694

WATER MANAGEMENT PLAN
PROPOSED LIMESTONE AND SAND QUARRY
LOTS 1001 and 1002, PRESTON BEACH ROAD NORTH

MAY 2016

Proposed Excavation

A limestone resource lies on part of Lot 1002, Preston Beach North Road, Preston Beach.

The resource has been identified by the Geological Survey of Western Australia as a Regionally Significant Basic Raw Material – Limestone.

The material is of high grade and is suitable for the supply of agricultural lime and road bases.

This proposal seeks Development Approval and an Extractive Industries Licence for the extraction of material from13.0 hectares of Lot 1002, Figure 1.

A limestone pit, initially of about 2 hectares will be established and then 0.5 – 1.0 per year depending on the elevation of the ridge. Some vegetation will have to be cleared for the limestone extraction.

Sand excavation will also be undertaken and can occur for the most part without the need to clear native vegetation.

Stockpiles will be located near the processing area.

The limestone will be processed on the floor of the pit near the active face to reduce internal vehicle movements. The processing will consist of mobile crushing and screening plant that will move across the floor as the excavation proceeds.

The proposed equipment is listed in the table below. Figure 3.

Site office	A caravan is proposed to serve as a site office.
Toilet system	Portable serviced system will be used
Bulldozer	Removal of limestone rubble and road base, track crushing of limestone as required and pushing down the resource.
Excavator	May be used to remove limestone.
Portable crushing plant	Preparation of road base and agricultural lime.
Screening plant	Preparation of limestone for road base.
Water tanker	Used for dust suppression on the access roads and working floors as necessary.
Loader	Loading and handling materials from the stockpiles.
Fuel Storage	Refuelling will be undertaken using potable tankers located 800 metres from Lake Pollard and not upstream of the lake. If required, fuel will be stored in an above ground tank with a capacity of approximately 5 000 litres, appropriately located on

	the floor of the pit to Department of Environment Regulation, Department of Water and Department of Mines and Petroleum Guidelines. Fuel storage will be located in a bunded area lined with an impermeable membrane a minimum of 800 metres south west from Lake Pollard 4 metres above the highest known water table.

Water Supply

Water will only be required for dust suppression, which will be carried out as required during drier weather. A water tanker will be used to water the access road and the pit floor whenever necessary to minimise dust generation from transport and during crushing. Normally only small volumes of water will be used for a quarry of this type. A quarry could be expected to require less than 5 000 kL per year.

Water will be drawn from a sump located to the west of Lot 1001. A licence from Department of Water will be applied for to enable the taking of 5 000 kL water per year for dust suppression.

Potable water will be brought to the site as required.

Water Protection Policies

The protection of water, whether groundwater or surface water, is an important part of the management of quarries. Different types of quarries have different potential impacts which are listed below in general terms. Not all potential impacts will apply to this quarry and the main impacts affecting this site are also listed.

Guidance on the quality of water can be found in;

- *Western Australian Water Quality Guidelines for Fresh and Marine Waters, EPA Bulletin 711, 1993.*
- *ANZECC, 1992, Australian Water Quality Guidelines for Fresh and Marine Waters.*

A number of documents provide guidance on the management and disposal of surface water that can lead to waterways, wetlands and underground water systems. These mainly apply to urban development but the methods are also applicable to the quarrying industry.

- *Engineers Australia 2003, Australian Runoff Quality, National Committee on Water Engineering.*
- *Stormwater Management Manual for Western Australia, Department of Environment WA, 2004.*
- *Guidelines for Groundwater Protection in Australia, ARMCANZ, ANZECC, September 1995.*

Documents specific to the mining and quarrying operations are the DOW – DMP Water Quality Protection Guidelines for Mining and Mineral Processing.

- *Overview*
- *Minesite water quality monitoring*
- *Minesite stormwater*
- *WQPN 28 Mechanical servicing and workshop (2006)*
- *Mine dewatering*
- *WQPN Landuse Compatibility in Public Drinking Water Source Areas (2004)*
- *WQPN 15 Extractive Industries near sensitive water resources.*

The sand and limestone excavation complies with all the documents above. The most relevant document is WQPN 15 *Extractive Industries near sensitive water resources.* The location of the sand and limestone and its proposed excavation complies with all Advice and recommendations, of the policy (Numbers 1 – 62).

Site Hydrogeology

There is no surface drainage due to the porosity and permeability of the limestone, with precipitation draining to the water table. It has been estimated that perhaps <10 - 20 % of the rainfall will reach the water table.

The amended limestone quarry site lies 600 metres south west from Lake Pollard much greater than the previous 200 metre separation and does not lie up groundwater gradient from Lake Pollard.

As part of the studies for proposed developments, Cape Bouvard Investments (2009) completed extensive hydrogeological studies of the southern portion of their land which abuts Lot 1001 to the north of Lot 1002. Those studies provide high levels of information on the local hydrogeology, including Lake Pollard.

The line of drill holes was placed along the southern boundary of Lot 1000, Cape Bouvard Investments land and is very relevant to the subject site because it lies adjacent to the northern boundary of Lot 1001 and provides a good cross section of the groundwater across Lot 1002 just 500 metre south of the borehole line, on the same geological and geomorphological features.

The groundwater flow is in line with normal hydrogeological principles for a unconfined aquifer that spreads from a central ridge. In such situations the flow paths east and west are similar distances which places the western edge of the proposed limestone pit near groundwater divide.

From evidence of the soils, the sump and vegetation, the water table lies at about 1 metre AHD. See Figure 3 in Deeney (undated). Figure 6.

A line of drill holes was placed along the boundary of Lot 1001 and the Cape Bouvard Investments land and is very relevant to the subject site, Cape Bouvard Investments MWS1, MWS2, MWS3, MWS4, MWS 5 and MWS6. Figure 3.

The site lies at the south from the Cape Bouvard Investments Land, which was once owned by the landholder of Lots 1001 and 1002.

Lake Pollard is brackish as confirmed by (Cape Bouvard Investments 2009 Figure 8). A fresh water lens overlays the subject land with water flow both to the east to Lake Pollard and west towards the coast. There is also a suggestion that there could be a connection in water flow between Lake Pollard and Lake Clifton because of the large surface area of Lake Clifton causing a small draw from Lake Pollard.

Cape Bouvard Investments 2009 found that the water elevation in Lake Pollard ranged from -0.4 metres AHD in February 2008 to +0.5 m AHD in July – September 2008 (Cape Bouvard Investments 2009 Figure 9). Figure 11.

They also found that the ground water along the northern boundary of Lot 1001 was slightly elevated at between 0.2 – 0.3 m AHD with a groundwater divide near the western boundary of Lot 1001. The divide was around 100 metres west of the boundary in February 2008 and around 200 metres east of the western boundary in September 2008, that is well to the west of the proposed excavation. The variation being due to seasonal factors, most likely winter precipitation, evapotranspiration from vegetation and evaporation from Lake Pollard/Lake Clifton (Cape Bouvard Investments 2009 Figure 10).

The groundwater salinity was found by Cape Bouvard Investments, on Monitoring Bores MWS5 and MWS6 located near the western edge of the northern boundary of Lot 1001, to be fresh down to – 7.0 metres AHD where the interface of the saline groundwater occurred, with some reductions in salinity due to mixing from winter precipitation. At MWS1, located east of the eastern end of the northern boundary of Lot 1001, the salt water interface varied from -7.0 - -8.0 mAHD (Cape Bouvard Investments 2009 Figures 14 and 15). This indicates fresh water flows to Lake Pollard.

The same parameters are interpreted for the amended limestone excavation being in the same geological and geomorphological conditions 500 metres south.

Limestone excavation does not affect the quality of water in the shallow ground water system because the only chemicals used are normal fuels and lubricants; a fact that is recognised by the Department of Environment Regulation who permit extractive industries in Priority Groundwater areas such as Lake Gnangara where sand excavation occurs within 3 metres of the water table.

- ***Groundwater Protection and Water Use***

Groundwater Protection

The floor of the limestone pit once excavated will have 4 metres separation to the water table in compliance with Department of Water Guidelines.

The relocated pit now lies 600 metres south west from Lake Pollard. Groundwater flow flows east to the south of Lake Pollard rather than directly to Lake Pollard for the previous proposal which was located 200 metres west of Lake Pollard.

Groundwater flows to a vegetated area to the south of Lake Pollard and between Lake Pollard and Martin's Tank Lake and not to a lake or open body of water. The groundwater flows more than 1 km before it intersects the areas between Lake Pollard and Martin's Tank Lake.

The limestone resource is lower in the landscape at a maximum of around 5 to 15 metres AHD compared to 30 metres AHD of the ridge. Figure 11.

The limestone resource lies west of the main 30 metre limestone ridge that now separates the excavation from the Lake Pollard – Martin's Lake chain.

Groundwater Use

The site lies within the Coastal Subarea of the South West Coastal Groundwater Area.

Water will be sourced from the property by way of the use of a sump that is also used for stock. A Licence from the DOW may be required for the anticipated 1 500 kL of water likely to be required for the management of dust.

For limestone extraction, the water table will be a minimum of 4 metres below the final land surface at 0 - 1 metres AHD, well in excess of the minimum of 2 metres separation specified in Government Policies and Guidelines.

The base of the pit, at 11 - 14 metres AHD, will be well above the groundwater elevation of 0 – 1 metres AHD.

For sand excavation the thin resource and low elevation requires cutting to 4 metres AHD, 3 metres above the water table in compliance with DOW guidelines and matching nearby and adjoining swales.

Wetlands

Lake Pollard lies 600 metres in a north easterly direction from the proposed extraction area.

Lake Pollard, is a recognised EPP wetland with a simialr status to Lake Clifton to the east. It forms part of the Ramsar listed wetlands that have been classified as the boundary of the Yalgorup National Park.

The Ramsar wetlands including Lake Pollard are listed on the Commonwealth EPBC database.

The dune systems within Yalgorup National Park that adjoins Lots 1001 and 1002 are the result of coastal deposition at a time of sea level changes. The limestone rocks and soils that can be seen at the surface inland from the coast are derived from the older Spearwood system, superimposed over the Spearwood system, for up to two kilometres from the beach. These are the sand dunes of the Quindalup Dune System, which have been blown in from the sea or washed ashore over the last 10,000 years.

The lakes that characterise the area lie in the depressions between a series of coastal dunes within the Spearwood system. The lakes form three distinctive lines parallel to the coast. Lake Preston is extremely elongated and lies closest to the coast. The lakes behind the next ridge are far more broken, comprising (from north to south): Swan Pond, Duck Pond, Boundary Lake, Lake Pollard, Martins Tank Lake, Lake Yalgorup, Lake Hayward and Newnham Lake. Lake Clifton is the furthest from the coast and the nearest to the Old Coast Road. It too is extremely elongated. (Modified from DPaW website).

Lake Clifton is some 2 km up from the proposed excavation. Lot 1002 lies outside the Lake Clifton catchment*, (EPA Guidance No 28, Protection of the Lake Clifton Catchment 1998).*

Rock-like structures known as thrombolites can be seen on the edge of Lake Clifton. The thrombolite-building micro-organisms of Lake Clifton appear to be associated with upwellings of fresh groundwater that are high in calcium carbonate entering from the east and therefore not related to, and environmentally/hydrogeologically isolated from, the proposed limestone pit because the groundwater flows to a vegetated area between Lake Pollard and Martin's Tank Lake around 1 kilometre from the edge of the limestone pit.

The micro-organisms living in the shallow lake environment are able to precipitate calcium carbonate from the waters as they photosynthesise, forming the mineralised structure that is the thrombolite. (Modified from DPAW website). There do not appear to be any Thrombolites in Lake Pollard although DPaW notes that the lake contains relic microbialite structures.

The Yalgorup lake system is significant for waterbirds and is recognised under the International Ramsar Convention.

The lakes provide important habitat for the international transequatorial waders that migrate from the northern hemisphere. These waders include the bar-tailed godwit, red-necked stint, greenshank, red knot, whimbrel and three species of sandpiper. Other waterbirds that use the lakes include the banded and black-winged stilts, red-necked avocet, hooded and red-capped plovers, Australian pelican and coot.

The quacking frog, turtle frog and slender tree frog are among the eight frog species that inhabit the park and the long-necked oblong tortoise is present in Lake Clifton.

Surveys carried out in south-western Australia between 1988 and 1992, showed that the Yalgorup lakes consistently supported the high numbers of musk ducks, Pacific black ducks, black swans and shelduck.

Black swans also live in high numbers at Lake Pollard, where they graze on extensive growths of stoneworts (musk grasses). The Shire of Waroona has in place a walking trail that runs from well to the south at Martin's Tank to Lake Pollard where a bird hide is located.

- ***Lake Pollard***

Lake Pollard is a Conservation Category Lake (UFI 3100) and is listed under the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 as an environmentally sensitive area under the Environment Projection (Clearing of Native Vegetation) Regulations 2004.

DPaW notes the vegetation surrounding Lake Pollard as Regionally Significant and a regionally ecological linkage is located immediately east of Lake Pollard.

The salinity of Lake Pollard, and Lake Clifton are similar and stratification does not generally occur.

DPaW notes that Lake Pollard is the only lake to support extensive areas of the aquatic plant *Lamprothamnium papulosum* which provides a valuable food source and supports large numbers of grazing water birds, up to 5 000 Australian Shellduck (*Tadoma tadornoides*) and 3000 Black Swan (*Cygnus atratus*). The lake also supports nesting habitat for Black Swans between October to March.

DPaW also notes that the lake contains relic microbialite structures.

As noted above Lake Pollard accepts fresh water inflows from the west, including from Lot 1001 predominantly with very minor to no inflows from Lot 1002 because Lot 1002 lies to the south of Lot 1001 and the eastwards flow of water predominantly flows to soils south of Lake Pollard.

Monitoring work performed by Cape Bouvard Investments to the north found that the salinity in Lake Pollard varied from approximately 25,700 to 72,300 mg/L with salinities highest in the summer/autumn period.

The water levels and quality were assessed by Cape Bouvard Investments during the studies. They found that the lowest water level was recorded in March 2008 when the lake was slightly below mean sea level.

Cape Bouvard Investments 2009 found that the water elevation in Lake Pollard ranged from -0.4 metres AHD in February 2008 to +0.5 m AHD in July – September 2008 (Cape Bouvard Investments 2009 Figure 9). The lake was alkaline at pH 8 to 10 and in summer the high pH leads to precipitation of calcium carbonate making the water more turbid.

There has been some questions raised with respect to the carbonate concentrations in Lake Pollard and whether that will change as a result of limestone excavation.

The amended limestone quarry is now 600 metres from Lake Pollard and Lake Pollard is not downstream of the quarry. The groundwater from the quarry travels to a vegetated area between Lake Pollard and Martin's Tank Lake and therefore will not influence the water in the lake.

Limestone such as this is crushed to increase the surface area and potential for soil acids to dissolve the calcium carbonate slowly over a number of years.

The crushing of the limestone floor may slightly increase the HCO_3^- content of water infiltrating under the floor of the pit, but like all limestone areas the water becomes saturated with respect to HCO_3^- and no further dissolution is possible.

The maximum dissolution will occur in winter as a result of the winter rainfall. It is noted that Lake Pollard is saturated in calcium carbonate which can lead to precipitation in summer as a result of water chemistry changes due to evaporation.

If there is any change to the calcium carbonate content of the groundwater as a result of the pit the groundwater logically will reach saturation with respect to HCO_3^- closer to the pit and then travel as saturated carbonate water in the same manner as currently exists. Once saturated no further dissolution can occur.

Therefore with the saturation of HCO_3^-, dilution factors, distance to the lakes and the water not directly entering the lakes from groundwater from under the pit there would not seem to be any significant mechanism for changes to the calcium carbonate content of the local groundwater and no impacts on the lake system

Recharge is not anticipated to change significantly and it if does there will be a slight increase as ground is opened and this will reduce as ground is closed.

- ***Acid Sulfate***

There has been an increased interest in acid sulfate soils since the release of WAPC Planning Bulletin 64.

However the interest has been over-reactive with assessments sought and risk applied in many areas where there is no geological risk or evidence of acid sulfate potential or actual conditions.

The most definitive survey procedure was produced by the Acid Sulfate Soil Management Advisory Committee NSW, 1998, in their *Acid Sulfate Manual.* This Manual forms the basis for much of the assessment procedures in Australia, including those adopted by the Western Australian Planning Commission and the Department of Environment Regulation. The *Acid Sulfate Manual* adopts the procedure of reviewing the published data followed up by field assessment, which has been completed for this site. If a geological risk is determined, then a Preliminary Acid Sulfate Assessment is conducted.

The site is shown as buff coloured, Low to No Risk of acid sulfate conditions at depths of > 3 metres, in WAPC Planning Bulletin 64.

A geological examination of the site by Lindsay Stephens of Landform Research in May 2012 showed that the site has no risk of containing acid sulfate conditions in the proposed depths of excavation. No evidence of acidic or reducing conditions have been encountered in any of the nearby quarries and none would be expected.

For example the resource of limestone is high in the landscape, highly oxidised and alkaline. The same limestone is in fact used for neutralisation of acid soil conditions and the resource is to be used for agricultural lime which is used to neutralise soil acidity.

The site is underlain by deep limestone, and the water in Lake Pollard is alkaline.

Water Balance

There will be no significant changes to the water balance. Recharge to groundwater will increase slightly and will compensate for evaporation from dust suppression actions.

The area has no surface drainage because of the permeable and porous nature of the sand and limestone. There is no surface drainage from the excavation site. All excess water will infiltrate the permeable limestone. There will be no dewatering.

There will be no alteration to drainage lines or groundwater. On closure the surface will continue to be free draining to the water table.

The nature of limestone extraction is that excavation is conducted dry, with water being used as a dust suppressant. There is no potential for water recycling or reuse as the limestone is so porous, and this will not be undertaken.

As the limestone is so porous the only potential runoff is minimal surface water during heavy storm events. Therefore the only requirement for stormwater treatment is the direction of stormwater away from hard surfaces towards infiltration areas which will normally be broad areas of infiltration adjacent to the roads and hard stand.

Recharge from parkland pasture is anticipated currently to be near 20% based on the vegetation and elevation above the water table. Recharge on excavated areas will increase to perhaps 30% because of smaller separations to the water table and removal of the vegetation. (*Environmental Protection Authority Bulletins 512, 788, 821 and 818*). This will result in a slight increase in recharge with excavation, which will reduce as rehabilitation grows.

It must be remembered that until a few decades ago the land was densely vegetated and the recharge has increased as a result of clearing of the land. In turn rainfall has reduced since the 1930's and the additions will have helped compensate for this.

Experience shows that dust control only needs to be applied to the limestone roads, and normally takes in the order of 1 500 kL per year for short campaigns. This is similar to the amount of water used by the cattle when grazing on site, which according to Department of Agriculture and Food data consume 15 to 20 kL per year per head. To be conservative it is assumed that the amount of water required will be up to 5 000 kL.

The groundwater was considered by the *Environmental Protection Authority in Bulletins 512, 788, 821 and 818,* and whilst these do not specifically refer to the extraction of basic raw materials they do consider the impact of clearing, planting trees and rural residential developments. The figure the EPA used for recharge from native vegetation was 10 – 15% rainfall, whereas cleared land had a recharge of 30 – 40 %. The floor of the quarry is also cleared and so there is not expected to be any reduction in recharge to the site.

Based on Environmental Protection Authority Bulletins 512, 788, 821 and 818, and an annual average rainfall of 900 mm, the main changes to the current recharge for parkland pasture is estimated to be 20% annual rainfall. Cleared land such as the pit floor will have an estimated recharge of 40% annual rainfall. Therefore for one hectare of pit the additional recharge will be;

0.888 m rainfall x (40 % - 20 %) difference in recharge x 10 000 m^2 area = 1 577 m^3 or kL per hectare/year.

Therefore the additional recharge created as a result of the opening of the quarry will compensate for the water requirements for dust suppression. When the quarry closes the recharge for the disturbed land will return to the pre-excavation condition as the pasture and native vegetation grows.

Therefore there will be no significant change to recharge or water flows to Lake Pollard during excavation or as a result of excavation.

With revegetation this additional recharge will reduce back to a similar level to that of today. Any increased recharge will help compensate for the reducing rainfall that is occurring in recent times. As noted above the greatest change to recharge will be the growth of dense vegetation, back to a density near natural bush. This in turn could also alter the recharge by 20% and reduce the recharge per hectare by 1 800 kL/hectare per year. The revegetation belts will therefore lead to a slight reduction in recharge.

The more revegetation, the greater the reduction.

It must be remembered that until a few decades ago the land was densely vegetated and the current recharge is an increased recharge resulting from clearing of the land rather than the pre-clearing recharge. In turn rainfall has reduced since the 1930's and the additions will have helped compensate for this.

This is further covered by the Water Authority 1989, *South West Coastal Groundwater Area Groundwater Management Review, Report WG 84* in which the recharge, development implications and potential allocations were considered.

On this basis the recharge has significantly increased as a result of land clearing when compared to the pre-clearing conditions. This will help negate the reduced rainfall over the last three decades and help minimise climatic effects on Lake Clifton and the thrombolites within the lake.

There will be a net gain in recharge during the life of the quarry, reducing as revegetation grows, followed by a slight increase when the site is subdivided and developed. The difference between stock and water used for dust suppression is minimal.

The proposed final land surface will be an undulating low ridge.

All rainfall will be retained within the excavated area and on the site because of the highly porous ground, the same as currently occurs on the much steeper ridge on site. The water table is not anticipated to change and, with the proposed final landform, the flow directions are also not anticipated to be affected.

Assessment of the proposal against *EPA Bulletin 864 and EPA Guidance 28* shows that Extractive Industries are not listed as a landuse requiring management with respect to Lake Clifton. This includes the potential for impacts from quarries which have been actively conducted in the catchment for many years, long before the documents were published.

The EPA conducted a number of assessments in the catchment, EPA Bulletins 512, 788, 821 and 818. These and the additional notes show that the greatest change to recharge will depend on the density of the vegetation on the final land surface. The quarry will actually slightly increase recharge, but a return to native trees and shrubs will reduce recharge.

Quarrying will therefore not have any significant impact on the groundwater in terms of volumes. Revegetation to tree cover will reduce the recharge to the local groundwater.

- ***Surface Water, Dewatering and Drainage***

Limestone is very porous and direct infiltration of rainfall is normal without any detention basins or other collection systems.

Dewatering of the pit will not be necessary because of the porous nature of the limestone base.

There are no watercourses on site or nearby and therefore surface water will not be altered or impacted on. Figure 3.

There is no need for defined detention basins. There will be no dewatering.

The only change will be from climate change and rainfall variation.

Water Quality

The extraction of limestone is a clean operation similar to sand excavation in the nature of the risk to groundwater. No chemicals are used apart from normal lubricants, which is similar to sand excavation. Sand excavation is one of the few industries that are permitted to operate in a Priority 1 Public Drinking Water Source Area, indicating the clean nature of the activity. See Department of Water *Land Use Compatibility in Public Drinking Water Source Areas.*

All spills are to be cleaned up in accordance with Doyles Lime Service normal operational procedures and DOW – DMP Guidelines.

Hydrocarbon is managed in accordance with the procedures specific to fuel and maintenance in the DOW – DMP Water Quality Protection Guidelines for Mining and Mineral Processing.

- *Mechanical servicing and workshop facilities*
- *Above-ground fuel and chemical storage*

Fuel storage is to be used in conjunction and refuelling from a mobile tanker the same as used in many farms, mine sites and quarries. All equipment is mobile and will move across the site as excavation proceeds.

Doyles Lime Service has in place safety and pollution management procedures for all their operations.

Loaders, bulldozers and other equipment will continue to be refuelled on site.

If a fuel tank is used on site it will be a 5 000 litre tank contained to Department of Water and Department of Mines and Petroleum requirements. Liners are normally used for static tanks which include trailer mounted tanks such as those outlined in Water Quality Protection Note "Temporary Trailer Mounted Mobile Fuel Transfer in Public Drinking Water Source Areas".

A summary of the fuel and maintenance management that Doyles Lime Service uses in all its pits, and which is used in quarries in Priority Groundwater Protection Areas, is listed below.

- All major servicing of vehicles will be conducted off site. Wastes generated from excavation and processing activities will be collected and removed off site weekly to an approved landfill site.

- Vehicle washdown is not proposed.

- Waste oil and other fluids derived from the routine maintenance of mobile machinery, will be transported off site and disposed of at an approved landfill site. Grease canisters, fuel filters, oil filters and top-up oils will be stored in appropriate containers in a shed or brought to the site as required.

- Any waste chemicals derived during routine maintenance activities will be stored in appropriately sealed containers within a designated storage area or taken from site and disposed of at an approved facility.

- There is not proposed to be any wash down of mechanical equipment.

- Major servicing of large machinery is only to be undertaken offsite or in specially designed facilities approved for the location of the quarry.

- Accidental spill containment and cleanup protocol will be implemented as necessary.

- Rubbish generated is to be recycled wherever possible and periodically disposed of at an approved landfill site.

- Dispose of waste chemicals in accordance with the Site Waste Guidelines

Refueling and Waste Management

All earth moving equipment will be fuelled from a dedicated fuel and oil dispensing vehicle, which will visit the site as required. No oil or fuel will be stored on the property.

Doyles Lime Service operations are consistent with *DOW – DMP Water Quality Protection Guidelines 2000.*

- **Dangerous Goods and Hazardous Substances**

Apart from fuel there will be no transport, storage or handling of hazardous materials involved in limestone extraction.

Fuel Management Plan

Limestone has high absorbency, and any lubricant spills are plainly visible as they remain on the surface and are easily isolated and contained.

- Refuelling is to be carried out using mobile tankers This is proposed to take place to the west of the proposed limestone pit 400 metres from Lake Pollard, or designated area where any spills will be contained.

- Fuel and maintenance will be carried out in accordance with the DOW – DMP Water Quality Protection Guidelines for Mining and Mineral Processing, Mechanical servicing and workshop facilities and Above-ground fuel and chemical storage.

- Soils and limestone hardstand such as those on this site are adsorptive. The main risk of contamination is the minor drips that occur during the removal of hoses etc. Any minor spills or leaks that are undetected at the working face will normally be picked up as the limestone is excavated and removed off site with the resource. Minor spills on the floor of the pit are broken down by soil microbial material in the same manner that soils contaminated by oil are remediated.

- Refuelling and lubricating activities are 10 plus metres above the water table, and equipment for the containment and cleanup of spills is to be provided.

- Spillage will be contained in plant and working areas by shutting down plant or equipment if the plant or equipment is the source of the spill (provided it is safe to do so).

- All significant adverse incidents (such as a fuel spill of >5 litres) in one dump, are to be recorded, investigated and remediated. A record is to be kept of incidents, and DOW, and DMP notified within 24 hours of an incident.

- In the event of a spill or adverse incident, activities will be stopped in that area until the incident is resolved.

- Any spills will be contained by the excavation. Soil, sand or limestone and resource will quickly be placed around the spill to contain it in as small an area as possible. When contained, the contaminated material will be scooped up and removed to an approved landfill or other approved site.

Servicing and Maintenance

Soils such as those on this site are highly porous and adsorptive. The main risk of contamination is the minor drips that occur during the removal of hoses etc. Minor spills are quickly degraded by soil microbial matter.

No potential chemical pollutants, fuel or oils will be stored on site. Minor servicing will be conducted onsite by mobile service vehicles, or offsite. Major servicing of large machinery will be conducted offsite.

All major servicing of vehicles will be conducted off site. Wastes generated from excavation and processing activities will be collected and removed off site weekly to an approved landfill site. Regular inspections (at least weekly) will be conducted to ensure no wastes, litter and the like are present in or around the excavation area.

Vehicle washdown is not proposed.

Waste oil and other fluids derived from the routine maintenance of mobile machinery, will be transported off site and disposed off at an approved landfill site. Grease canisters, fuel filters, oil filters and top-up oils will be stored in appropriate containers in a shed or brought to the site as required.

The following activities and management will be used on site.

- Regular inspections and maintenance of fuel, oil and hydraulic fluids in storages and lines are to be carried out for wear or faults.

- Servicing plant and equipment is to be maintained in accordance with a maintenance schedule.

- Major servicing is to be undertaken offsite.

- Only minor servicing and lubrication is to be conducted on site such as in the pit using mobile facilities.

- Any waste chemicals derived during routine maintenance activities are to be stored in appropriate sealed containers within a designated storage area or taken from site and will be disposed of at an approved facility.

- Grease canisters, fuel filters, oil filters and top-up oils are to be stored in appropriate containers in a shed or brought to the site as required.

- Waste oil and other fluids derived from the routine maintenance of mobile machinery, is to be transported off site and recycled. Materials that cannot be recycled are disposed off at an approved landfill site.

- No wash down of mechanical equipment is proposed.

- Mobile drum storage is to be located on an impermeable liner capable of holding 110% of the volume contained. All storage facilities for lubricants and oils comply with requirements of AS1940.

- Accidental spill containment and cleanup protocol will be implemented.

- The site will be maintained in a tidy manner.

Waste Rock and Tailings Management

There will be no washing of limestone or products. Subgrade materials will be incorporated into the bunding to be used above the faces to protect against unauthorised intrusions.

Waste Materials

The potential for rubbish to be dumped relates mainly to unauthorised access and is low as the site is set back from roads. The site is currently fenced. Gates will be locked at all times when the site is unmanned and equipment is retained on site. Fences will be maintained.

Wastes generated will be recycled wherever possible and periodically disposed of at an approved landfill site. Any illegally dumped materials are to be removed promptly to an approved landfill or other suitable site, depending on the nature of the material.

All solid domestic and light industrial wastes will be removed to an approved landfill facility. There will be no waste disposal onsite.

Any waste chemicals derived during routine maintenance activities will be stored in appropriate sealed containers within a designated storage area or taken from site and disposed of at an approved facility.

There is not proposed to be any wash down of mechanical equipment.

A serviced portable toilet is proposed to be in place while the site is operating.

Conclusions

The risk of groundwater pollution from Limestone extraction is the lowest of any extractive industry and lower than most almost other land uses. Extractive Industries are one of the few land uses permitted in Priority 1 Drinking Water Source Protection Areas.

Therefore there will be no change to recharge or water flows to Lake Pollard during excavation or as a result of excavation based on recharge calculations because the groundwater flow is 600 metres south west from Lake Pollard, with the groundwater flow being east to a point between Lake Pollard and Martin's Tank Lake.

Water Management - Applicable Legislation / Policies

DOW – DMP Water Quality Protection Guidelines for Mining and Mineral Processing

- *Overview*
- *Minesite water quality monitoring*
- *Minesite stormwater*
- *Mechanical servicing and workshop facilities*
- *Mine dewatering*
- *Health Act 1911*

EPA Bulletin 864 and EPA Guidance 2

Commitments to Water Management

- The site complies with Department of Water Guidelines for separation to groundwater.
- The nature of the operation and the depth to groundwater will minimise any risk to groundwater systems and Lake Pollard.
- Management procedures outlined above are committed to, to protect water quality.
- Extractive industries are not listed as a significant contributor to potential environmental impacts on the Peel Harvey Estuary. Limestone extraction has the lowest potential to cause pollution because any drips are readily retained by the limestone.
- Extractive Industries are permitted within 3 metres of the Highest Known Watertable in Priority 1 Drinking Water Catchments.
- There will be no alteration to surface water flows or groundwater levels.
- Doyles Lime Service has in place a site code outlining requirements for operators and drivers.
- Doyles Lime Service conducts training programs on pollution minimisation practices.
- Doyles Lime Service conducts regular water sampling of the water source sump and maintains the water quality protection measures listed above.

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Appendix 7

LIMESAND - LIMESTONE AVAILABILITY AND USE FOR AGRICULTURE - 2016

Jurien

JURIEN
Limesand
LARGE
RESERVES

AGRICULTURAL LIMIT

Wedge Island

LANCELIN
WEDGE
Limesand
LARGE
RESERVES

Lancelin

94

WANNEROO
LARGE
Limestone
High Grade
RESERVES

Wanneroo

95

Perth

AGRICULTURAL LIMIT

1

LAKE PRESTON
NORTH
Soft limestone that
has been purchased
by the Sate and
sterilised.

Mandurah

MYALUP
Limestone
too low grade
UNSUITABLE

MYALUP
Soft limestone
EXHAUSTED

AGRICULTURAL LIMIT

Esperance

ESPERANCE
Limesand
Very Restricted
in area and
conservation
VERY LIMITED

Yalingup

YALINGUP
Limesand restricted
by development and
conservation.
VERY LIMITED

SOUTH COAST
Limesand
Very Restricted
by conservation
VERY LIMITED

Augusta

AUGUSTA
Limesand restricted
by conservation
LIMITED

Albany

ALBANY
Limesand
Very Restricted
by conservation
VERY LIMITED

AGRICULTURAL LIME

LIMESAND - LIMESTONE AVAILABILITY AFTER GREEN GROWTH PLAN DRAFT 2016

Proposed resource in yellow is capable of providing significant environmental benefits by reducing truck travel distances and subsequent greenhouse gas emissions.

Jurien

JURIEN
Limesand
LARGE
RESERVES

AGRICULTURAL LIMIT

Wedge Island

LANCELIN
WEDGE
Limesand
LARGE
RESERVES

Lancelin

WANNEROO
LARGE
Limestone
High Grade
RESERVES
TOO
RESTRICTED
TO BE USED
FOR
AGRICULTURE

Wanneroo

95

Perth

AGRICULTURAL LIMIT

1

Mandurah

VALUABLE
HIGH GRADE
LIMESTONE
LOST

PRESTON NORTH
Proposed resource
excavation capable of
supplying near areas

MYALUP
LIMESTONE
TOO LOW
GRADE

Yalingup

AGRICULTURAL LIMIT

Esperance

FUTURE
SUPPLIES
PROBABLY
LOST

ESPERANCE
Limesand
Very Restricted
in area and
conservation
VERY LIMITED

SOUTH COAST
Limesand
Very Restricted
by conservation
VERY LIMITED

Augusta

AUGUSTA
Limesand restricted
by conservation
LIMITED

Albany

ALBANY
Limesand
Very Restricted
by conservation
VERY LIMITED

FUTURE
SUPPLIES
PROBABLY
LOST OR AT RISK

STATE OF THE ENVIRONMENT REPORT Western Australia 2007 Chapter 3 LAND

Key findings

- About two-thirds of South West agricultural soil is at risk of acidification.
- Between 1990 and 2004, use of lime and dolomite as a soil treatment increased nearly 900%.
- Farmers are using about half of the lime required to maintain current acidity levels in South West soils.
- Subsurface acidification is now recognised as a serious and growing problem.

3.3 Soil acidification

Description

Many soil types are naturally acidic. Problems arise when acidity increases and affects plant growth. Soil acidification occurs due to a gradual increase in the hydrogen ion content of the soil, and is measured by a decrease on the 'pH' scale. This scale varies from pH 0 (strongly acidic) to pH 14 (strong base), with pH 7 being neutral. The most widespread cause of soil acidification is from agriculture practices including application of nitrogenous fertilisers, the leaching of nitrate from legume crops and pastures, and the gradual removal of alkalinity (material that buffers against soil acidity) from soil into harvested or grazed plants. Unfortunately, these are side-effects of agricultural production. Acidification can also be caused by the oxidation of sulfide soil minerals during mining or land development, acid deposition from industrial atmospheric pollutants (e.g. sulfur dioxide) or land contamination.

Soil acidification is difficult to identify, particularly when it occurs below the soil surface. A decline in vegetative condition or agricultural productivity is often the first sign. The critical point for this decline is generally accepted to be about pH 4.5, but this varies among plant and crop species. Soil acidification is primarily managed through lime application, either as lime sand or crushed limestone. Dolomite is also used in some areas. Other practices such as reduced nitrogen fertiliser input, the use of nitrate-based fertilisers, improved timing of fertiliser application with regard to plant growth, and efficient irrigation practices can also be adopted to help reduce acidification. Over time, unchecked acidification can result in nutrient deficient soils and the accumulation of toxic materials, such as aluminium and manganese, which inhibits plant root growth and reduces crop yields. Unmanaged, it may also cause subsurface soil acidification (10-30 cm below the soil surface) which is much more difficult to treat.

Objectives

- To prevent the development of critical levels of soil acidification (pH < 4.5) in agricultural systems and return acidified soils to pH levels suitable for agricultural production.
- To minimise and prevent, where possible, formation of acid soils.

Condition

Indicator L8: Area of land with soils at risk of acidification.

Most farmers have a general awareness of soil acidity and knowledge of how to treat acidity problems. While no broadscale

monitoring exists, regional modelling for the South West is available to determine areas at risk of surface and subsurface acidification. Most of the South West shows evidence of elevated surface soil acidity risk, although some soils are more susceptible than others (Figure L3.1). It is estimated about two-thirds of the agricultural Wheatbelt is affected by surface soil (topsoil) acidity, or is at risk of acidification. The estimated area of strongly acidic soils (pH < 4.8) is 1-8 million hectares, and of moderately acidic soils (pH 4.8-5.5) is an additional 7-19 million hectares (Commonwealth of Australia, 2001b). This area is much greater than the land affected by dryland salinisation (see '*Land salinisation*').

Subsurface soil acidity can have as much effect on plant growth as surface acidity, but is more difficult and costly to treat, and in the long term may be more problematic and threatening. It is estimated there are 0.2-4.8 million hectares of acid subsurface soils in Western Australia (Commonwealth of Australia, 2001b). The areas with, or at highest risk of, subsurface acidification include the northern Wheatbelt and soils from Perth to Geraldton and Augusta to Albany (Figure L3.2). Estimates for the Avon River Basin, indicate that about 93% of surface soils and 83% of subsurface soils have moderate to high risk of acidification (Department of Agriculture and Food, unpublished).

Figure L3.1: Modelled surface soil acidification risk for the South West.

Data source: Department of Agriculture [ver. 2005]; Presentation: Department of Agriculture.

Figure L3.2: Modelled subsurface soil acidification risk for the South West.

Data source: Department of Agriculture [ver. 2005]; Presentation: Department of Agriculture.

Pressures

Indicator L9: Area of land planted for cropping, including legumes and wheat crops.

Plants take up nutrients (including acid-buffering chemicals) from soil, resulting in a separation of acidity in the soil and alkalinity in the plant. As agriculture removes plants from land (by harvesting crops or grazing pasture) less alkalinity is returned to the soil and over time it becomes progressively acidic. In the 10 years from 1994-2004, the total area of land dedicated to cropping has increased by about one-third, from 6.1 to 8.1 million hectares (Commonwealth of Australia, 2001b; Australian Bureau of Statistics, 2005). More land dedicated to cropping puts a greater area of land at risk of soil acidification.

Grasses, legumes and wheat typically acidify the soil faster than pasture due to their inefficient use of nitrate. In contrast, annual and perennial pastures are able to establish earlier at the break of the season (when rain starts) and effectively utilise the nitrate thereby reducing the rate of acidification. The area under legume production has decreased by nearly 40% between 1999 and 2005. This may help to alleviate high rates of soil acidification in some areas. The area under wheat production is about 13% higher and has increased in recent years due to favourable growing conditions (Table L3.1).

Table L3.1: Area of Western Australian land under legume and wheat production, 1999-2005.

Year of production	1999	2000	2001	2002	2003	2004	2005
Area of legume crop ('000 hectares)	1229	[illegible]	[illegible]	[illegible]	886	[illegible]	[illegible]
Area of wheat crop ('000 hectares)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Data source: Australian Bureau of Statistics - Agricultural Commodities Australia reports.

Indicator L10: Annual amount of nitrogenous fertiliser applied per hectare in agricultural areas.

Fertiliser containing nitrogen is primarily used for enhancing grain and pasture production. Dependency on fertiliser in WA is rising. Between 1989-90 and 2001-02, the amount of nitrogen-based fertiliser applied to soil grew about 450%, from 88 000 tonnes to 399 000 tonnes (McLennan, 1996; Australian Bureau of Statistics, 2002). When these fertilisers leach into soil, 'nitrification' (the natural process of conversion of ammonium to nitrate) occurs, during which acid is produced. If growing plants take up nitrate the potential for acidification is reduced, but if nitrate is leached from the root zone then acidity can build up. All ammonium-based fertilisers cause acidification, whether leached or not. Fertilisers that are not ammonium-based (such as urea) only cause soil acidification if the nitrate, into which they are converted, leaches from the root zone. Superphosphate fertilisers are not directly acidifying, but indirectly add to soil acidity by improving plant growth, and hence the amount of plant material (containing acid buffering chemicals) removed by harvesting or animal grazing. Application of sulfur to soil is also acidifying.

Current responses

Indicator L11: Annual amount of lime applied per hectare in agricultural areas.

Soil acidification in agricultural areas is primarily managed through lime or dolomite application. Best practice guidelines indicate that lime should be applied at one to 1.5 tonnes per hectare every 3-7 years. If soil pH is below 4.5, then two applications of lime are required within 5 years to lift the pH to within the normal range, which is then maintained by a liming maintenance regime. The best agricultural production responses to lime have occurred when the topsoil pH is very low (i.e. pH < 4.5). Moderately acidic soils (pH 5-5.5) typically show little yield response but depending on the crop, season and yield potential this may not always be the case.

In 2004, the amount of lime and dolomite applied to agricultural soils affected by acidity was 1.03 million tonnes - the highest level of use yet recorded in WA (Figure L3.3). There is evidence of a gradual rise over the past decade in both the area of farmland treated and the quantity of lime being used. While growth in lime use is encouraging from an agricultural perspective, the actual amount of lime required to maintain current acidity in agricultural soils is about double (2 million tonnes per year). Unfortunately, monitoring of lime use has since ceased and was not undertaken in 2005 and 2006.

Treatment of subsurface soil acidity with surface applications of lime can take many years. Subsurface soil acidification under crops has the potential to severely limit crop and pasture production. For long-term soil health, the prevention or minimisation of subsurface soil acidity is vital.

Figure L3.3: Western Australian lime and dolomite use and area treated over time.

Data source: Australian Bureau of Statistics, 1996 & 2002; O'Connell & Gazey, 2003; C Gazey, Department of Agriculture and Food, pers. comm.

Indicator L12: Percentage of farmers undertaking soil pH testing.

Estimates of surface soil testing for pH vary from 30% of farmers testing portions of their farms (Nutrient Management Systems, pers. comm.) to 65-75% of farmers undertaking regular pH testing of surface soils (Department of Agriculture, 2006). It is estimated that only 10% of farmers test acidity levels of subsurface soils (C Gazey, Department of Agriculture and Food, pers. comm.). Surveys also show that farmers have developed an increased awareness of acidification problems and the skills to help correct the problem (Department of Agriculture, 2006).

Draft State Lime Supply Strategy: was initiated in 1998 with the intention of enabling informed decisions about lime production and supply in relation to environmental, conservation, urban and heritage issues. The Department of Industry and Resources oversaw development of the strategy, with guidance from other government agencies (Department of Industry and Resources, 2001). The strategy is currently in draft form and is considered to be an evolving document.

Natural Heritage Trust/National Action Plan for Salinity and Water Quality (NHT/NAP): Through these two Commonwealth Government programs, the South West, Swan, Avon, Northern Agricultural and South Coast regional natural resource management groups have recognised soil acidification as a threat to natural resources. Strategies have outlined specific targets and onground projects to address soil acidification.

Integrated Soil Acidity Research, Development and Extension Program, 1992-2002: The Department of Agriculture and Food in conjunction with University of Western Australia, the Grains Research Development Corporation, and the Natural Heritage Trust coordinated this program. It investigated methods for slowing the rate of soil acidification, establishing the relationship between the level of subsurface acidity and crop yield losses, and developed techniques to add alkalinity back to acidifying soils. It was supported by a promotional extension campaign 'Time to Lime', during which annual lime use by farmers increased by 530% from 150 000 tonnes in 1994 to more than 800 000 tonnes in 2002 (Figure L3.2). The number of farmers using lime rose by 240% from 1353 to 3292 over the same period (Department of Agriculture, 2003).

Implications

Across Australia, the economic implication of soil acidification is estimated to be five to six times higher than dryland salinity (Commonwealth of Australia, 2001b). Acidity is insidious, with yield declines of 20-30% occurring over time (Department of Agriculture, 2000). Such losses may go unnoticed if farm productivity is improving for other reasons, such as increased fertiliser use. Plant and crop growth is often limited because of a reduction in the availability of nutrients (calcium, magnesium, boron, molybdenum) or an increase in toxic levels of aluminium, iron or manganese. Toxic levels of aluminium decreases root growth which leads to reduced water uptake by plants and crops, hence contributing to other problems such as waterlogging, erosion and salinisation. Extreme acidification can result in poorly structured or hard-setting topsoils that don't support enough vegetation to prevent soil erosion. Soils may also acidify to the point where acid, nutrients, sediment and heavy metals are exported and impact nearby inland waters (see '*Acidification of inland waters*').

Liming is viewed as the major remediation option for soil acidification on farms. Risks of substantial farm losses exist if liming programs are not commenced before critical surface and subsurface pH levels are reached. However, due to the rapid increase in lime use in agricultural, mining and construction industries, significant pressure has been placed on existing and potential limestone stocks. Lime is currently quarried at about 30 coastal sites between Geraldton and Esperance, with many situated in areas of conservation value. These sites are under significant threat from increased lime mining activity as demand increases, and questions are being raised about the sustainability of liming.

Suggested responses

3.7 Develop and implement a Soil Acidification Management Strategy as a component of the proposed State Soil Protection Policy, covering all types of acid soils.

3.8 Finalise and implement the draft State Lime Supply Strategy incorporating sustainability principles.

GOVERNMENT OF WESTERN AUSTRALIA
Department of Agriculture and Food

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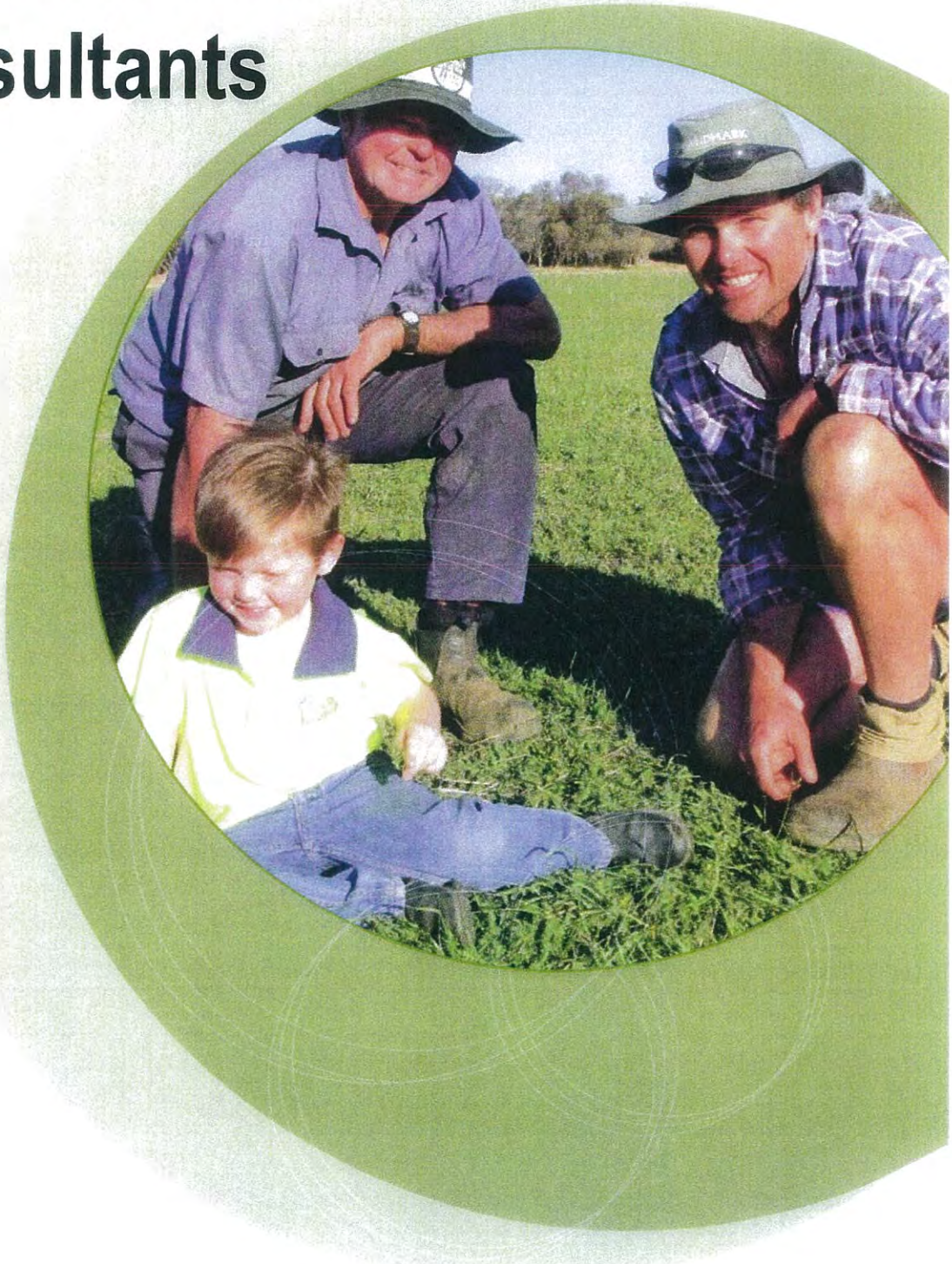
Soil acidity

A guide for WA farmers and consultants



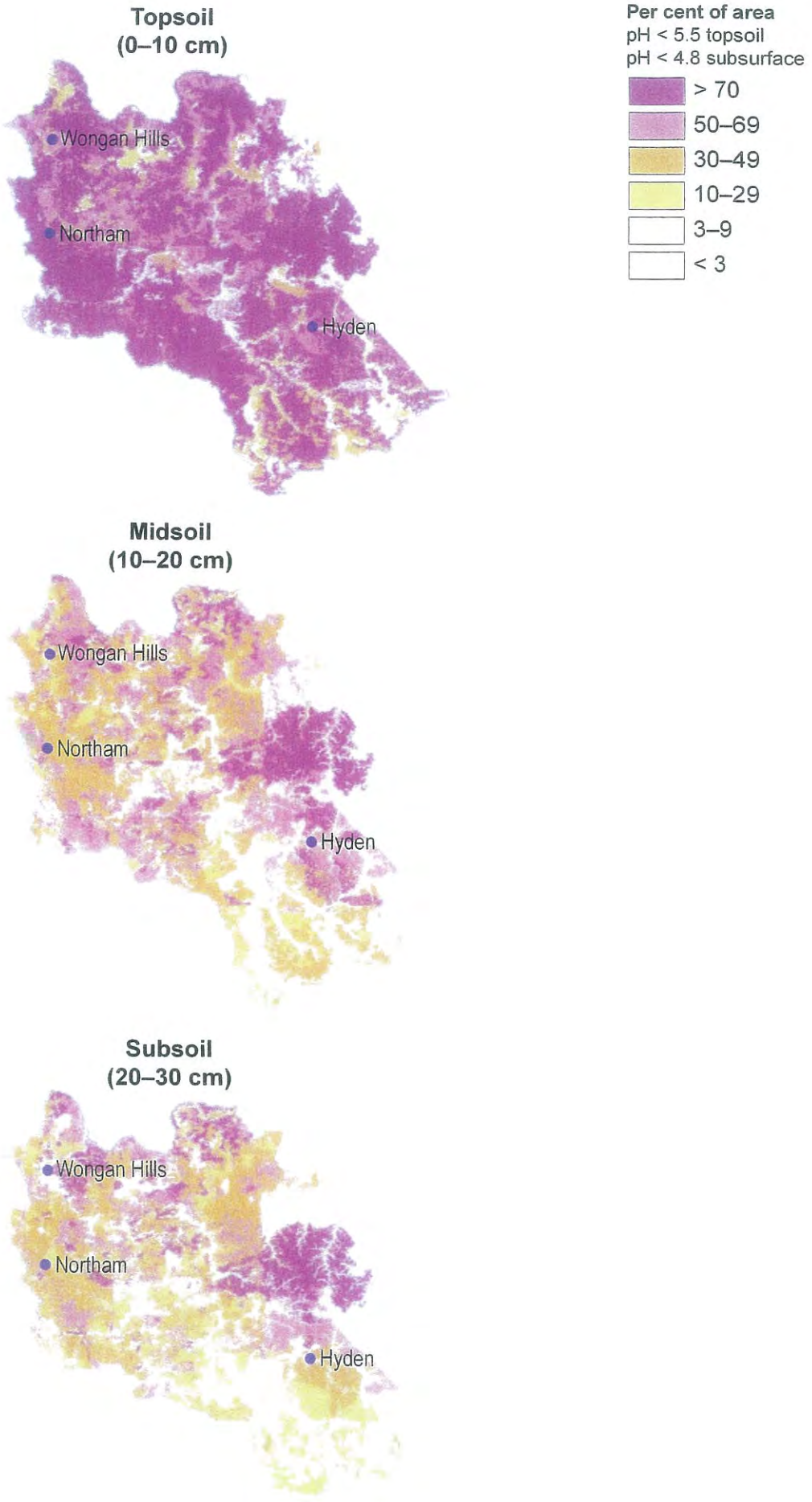


Figure 2 **Percentage area of the Avon River Basin (Figure 1) with soils below DAFWA pH targets**

PART 1

Management of soil acidity

Diagnosing soil acidity

The only way to diagnose soil acidity is to sample the soil and test the pH. While liming to counter soil acidity needs to be part of normal farming practice in most of the wheatbelt, accurate knowledge of the soil pH allows more precise management decisions. Subsurface soil testing to determine the pH profile of the soil is vital. In many soils, an acidic subsurface or acidic subsurface layer may be limiting root growth and access to water and nutrients (Figure 3).

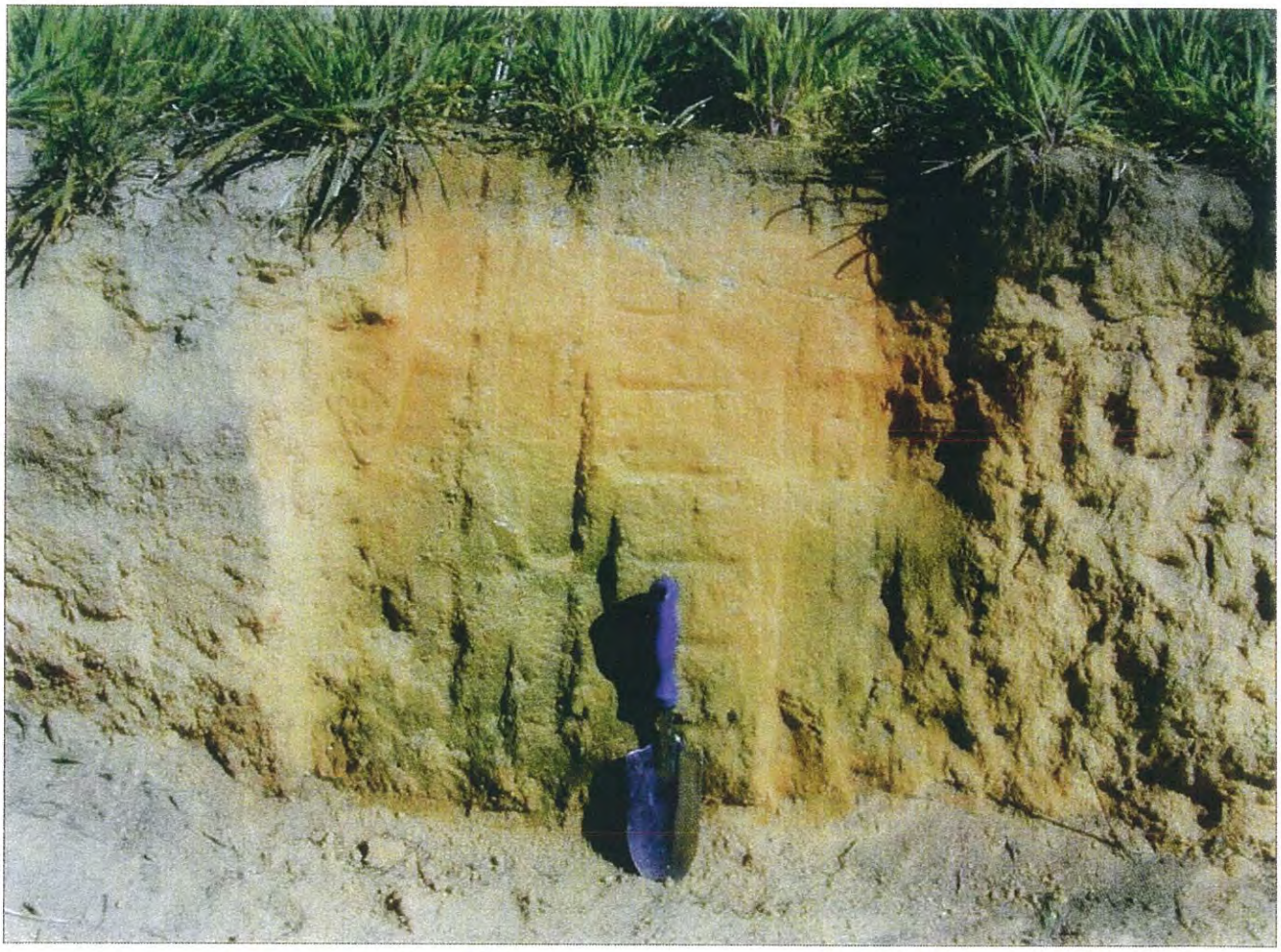


Figure 3 **Soil profile at Tammin stained with universal indicator showing acidic subsurface layer (stained orange) which prevents root access to soil with suitable pH below (stained green)**

Soil sampling

Topsoil pH can be quite different from the subsurface soil pH and sampling only the topsoil may lead to inadequate lime applications. Acidity in the subsurface cannot be detected or estimated by knowing the topsoil pH. Samples should be taken at 0–10, 10–20 and 20–30 cm to determine a soil pH profile.

Ideally, soil samples should be taken in summer, when most soils are hot and dry with minimal biological activity. This will minimise the impact of seasonal variations in pH, which will be further reduced by measuring pH in a calcium chloride solution rather than water.

Paddock variability, particularly soil type changes, should be taken into account when designing sampling programs. It is important not to under-sample; knowing and understanding 'management areas' within paddocks will allow targeted lime inputs to maximise economic return. For example, clay soils are generally slower to acidify but require more lime to lift pH when they become acidic.

Diagnosing soil acidity

Commercial contractors

The best option is to use a specialised soil-sampling contractor and seek expert advice for individual liming recommendations (Figure 4). Professional soil-sampling contractors should geo-locate sampling sites and arrange laboratory testing of the samples. They may also provide record-keeping services and liming recommendations. Sampling for soil pH testing is often done in conjunction with soil nutrient sampling for fertiliser recommendations.

Do-it-yourself sampling

A do-it-yourself approach to soil sampling is possible. Divide the paddock up according to soil type and areas that have different crop or pasture growth. Typically, six to eight sample sites per paddock is adequate, with representative sites from each soil type or management area in the paddock. If the paddock is uniform, a grid pattern can be used or evenly space sites over the whole paddock. Avoid unrepresentative areas such as stock camps, paddock corners and harvest windrows.

Collect cores from around each site and bulk them into one sample, keeping the 0–10, 10–20 and 20–30 cm layers separate and being careful to prevent topsoil contamination of the subsurface samples.

Traditionally, soil sampling has been done with a 'pogo stick' sampler, designed to sample the top 10 cm of soil. This type of sampler is unsuitable to sample the 10–20 and 20–30 cm soil layers that are necessary for soil pH sampling. A 5 cm diameter exhaust tube, marked in 10 cm increments, is a suitable alternative (Figure 5).

Soil samples should be sent to a laboratory accredited with the Australasian Soil and Plant Analysis Council Inc. and the pH measured in a one part soil to five parts 0.01 M calcium chloride solution (see measurement of pH, page 25).

Do-it-yourself soil sampling has a number of drawbacks; it requires a dedication to the task and inputs of time for sampling, arranging laboratory testing, sourcing liming

Figure 4 **Soil sampling at Kellerberrin. Professional soil-sampling contractors should be able to accurately sample the soil profile.**

recommendations and accurate record keeping to enable comparable repeat sampling over years for monitoring pH change.

Commercial soil sampling kits

Prepaid commercial soil sampling kits are available and may be the most convenient method for the do-it-yourself approach as they include full instructions, sample bags, postage and laboratory testing of the samples. These kits are primarily aimed at topsoil sampling and testing for fertiliser recommendations, but the subsurface 10–20 and 20–30 cm layers may be sampled for pH at the same time (a suitable sampling tube, or commercial soil sampling contractor able to accurately sample the subsurface, will need to be used).

Field pH testing

Laboratory testing of pH provides the most accurate measurement of soil pH. Field testing with a hand-held pH probe may provide an indication of areas that need accurate soil sampling and testing. Hand-held pH probes are available from scientific equipment suppliers and come with instructions. When field testing soil pH, it is usually more convenient to use deionised or distilled water instead of 0.01 M calcium chloride and so the results will need to be converted by subtracting 0.7. It is important to maintain the probe in good condition and calibrate with standard pH buffer solutions each day it is used.

Soil pH test kits that use indicator solutions and colour to estimate pH are inexpensive and easy to use. However the results are subjective and should be used with caution. The chemicals used with the kits are subject to deterioration.

Monitoring soil pH

Monitoring soil pH by re-sampling every three to four years enables liming programs to be developed and refined for individual situations. Tracking changes in the soil pH requires samples to be collected from the same location over time. Samples need to be properly geo-located, preferably by GPS, to allow comparable repeat sampling.

Sampling 25 per cent of a farm each year enables a four-year rotation. This is an adequate time frame to detect changes and allow adjustment of liming practices.

Figure 5 **An exhaust tube marked in 10 cm increments is useful for do-it-yourself sampling.**

Liming acidic soils

Soil acidification is an inevitable and ongoing consequence of productive agriculture. Whether soil becomes acidic depends on how well ongoing soil acidification is managed as part of the farming system.

Target pH

DAFWA recommends soil pH values at or above 5.5 in the topsoil and 4.8 in the subsurface (Figure 6). These values have been developed based on hundreds of trial-years of data. Maintaining topsoil pH above 5.5 will treat ongoing acidification and ensure that sufficient alkalinity can move down the soil profile and treat subsurface acidification. The effects of aluminium toxicity in the subsurface are minimised if the pH is above 4.8.

Soil pH test results can be interpreted using DAFWA targets as a basis. If the top and subsurface soil pH values are at or above target values, only maintenance levels of liming will be required to counter ongoing acidification due to agriculture.

If the topsoil pH is below 5.5, recovery liming is recommended to prevent the development of subsurface acidity, even if the subsurface pH is currently at 4.8. When the topsoil pH is below 5.5, insufficient alkalinity can move down to counter ongoing acidification in the subsurface and the pH is likely to drop. If the subsurface pH is below 4.8, liming to maintain (or recover) topsoil pH at or above 5.5 is essential and subsurface pH should be monitored in three to four years so that the liming rates can be adjusted if insufficient alkalinity has moved down to treat the subsurface acidity.

Figure 6 **Discussing the implications of a target pH profile at Casuarina, north of Mingenew**

Liming acidic soils

Applying agricultural lime is the most cost-effective way of treating soil acidity. The amount of lime required will depend on the current pH profile, soil type, rainfall, farming system and lime quality.

Maintenance liming

Knowing how farming system inputs and exports contribute to soil acidification will help to calculate the amount of lime required to counter ongoing soil acidification due to agriculture (maintenance liming).

Different amounts of alkalinity are exported in various farm products and need to be replaced in the form of lime to prevent soils acidifying (Table 1).

The amounts of lime required to counter the acidifying effects of common nitrogen fertilisers are given in Table 2. Ammonium fertilisers are the most acidifying. Elemental sulfur can contribute to soil acidification when it is converted to sulfate (the form that can be taken up by plants), however, relatively little elemental sulfur is applied in WA farming systems and its contribution is small compared to ammonium fertilisers. If sulfur is applied in the form of sulfate, as in calcium sulfate (gypsum) it is non-acidifying. Phosphate fertilisers are non-acidifying.

Typically, a wheatbelt farming system operating a winter crop/pasture rotation in WA has an acidification rate equivalent to 25–345 kg/ha/year of pure calcium carbonate (Dolling 2001). Required liming rates can only be estimated and monitoring of the soil pH profile every three to four years is recommended so that the liming program can be refined.

Table 1 **The lime equivalent (as pure calcium carbonate) of various farm products (Moore 1998)**

Product removed	$CaCO_3$ equivalent (kg/t)
Cereal grains: wheat	9
barley	8
triticale	7
Cereal whole tops	20
Canola	2
Lupin grain	20
Lupin whole tops	60
Lucerne hay	60
Hay (mixed grasses)	30
Subclover (whole plant)	40
Sheep: dung	25
urine	9
lambs	3
wool (6 kg/sheep)	0.4

Table 2 **Lime (as pure calcium carbonate) required to neutralise acidity generated by various common nitrogen fertilisers (Moore 1998)**

Nitrogen fertiliser	$CaCO_3$ required to neutralise nitrogen addition (kg $CaCO_3$/kg nitrogen[1])	
	none leached	100% leached
Ammonium sulfate (Agras #1, MAP)	3.6	7.1
Ammonium nitrate (Agran)	0	3.6
Urea	0	3.6
DAP	1.8	5.4
Potassium nitrate	–3.6[2]	0
Sodium nitrate	–3.6	0

[1] Per weight of nitrogen (N) in the fertiliser, not per weight of the fertiliser.

[2] Negative values indicate a liming effect by the fertiliser.

Recovery liming

Estimating the amount of lime required to recover acidic soil to recommended pH targets is complicated. Enough lime needs to be applied to treat ongoing acidification as well as the already acidified soil (Figure 7).

The rule-of-thumb guide (Table 3) indicates of the amount of lime that may be required to achieve topsoil pH above 5.5 and subsurface pH above 4.8 after 10 years. Increases in pH will depend on soil type, rainfall, lime quality and quantity applied and other farming practices as well as the soil pH profile. Expert advice should be sought for individual recommendations.

Monitoring the topsoil and subsurface soil about every three years is very important when liming to recover acidic subsurface soil. This will allow adjustment of the liming schedule as the soil pH increases or if it does not respond as expected. It is essential to maintain the topsoil pH above 5.5 for alkalinity to move down to treat acidity in the subsurface soil.

Table 3 **Rule-of-thumb lime guide developed for the Avon Catchment Council**

Soil depth (cm)	pH	Lime amount over 5 years
0–10	< 5	2 t/ha
	< 5.5	1 t/ha
		plus
10–20	< 4.5	2 t/ha
	< 4.8	1 t/ha
		plus
20–30	< 4.5	1 t/ha
	< 4.8	measure pH in 3 years

Figure 7 **Liming trial at South Bodallin. When enough lime is applied to treat an acidic soil profile significant plant growth and production responses can be achieved.**