

5. VEGETATION AND FLORA

5.1 ASSESSMENT CRITERIA

5.1.1 EPA Objective

The EPA management objective for flora and vegetation is:

- *To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvements in knowledge.*

5.1.2 EPA Position Statements and Guidance

Position Statement No. 2 (2000)

Position Statement No. 2, *Environmental Protection of Native Vegetation in Western Australia* (EPA 2000a), outlines EPA policy on the protection of native vegetation in Western Australia. It identifies basic elements that the EPA should consider when assessing Proposals that impact on biological diversity, such as:

- comparison of all Proposal options
- avoidance of species and community extinctions
- an expectation that implementing the Proposal will not take a vegetation type below the “threshold level” of 30%

Proponents should demonstrate that on- and off-site impacts can be managed.

Position Statement No. 3 (2002)

Position Statement No. 3, *Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA 2002b) discusses the range of International, National and State agreements and policies currently influencing the future protection of biodiversity in Western Australia and the need to review and improve the quality and quantity of information required for environmental impact assessment. In these regards, the EPA has set the following positions and expectations:

- the EPA will adopt the definition of Biological Diversity and the Principles as defined in the National Strategy for the Conservation of Australia’s Biological Diversity (Commonwealth of Australia 1996)
- the quality of information and scope of field surveys should meet standards, requirements and protocols as determined and published by the EPA
- the Interim Biogeographic Regionalisation of Australia (IBRA) should be used as the largest unit for EIA decision-making in relation to the conservation of biodiversity
- terrestrial biological surveys should provide sufficient information to address both biodiversity conservation and ecological function values within the context of Proposals
- the results of surveys should be publicly available.

Guidance No. 6 (2006)

Guidance No. 6, *Rehabilitation of Terrestrial Ecosystems* (EPA 2006b), represents the EPA's minimum expectations for the satisfactory rehabilitation of disturbed ecosystems. It is relevant in this review as it provides the framework for assessing the significance of difference in composition before and after disturbance (one of the considerations for biodiversity protection).

The Guidance considers the following information as necessary for accurate environmental impact assessment, in terms of rehabilitation:

- sufficient baseline information for environmental management and to assess rehabilitation performance
- accurate information about landform, soils and hydrology and their relationship to biodiversity, so that predicted permanent changes to biotic components can be assessed
- information about the diversity of plants and their capacity to recruit from seeds.

Guidance No. 10 (2006)

Guidance No. 10 *Level of Assessment for Proposals Affecting Natural Areas Within the System 6 Region and Swan Coastal Plain Portion of the System 1 Region* (EPA 2006c) includes the criteria the EPA will use when determining the level of assessment for a Proposal. Criteria for the identification of regionally significant natural areas (which are considered by the EPA to be a 'critical asset') are also provided.

Guidance No. 51 (2004)

Guidance No. 51, *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004d) is a supporting guideline for the implementation of EPA Position Statement No. 2 and aims to promote survey work that is uniform and of sufficient rigour to contribute to a more systematic inventory of Western Australia's biodiversity. It provides the general standards and a common framework for terrestrial flora and vegetation surveys for environmental impact assessment (EIA), the quality and quantity of information that should be derived from these surveys and the consequent analysis, interpretation and reporting.

In regards to the approaches, resources and standards required for flora and vegetation surveys, the EPA expects that:

- resources for the survey and documentation of the flora and vegetation will be commensurate with the scope of the survey and complexity of the subject area, for example:
 - sampling intensity (number, interval etc of sample sites/observations) is attuned to the complexity of the flora and vegetation of the Proposal
 - resources for plant identification and specimen processing are adequate
 - resources for data analysis, mapping and interpretation are also adequate
- there will be a high degree of rigour in the reporting, including the identification and discussion of survey limitations
- there will be a requirement for standardisation of techniques and technology, i.e. minimum standards apply so that future work is comparable

- surveys should be led by appropriately trained and experienced botanists
- surveys should be conducted at an appropriate time of the year
- surveys should be prepared in consultation with the EPA.

Native vegetation clearing principles

The EPA has a presumption against recommending approval for Proposals that are likely to have adverse impacts to native vegetation that are seriously at variance to the principles to protect native vegetation listed under Schedule 5 of the Environmental Protection Act (EPA 2006a). The assessment of the Proposal against the principles is presented in Section 8 of the ERMP, as it includes consideration of factors relating to fauna (Section 6) and rivers and wetlands (Section 7).

5.1.3 Other relevant legislation and policies

Wildlife Conservation Act 1950

Under the Wildlife Conservation Act, individual species of plants and animals are protected, with the level of protection varying depending on whether the species is rare or endangered. To be protected under the Act, flora must be “declared” as such by the Minister for the Environment. Currently, all flora native to the State is protected, including marine plants such as seaweed and seagrass. The Minister for the Environment may also declare any species of flora as being rare where that species is likely to become extinct or is otherwise in need of special protection.

Under the Act it is an offence to “take¹⁵” protected flora:

- on Crown land (that is, any land other than private freehold land) without a licence from the DEC
- on private land where the flora is taken without the consent of the owner or occupier of the land; or is taken for the purpose of sale, and the person does not hold a licence from DEC.

The DEC Policy Statement No. 9 discusses the legislation relating to Declared Rare Flora (DRF) and outlines the criteria for gazettal.

5.1.4 Other assessment requirements

Policy Statement No. 9 (draft)

The DEC’s draft policy statement on conserving threatened species and ecological communities is yet to be finalised and effected. It sets out the objectives and processes for managing threatened or potentially threatened species and ecological communities and the criteria for their listing as such. The draft policy also describes the role of the Western Australian Threatened Species Scientific Committee (WATSSC).

¹⁵ To “take” in relation to flora includes to gather, pluck, cut, pull up, destroy, dig up, remove or injure the flora or to cause or permit the same to be done by any means.

Forest Management Plan (2003)

Approximately one-third of the native vegetation to be cleared as part of the Proposal lies within State Forest, which is outside of the scope of Guidance Statement No. 10 (EPA 2006c) but comes under the administrative influence of the Forest Management Plan (FMP, CCWA 2004).

The Conservation Commission of WA (CCWA) recognises that mining companies operate within and that many mineral and basic raw material resources are located on State Forest lands. Accordingly, the FMP includes the following actions that relate to mining activities and Proposals for State Forest areas:

- CCWA will encourage mining companies to act in a manner that is consistent with the FMP
- CCWA will recommend the inclusion of a formal requirement for the rehabilitation of State Forest areas that are proposed to be mined
- CCWA will make submissions in relation to mining Proposals submitted to it for comments or advice which seek to reduce the impact of those Proposals on informal reserves and the forest generally.

In regards to the first and last points, there is also a number of subordinate plans that the CCWA will refer to when commenting on mining Proposals, such as the Soil and Water Conservation Guidelines (DEC 2008a).

5.1.5 Environmental Scoping Document

The Environmental Scoping Document (ESD, Strategen 2007) provides a preliminary review of the vegetation and flora of the Proposal site and surrounds and requires Bemax to address the following comprehensive list of actions in the ERMP:

1. Consolidate all floristic information collected to date into a publicly available review, including raw data.
2. Continue to liaise with other floristic survey and/or assessment programs, such as Swan Bioplan, Regional Forest Agreement, and other Proposals in the area, for the supply and exchange of data.
3. In collaboration with DEC (including Swan Bioplan Project Officers), use necessary data, including Whicher Bioplan survey data, to determine the regional significance of site flora and vegetation and the presence of Threatened Ecological Communities (TEC) in the Proposal site. For those vegetation units where the Proposal is deemed to have a significant impact on the known remaining population (on advice from DEC), this determination will be at the vegetation unit level of vegetation community mapping.
4. Further examine and document the relationships between vegetation communities and conservation significant plant species with landforms, soils, elevation, moisture regimes, etc. Utilise outcomes to increase understanding of regional distribution.
5. Develop a Significant Species List that, for each species, includes a description of the species, its habitat requirements, its pre-mining distribution, the importance and location of other known populations in relation to determining the significance of proposed clearing, current reservation status, an assessment of susceptibility, opportunities for increasing the size/extent of the species, and how all this fits into the Rehabilitation Plan.

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6. Further describe the habitat requirements and review and document the numbers of the DRF species *Daviesia elongata* ssp. *elongata* within and outside of the mineral lease area.
7. Assess vegetation in riparian zones, in regards to seasonality of certain species.
8. Undertake a further dieback survey within the project area (on Crown and private lands).
9. Review plot and transect data to determine vegetation condition across the study area, as a baseline to detect mine-related impacts.
10. Assess clearing requirements by identifying and costing alternative locations on cleared land for stockpiles and other infrastructure and comparing with environmental impacts for each area.
11. Estimate and map any potential areas where additional plant deaths may occur as a result of the mining Proposal, such as those linked to groundwater drawdown or contamination, interruption of surface flows, dieback spread, dust, etc.
12. Investigate data standardisation and (perpetual) sharing opportunities.
13. Design, conduct and analyse vegetation and flora surveys in accordance with EPA Guidance No. 10 and No. 51.
14. Conduct assessment for local and regional significance against EPA Position Statement No. 2, Appendix 3 of Guidance No. 10 and Table 6 of Guidance No. 6.
15. Compare the proposed clearing area against the north-eastern Whicher Scarp, which is considered floristically different to the remainder of the scarp.
16. Identify the local and regional linkage values within, and in the vicinity of, the mining tenements and assess the impacts on these linkages of the proposed clearing methodologies used in the preparation of the Greater Bunbury Region Scheme (WAPC 2004).
17. Examine role of riparian environments as ecological linkages in the Proposal site.
18. Review proximity to and/or interaction with informal conservation areas and identify opportunities to extend formal conservation areas through offset provisions.
19. Review impact on possible long-term conservation/reservation plans for the area, in consultation with DEC.
20. Consult with DEC and other stakeholders on potential rehabilitation definitions, completion criteria and to identify and progress on constraints.
21. Review rehabilitation performance to date by the Proponent, by the industry, and by other projects in the area to identify constraints, opportunities and performance benchmarks.
22. Identify and assess the constraints to rehabilitation that might apply to the Proposal, using Guidance No. 6.
23. Prepare a full species list and research optimum propagation methods and probability of success.
24. Identify seed collection areas that meet provenance requirements.
25. Research topsoil and soil profile characteristics and their importance to the rehabilitation definitions.
26. Conduct a preliminary assessment against Table 7 of EPA Guidance No. 6.

5.1.6 Application of assessment criteria

Approach

Criteria identified from the above policy, guidance and ESD have been used in this impact assessment to determine the significance of any potential impacts of the Proposal on native vegetation and flora. The assessment applies the most relevant criteria to the most relevant scale and/or survey method due to the definitions of vegetation communities varying according to scale or survey method (Section 5.1.7).

Scope

This section describes and addresses potential impacts to vegetation communities and flora, using the above derived criteria. Potential impacts to biodiversity and natural areas (that also consider landscape, soil and fauna values) are addressed in Section 8.

Unavoidable and indirect potential impacts

For the purposes of defining the potential impacts to vegetation and flora, it can be considered that the Proposal may result in disturbance to vegetation by:

- planned or unavoidable clearing of vegetation
- indirect or incidental disturbances, such as accidental vegetation clearing, groundwater drawdown or the spread of disease.

Indirect impacts that are largely preventable may be avoided by ensuring environmental management controls, such as hygiene procedures, are properly designed and implemented. Indirect impacts that are typically unavoidable, but may be unforeseen, include those that arise from reduced groundwater availability to vegetation surrounding the mine pits, resulting in vegetation stress and sometimes death.

The Proponent has investigated the potential for drawdown of superficial aquifers surrounding the mine pits (section 7) and found that the depth of the Happy Valley deposits does not intercept any significant standing watertable, however the potential exists for localised, seasonal perching to be affected by the Proposal (PB 2008b). This potential has implications for plant taxa that have a strong reliance on such hydrological features and that are growing close enough to the pit to be affected by groundwater drawdown.

The distance of propagation and extent of drawdown of perched systems from the mine pit is determined by:

- whether the system up or down-slope from the edge of the pit
- the hydrological gradient
- the lateral hydraulic transmissivity of the soils
- the presence of other barriers
- the sensitivity of each taxa to drawdown
- the availability of other plant water sources, including rainfall.

While the distribution of native plant taxa that have been noted as associated with wet and/or damp sands is widespread through the areas of shallow laterite up-gradient of the proposed pit, only two areas of sub-surface saturation have been identified (Section 5). Both of these areas have been previously drilled to 25 m+ depth on a 50 m by 25 m grid as part of the exploration programme in 1998 – the continued presence of saturation indicates a low lateral transmissivity, which has been confirmed by field work (PB 2008b).

Definition of disturbance footprint (sum of direct and indirect)

As described in Section 2, the Proponent has calculated that the area of vegetation that will be disturbed by the Proposal is 155 ha, and that this area includes a 25 m cleared buffer (average) around the pits and a 10 m cleared buffer around mine infrastructure. The Proponent is confident that the calculated area is a sufficiently conservative estimate of any final disturbance footprint given the confirmed absence of a significant standing watertable within the pit area, the low lateral hydrological gradient and limited examples of localised perching.

5.1.7 Definitions and concepts

Ecological community

An ecological community is a naturally occurring biological assemblage of species occupying a particular area, identified through a combination of parameters, including species composition, structure and habitat (DEC 2007b). The scale at which ecological communities are defined will often depend on the level of detail in the information source, therefore no particular scale is specified (from DEC 2007b).

Vegetation community

Vegetation communities can be defined in a number of ways ranging from mapping units based on the dominant species in each strata (structural) to units defined in terms of the composition of the vascular plants (floristics) (DEC 2007b).

A vegetation community may be considered to be significant for a variety of reasons, including:

- it is listed as a Threatened or Priority Ecological Community under a State or Commonwealth process
- its current extent is below a threshold occurrence level based on the pre-European extent of the community
- it contains unusual species or a novel combination of species
- its role as a key habitat for threatened species or large populations representing a significant proportion of the local to regional total population of a species
- its role as a refuge
- being representative of the range of a unit (particularly, a good local and/or regional example of a unit in 'prime' habitat, at the extremes of range, recently discovered range extensions, or isolated outliers of the main range)
- a restricted distribution (EPA 2004d).

Floristic Community Type (FCT)

FCTs are vegetation units generally defined by analysis of compositional pattern within plots of a standard size. The plots are classified into groups with similar [total] species composition, relying on the establishment of a sufficient number of plots to reasonably cover the geology, geomorphology and floristic variability found in the study area (DEC 2007b).

Structural units

Structural units (or formations) are a vegetation unit that considers plant associations that have a similar physiognomy (a combination of vegetation structure, growth-form and dominant taxa) and are less independent of total floristic composition.

Vegetation Complexes

The approach of Heddle et al. (1980) and also of Mattiske and Havel (1998) is a variation on the structural classification method, as these studies described and mapped 'vegetation complexes', using the boundaries of major soil and landscape units as surrogates for vegetation boundaries, working from the generally recognised observation that such boundaries often coincide because of the influence of underlying geology and geomorphology (WEC 2002). Thus, while delineation of mapping units is based on previously determined soil and geological boundaries, the vegetation is usually described using the structure and dominant species approach.

Threatened Ecological Community

A Threatened Ecological Community (TEC) is one that is found to fit into one of the following categories by the Threatened Species Scientific Committee of the DEC:

1. Presumed Totally Destroyed (PD) - an ecological community that has been adequately searched for but for which no representative occurrences have been located.
2. Critically Endangered (CR) - an ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated.
3. Endangered (EN) - an ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future.
4. Vulnerable (VU) - an ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range.

Priority Ecological Community

Possible threatened ecological communities that do not meet survey criteria or that are not adequately defined are added to the Priority Ecological Community Lists under Priorities 1, 2 and 3. These three categories are ranked in order of priority for survey and/or definition of the community, and evaluation

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of conservation status, so that consideration can be given to their declaration as threatened ecological communities. Ecological communities that are adequately known, and are rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation dependent ecological communities are placed in Priority 5.

Declared Rare Flora

Under the *Wildlife Conservation Act 1950*, the Minister for the Environment may declare any protected (native) flora to be 'rare flora' if he/she is of the opinion that it is likely to become extinct or is rare or otherwise in need of special protection. Many of these species are also protected under Commonwealth legislation.

Priority Flora

Priority Flora are those that appear to be rare or threatened, but for which there is insufficient scientific information to properly evaluate their conservation status. While they do not have the same legal status as Declared Rare Flora they are considered under the Native Vegetation Clearing Principles of the *Environmental Protection Act 1986*.

The DEC uses the following four ratings for Priority Flora:

- Priority One -Poorly Known Taxa. Taxa, which are known from one or a few (generally <5) populations, which are under threat.
- Priority Two -Poorly Known Taxa. Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat.
- Priority Three -Poorly Known Taxa. Taxa, which are known from several populations, at least some of which are not believed to be under immediate threat.
- Priority Four -Rare Taxa. Taxa which are considered to have been adequately surveyed and which whilst being rare, are not currently threatened by any identifiable factors.

Significant flora

Significant plant species (including subspecies, varieties, hybrids and ecotypes) are described by the EPA (EPA 2004d) as those species, other than Declared Rare Flora and Priority flora that may be significant for a range of reasons, including:

- having a keystone role in a particular habitat for threatened species, or supporting large populations representing a significant proportion of the local regional population of a species
- having relic status
- possessing anomalous features that indicate a potential new discovery
- being representative of the range of a species (particularly, at the extremes of range, recently discovered range extensions, or isolated outliers of the main range)
- being associated with the presence of restricted subspecies, varieties, or naturally occurring hybrids
- having local endemism/a restricted distribution
- being poorly reserved.

Several of these reasons, such as outliers, restricted sub-species, etc, are considered to be suitable surrogates for genetic diversity (EPA 2004d).

Population

A 'population of a species' is defined under the EPBC Act as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species, occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations
- a population, or collection of local populations, that occurs within a particular bioregion.

Important population

An 'important population' is a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:

- key source populations either for breeding or dispersal
- populations that are necessary for maintaining genetic diversity
- populations that are near the limit of the species range.

Critical habitat

'Habitat critical to the survival of a species or ecological community' refers to areas that are necessary:

- for activities such as foraging, breeding, roosting, or dispersal
- for the long-term maintenance of the species or ecological community (including the maintenance of species essential to the survival of the species or ecological community, such as pollinators)
- to maintain genetic diversity and long term evolutionary development
- for the reintroduction of populations or recovery of the species or ecological community.

Such habitat may be, but is not limited to: habitat identified in a recovery plan for the species or ecological community as habitat critical for that species or ecological community; and/or habitat listed on the Register of Critical Habitat maintained by the Minister under the EPBC Act.

5.2 EXISTING ENVIRONMENT

5.2.1 Overview of the vegetation and flora of the Whicher Scarp

A number of published botanical surveys of the southern Swan Coastal Plain (SCP), the Whicher Scarp and the northern Blackwood Plateau have been reviewed to identify vegetation and flora values that are of significance or interest and to provide contextual information on the local-scale studies of the Proposal area by the Proponent. The key studies identified in the review were:

- Gibson N, Keighery BJ, Keighery GJ, Burbidge AH and Lyons MN., 1994, *A Floristic Survey of the Southern Swan Coastal Plain*.

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- Keighery BJ, Keighery GJ, Webb A, Longman VM, and Griffin EA., 2008, *A Floristic Survey of the Whicher Scarp*¹⁶.

The main points made by these studies included:

- the soils and vegetation communities of the creeklines and wetlands are both varied and restricted
- there is a definite broad-scale gradation in the soils and landform from the laterites and gravelly loams of the ridges and upper slopes, through coloured sands and gravels with occasional and localised laterite outcroppings, dropping down to the grey sands of the foothills
- this gradation is reflected in the distribution of three main overstorey taxa: upland woodlands dominated by *Eucalyptus marginata* with some *Corymbia haematoxylon*; upper slopes where *C. haematoxylon* becomes more dominant except on the localised outcroppings; mid slopes of *C. haematoxylon*, *Banksia attenuata* woodlands; and open low woodlands of *B. attenuata*
- with the exception of wetlands and creeklines, the gradations are often indistinct and many dryland taxa are present in more than one floristic community type.

Several other studies were also reviewed and are summarised as follows.

A Preliminary Consideration of the Floristics of the Whicher Scarp by Webb et al. (2006).

This is an early part of the same study from which the report of Keighery et al. (2008) arose and described the vegetation patterns of the Whicher Scarp as being dominated by three soil-vegetation associations and creeklines. The three soil-vegetation associations were:

1. A widespread community of *Eucalyptus haematoxylon*, *Banksia attenuata* woodland on grey sand over laterite rock that in areas becomes exposed at the surface, dominant within the northern extent of Abba and Argyle Forest blocks.
2. A more restricted and diverse community of *Eucalyptus haematoxylon*, *Banksia attenuata*, *Eucalyptus marginata* woodland on yellow/orange sands over sandy clay soils and/or laterite rock at some depth as found particularly within Argyle and Boyanup Forest blocks but also within Abba block. The Treeton Forest block has a similar landform with yellow/orange sands but appears to be over soils with higher clay content and *Banksia attenuata* is absent.
3. A broad vegetation community on the surface lateritic gravel with loamy soils of the higher elevations of the Whicher Scarp, ranging from *Eucalyptus marginata*, *Eucalyptus calophylla* woodlands to *Eucalyptus marginata*, *Eucalyptus haematoxylon* woodlands to straight *Eucalyptus haematoxylon* woodlands.

Webb et al. (2006) also provides lists of significant flora species and a brief description of sub-regional differences over the length of the Whicher Scarp, which are both developed further in Keighery et al. (2008).

¹⁶ This report is summarised relevant to the Happy Valley study area in Section 5.2.2.

Floristics of Reserves and Bushland Areas of the Whicher Scarp 1: Flora and Vegetation of Dardanup Forest Block by Keighery, Keighery and Gibson (2008).

This study focused on the 880 ha Dardanup Forest Block, which is the only proposed conservation area to encompass the Darling and Whicher Scarps and associated Swan Coastal Plain foothills. In terms of floristics, the study identified occurrences of the community types 1a and 21b of Gibson et al. (1994) to the west of the Forest Block. The study mapped three vegetation communities:

- Banksia/Jarraah woodlands on lower slopes
- Jarraah woodland to forest mixed with varying amounts of Marri on lateritic soils
- Mountain Marri woodland to low forest with varying amounts of Jarraah and Marri on the midslopes, crests and valley floors/colluvial fans.

Keighery, Keighery and Gibson (2008) noted the presence of a very distinctive form of the Mountain Marri woodland community occurring on outcropping quartzite ridges along the Darling Scarp, suggesting other examples may exist along the southern Darling Scarp and Whicher Scarp, and that it may be rare and restricted. There are no such quartzite ridges in the Proposal area.

5.2.2 Studies by the Proponent

Previous studies (1998 – 2004)

Vegetation Complex mapping

In 1998 and 1999, as part of the development of the earlier proposal for the Gwindinup Mineral Sands Project (Cable Sands 2000), Environmental Survey and Management Pty Ltd (ESM) prepared two reports on the landforms, soils, vegetation and flora of that proposal site, which included the majority of the Happy Valley tenements. These studies described the vegetation communities and their landform associations using the Vegetation Complex framework of Mattiske and Havel (1998). ESM also mapped vegetation condition and made a number of valuable observations in regards to landscape and vegetation patterns which have been incorporated into more recent studies. In 2000, Bennett Environmental Consulting Pty Ltd (BEC) used the methods of ESM to extend the mapping of Vegetation Complexes and vegetation condition onto Location 215 (M70/479).

The Vegetation Complex maps of ESM and BEC have been replaced with the digital dataset given the availability of the digitised Vegetation Complex mapping of the region by Mattiske and Havel (1998) and the requirement for local mapping at a finer scale (see below). This also allows for statistical assessments of regional representation (at a Vegetation Complex level¹⁷) to be made.

Vegetation Unit mapping

In 2003, the EPA Services Unit (EPASU) advised the Proponent that vegetation mapping at the Complex level was too broad for the local scale and did not highlight any minority units or variation within each of the Complexes. Additionally, advice from the (then) Department of Conservation and

¹⁷ The EPA requires that a proposal not take the extent remaining of any vegetation type below the 30% threshold level (EPA 2000a), however, it acknowledges that statistics based on percentage remaining of defined ecological communities are only available for major landform units and vegetation complexes (EPA 2006c)

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Land Management (CALM) was that the Floristic Community Type (FCT) 1a *Corymbia (Eucalyptus) haematoxylon – E. marginata* Woodland (Gibson et al., 1994) on the Whicher foothills, listed as unreserved and susceptible in conservation status, was a potential Threatened Ecological Community (TEC)¹⁸.

In response, the Gwindinup/Happy Valley tenements were remapped by BEC at the more detailed level of vegetation unit, based on dominant tree and understorey species. BEC (Bennett 2003) classified the vegetation of the five tenements into twelve different groups of thirty-four units:

- ten units having Jarrah (*Eucalyptus marginata* subsp. *marginata*) as the dominant tree species with scattered occurrences of other tree species, particularly Mountain Marri (*Corymbia haematoxylon*)
- one unit having Jarrah (*Eucalyptus marginata* subsp. *marginata*) and Marri (*Corymbia calophylla*) as the dominant tree species over *Banksia attenuata* woodland
- two units having Jarrah (*Eucalyptus marginata* subsp. *marginata*) and *Allocasuarina fraseriana* as the dominant tree species over open low heath in sand
- two units having Jarrah (*Eucalyptus marginata* subsp. *marginata*) and *Banksia grandis* over laterite
- four units having Jarrah (*Eucalyptus marginata* subsp. *marginata*) and *Banksia attenuata* in sand
- two units having Marri (*Corymbia calophylla*) as the dominant tree species with varying occurrences of other tree species, including Jarrah (*Eucalyptus marginata*) subsp. *marginata* and Mountain Marri (*Corymbia haematoxylon*)
- three units having *Banksia attenuata* woodland in sand
- one unit having *Banksia attenuata* and *Corymbia haematoxylon* in sand
- one unit having *Banksia attenuata* and *Banksia grandis* low forest in sand
- one tall shrubland unit (regrowth at Gwindinup)
- two heath units, one in sand and one in laterite
- five creekline units.

BEC inferred that five of the Jarrah (*E. marginata* subsp. *marginata*) units, in particular, those where Mountain Marri (*C. haematoxylon*) co-dominated and where *B attenuata*, *C. calophylla* and *Melaleuca thymoides* were atypical species, were comparable with the FCT 1a of Gibson et al. (1994).

Conservation significant flora

In late 2003, BEC and Onshore Environmental Consulting Pty Ltd (OEC) conducted intensive surveys of the mining tenements for conservation significant taxa highlighted by the EPASU, namely:

- *Daviesia elongata* subsp. *elongata* (DRF)
- *Caustis* sp. Boyanup (P4)
- *Daviesia nudiflora* subsp. *nudiflora* (range extent)

¹⁸ FCT 1a has since been listed as a Priority Ecological Community – see section 5.3.6

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- *Ricinocarpos cyanescens*
- *Logania connii* (now described as *L. wendyae*, a P1 taxa)
- other species suggested by EPASU.

The outcomes of this study are presented and discussed in Section 5.3.7: Potential Impacts to Flora.

Recent studies (2005 – present)

Floristic classifications

Between 2005 and 2007, sixty-one 10 m by 10 m permanent quadrats were established and surveyed in the Happy Valley tenements and surrounds to:

- build on the list of flora known to be present within the various habitats of the tenements
- identify floristic patterns (i.e. groups and communities) for comparison with other regional studies, including that of Gibson et al. 1994 and Keighery et al. 2008 (then forthcoming).

In early December 2005, forty of these quadrats were surveyed by Dr Eleanor Bennet (BEC) and Dr Darren Brearley (OEC) and reported in Bennett (2006). In September 2007, an additional nine quadrats in creeklines and ten quadrats in areas outside of the tenements were established and surveyed. A selection of fifteen quadrats from the 2005 suite (1 quadrat from each floristic group) was also resurveyed to meet DEC requirements. One additional quadrat was also established in the Happy Valley tenement as part of a transect up the face of the Whicher Scarp. Information recorded at each quadrat included species present and their percentage cover, vegetation classification (after Muir 1977), soil type and vegetation condition (after Gibson et al 1994). A summary description of each quadrat is provided in Appendix V2, with locations in the landscape shown in Figure 5-1.

A total of 381 taxa, 182 genera and 56 vascular plant families were recorded during the 2005 and 2007 surveys.

A precursory examination of floristic patterning in the quadrat data by BEC (Bennett 2007) using the PATN software package and presence/absence data identified some distinct groupings (Figure 5-1):

- quadrats on laterite and crests (eleven quadrats – included some dieback infested areas)
- quadrats on creeklines (eight quadrats)
- quadrats on grey sandy soils on footslopes and drainage lines and flats (18 quadrats)
- quadrats on coloured sands on mid-slopes (24 quadrats, including eight quadrats outside of the tenements).

For some groups, further classification was possible, for example the coloured sands group were easily differentiated between those within the tenements surveyed in 2005 and those outside of the tenements surveyed in 2007, while those surveyed in 2005 also split into two groups. Bennett (2007) also classified the vegetation based on structural units, with some attempt to relate these to floristic groups and Vegetation Complexes, but no clear patterns emerged from the effort.

Reconciliation and classification with regional floristic dataset

The quadrat data (presence/absence) were provided to E. A. Griffin and Associates¹⁹ (Griffin 2008) to be combined with and compared against that data collected by the DEC and Wildflower Society of W.A. (Inc.) for the Whicher Scarp and nearby Swan Coastal Plain (114 plots), as described in Keighery et al. (2008). This work would allow the quadrats surveyed locally by Bennett 2006 to be compared to the regional Whicher Floristic Community Types (FCT) of Keighery et al. (2008) to gain some understanding of the wider distribution of the local floristic communities²⁰, including a number of Priority Ecological Communities (PECs). Although this approach is consistent with EPA Guidance on floristic surveys (EPA 2004d), such comparisons contain inherent limitations, including:

- new observations (i.e. classifications) arising from the combined dataset that may cause a 'significant departure' from the original (e.g. Belbin 1992, Griffin 2008)
- differences in survey effort – in this case the Bennett (2006) Happy Valley quadrat density was one for every 15 ha of the mining tenements, while the quadrat density of the DEC regional dataset was one for every 215 ha of the entire Whicher Scarp
- differences in data quality (Griffin 2008 identified a number of genera as having differences in nomenclature or frequency or recording in the two datasets).

In combining the two datasets, Griffin made a number of changes to the Happy Valley quadrat data, to endeavour to address these limitations. He then used the computing package PATN (Belbin 1987, in Griffin 2008) to study the similarity of the floristic composition of the quadrats (as presence/absence) in the data sets. However, Griffin was unable to complete the interpretation of the results of the comparison (an incomplete draft of Griffin's 2008 report is provided). While the outcomes of Griffin 2008 have been used in this environmental review as a preliminary assessment of the likely presence of PECs in the Happy Valley Proposal area (Section 5.3.6), the EPA has agreed to the finalisation of the regional floristic classification as a separate study.

To progress the assessment process the EPA has agreed to the commencement of the public submission period prior to the completion of the regional analysis. However, a report on the findings of the regional analysis will be made available for public review for a minimum of two weeks. Ideally this will occur in parallel with, and at the end of, the public review period of the ERMP document. The completed report will be posted on the Bemax website at www.Bemax.com.au and hard copies will be forwarded to interested stakeholders in response to written requests.

Site vegetation types

Further work was required to develop a classification of the vegetation of the Happy Valley tenements and in particular the disturbance footprint that took into account the functional relationships between landscape position, soil structure and properties (for both topsoil and subsoils), hydrology, hydrogeology and floristic data for identifying locally significant natural areas and as the basis for rehabilitation planning.

¹⁹ A co-author of the Keighery et al. (2008) study report.

²⁰ An overview of Keighery et al. (2008) in this regard is provided in Appendix V1

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Dr Brearley²¹ reviewed the information collected to date by Bennett, including the results of PATN classification (using both presence/absence and species dominance) to develop a community classification that could be used in the field to map discrete boundaries and calculate spatial extent. The results of a detailed soil survey and investigations into soil profiles (Section 4) were also used. The 'classify then map' approach and the classification system used was in accordance with the *Australian Guidelines for Surveying Soil and Land Resources* (CSIRO 2008), which is consistent with the Australia-wide National Vegetation Information System (NVIS) (ESCAVI 2003). Broadly, that approach involved the following stages:

- classify survey sites based on structure, dominant floristics in each strata, landform and soil type
- as a separate process, produce a map of determinable ecological boundaries derived using high resolution aerial photography, soils survey and knowledge of the study site
- overlay study sites from the first step with the polygons identified in the second step to produce a preliminary vegetation map and classification descriptions
- validate the map by recording vegetation descriptions at numerous releve sites and also distinct vegetation changes (community boundaries) within the study area (tenements) and making adjustments to the map and vegetation community descriptions, where necessary.

Brearley identified 13 vegetation communities (called here 'site vegetation types', or SVTs) within the tenement boundaries. This is similar to the number of units classified (but not mapped) by Bennett (2007).

Independent validation

Consistent with the survey guidelines (CSIRO 2008), the vegetation classification and mapping of Brearley was subjected to independent validation by Dr Russell Smith (Ekologica Pty Ltd), who is considered very familiar with the vegetation of the Whicher Scarp and Blackwood Plateau.

Ekologica (2008a) established 107 releves at random points throughout the study area, at which he recorded all plant taxa²² within a radius of approximately 10 m for understorey species and 20 m for trees, along with a brief description of the soil. A structural description for each releve using the method of Muir (1977) was produced, which was then compared with the relevant mapping unit of Brearley and a score was allocated with regard to the closeness of match.

As a result of the review, several changes were recommended (Ekologica 2008b), including changing map unit boundaries at certain locations, amending unit descriptions and the creation of an additional unit (Ekologica 2008b).

Outcomes

The final fourteen site vegetation types (SVT) are described in Table 5-2 and mapped in Figure 5-2. The spatial extent of each SVT (as mapped) is shown in Table 5-1. These values include additional areas of SVT 14 identified outside of the tenements.

²¹ of Onshore Environmental Consultants Pty Ltd, consulting directly to the Proponent.

²² Some taxa, particularly annual and annually renewed taxa could not be identified due to time constraints.

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Table 5-1 Mapped extents of Happy Valley Site Vegetation Types (includes targeted areas outside of the Happy Valley tenements)

Site Veg Type	Mapped Extent (ha)	No. Mapped Populations	Proposed Impact (ha)	No. Popn's impacted	Relative Impact (%)
1. CcChXoPc	10	1	4	1	42%
2. EmCcAfChPeHh	47	1	0.5ha	-	1%
3. EmCcChXoKaMtPeKrSIHhMt	37	2	-	-	-
4. EmCcChBaMtHhPc	66	4	6	2	9%
5. EmAfChBaBgDhMtSIHhPc	75	3	19	1	26%
6. EmChBaBgMtHhSIpc	25	2	-	-	-
7. EmAfChMtHh	20	1	3	1	16%
8. EmCcChBgXoPIXpXaDhHhCsDI	272	2	55	1	20%
9. EmChXaXpAlBarmLpBpLp	15	2	-	-	-
10. EmChKaDhXpAl	1	1	-	-	-
11. EmAfChBgDhHh	63	3	11	1	17%
12. EmCcChBgDhHhSI	35	4	18	2	53%
13. EmChBgXpLmHg	13	1	-	-	-
14. EmChXoBgRcDnSIHhSwDI	133	5	32	1	24%

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Table 5-2 Site Vegetation Types - Happy Valley

Landform	Site Vegetation Type	Comments
Wet or riparian units	1 CcChXoPc - Open Low Woodland B of <i>Corymbia calophylla</i> , <i>Corymbia haematoxylon</i> and <i>Xylomelum occidentale</i> over Tall Sedges of <i>Phlebocarya ciliata</i> [on grey sands over laterite on upper slopes].	It is restricted to an area of very shallow laterite underlying leached grey sands and has a seasonal perched water table (impeded drainage). Perhaps for this latter reason, it is heavily affected by dieback disease but still retains a number of species of local significance. The CcChXoPc unit is considered locally restricted, with a single population covering only 10 ha recorded within the study area. Overall, however, as it has no dedicated plant taxa, is in less than good condition and does not serve any identifiable landscape function (the perched water table is not permanent), it is not considered to have elevated conservation significance.
	2 EmCcAfChPeHh - Woodland of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over Open Low Woodland A of <i>Corymbia calophylla</i> and <i>Allocasuarina fraseriana</i> over Open Low Woodland B of <i>Corymbia haematoxylon</i> over Low Heath C of <i>Pericalymma ellipticum</i> over Open Dwarf Scrub D of <i>Hibbertia hypericoides</i> [on grey/brown/yellow sand].	The unit is associated with creek lines and broad valley floors of the Whicher Valley (WCv) Vegetation Complex. Soils range from sand, through sandy loam and loam to sandy clay. The vegetation is highly variable, with considerable diversity in the understorey species, particularly in the transition between the creekline and the area surrounding it. The overstorey consists mainly of <i>Eucalyptus marginata</i> , <i>Corymbia calophylla</i> and <i>Allocasuarina fraseriana</i> . There are 3 disjunct populations of this vegetation unit, including the creek line that crosses the HVN area.
	3 EmCcChXoKaMtPeKrSIHhMt - Low Woodland A of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> and <i>Corymbia calophylla</i> over Open Low Woodland B of <i>Corymbia haematoxylon</i> over Open Scrub of <i>Kingia australis</i> and <i>Xylomelum occidentale</i> over Low Scrub B of <i>Melaleuca thymoides</i> , <i>Pericalymma ellipticum</i> and <i>Kunzea recurva</i> over Dwarf Scrub D of <i>Hibbertia hypericoides</i> and <i>Stirlingia latifolia</i> over Very Open Tall Sedges of <i>Mesomelaena tetragona</i> [on grey sand].	In the study area it occurs on the Whicher Scarp (slopes and valleys), Rosa (slopes and valleys) and Cartis (lower sandy slopes and sand plain) landforms and is associated with the creeklines and downslope wet areas on Loc 4485 and 4965. It is the only site vegetation type that includes <i>Agonis flexuosa</i> var. <i>flexuosa</i> and also <i>Cyathochaeta avenacea</i> (a sedge species).
Units with SCP affinities	4 EmCcChBaMtHhPc - Open Low Woodland A of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> and <i>Corymbia calophylla</i> over Open Low Woodland B of <i>Corymbia haematoxylon</i> and <i>Banksia attenuata</i> over Open Low Scrub B of <i>Melaleuca thymoides</i> over Dwarf Scrub D of <i>Hibbertia hypericoides</i> over Very Open Low Sedges of <i>Phlebocarya ciliata</i> [on grey sand].	SVT4 occupies the lowest foothill slopes along the western edges of the project area, abutting cleared land.
	5 EmAfChBaBgDhMtSIHhPc - Forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> and <i>Allocasuarina fraseriana</i> over Open Low Woodland B of <i>Corymbia haematoxylon</i> , <i>Banksia attenuata</i> and <i>Banksia grandis</i> over Open Low Scrub B of <i>Melaleuca thymoides</i> and <i>Dasyogon hookeri</i> over Dwarf Scrub D of <i>Hibbertia hypericoides</i> and <i>Stirlingia latifolia</i> over Open Low Sedges of <i>Phlebocarya ciliata</i> .	SVT5 is a variable mosaic of both Blackwood Plateau and Swan Coastal Plain vegetation, presumably facilitated by the presence of laterite and gravels but also of patches of deep grey sands where <i>Banksia attenuata</i> occurs. The vegetation includes many damp sands species (Keighery et al 2008) and is heavily affected by dieback.
	6 EmChBaBgMtHhSIPc - Open Low Woodland A of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over Low Woodland B of <i>Corymbia haematoxylon</i> , <i>Banksia attenuata</i> and <i>Banksia grandis</i> over Low Scrub B of <i>Melaleuca thymoides</i> over Open Dwarf Scrub D of <i>Stirlingia latifolia</i> and <i>Hibbertia hypericoides</i> over Very Open Low Sedges of <i>Phlebocarya ciliata</i> .	SVT6 is presumably a drier version of SVT5, being further up slope.
	7 EmAfChMtHh - Low Forest A of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> and <i>Allocasuarina fraseriana</i> over Open Low Woodland B of <i>Corymbia haematoxylon</i> over Open Low Scrub B of <i>Melaleuca thymoides</i> over Open Dwarf Scrub D of <i>Hibbertia hypericoides</i> .	By all appearances restricted to a steep, south-facing valley wall at HVS. The area is noted as being dieback affected, logged and partially grazed, with some laterite boulders and gravel outcrops on slopes.

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Landform	Site Vegetation Type	Comments
Upland (lateritic) units	8 EmCcChBgXoPIXPXaDhHhCsDI - Low Woodland A of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> and <i>Corymbia calophylla</i> over Open Low Woodland B of <i>Corymbia haematoxylon</i> , <i>Banksia grandis</i> and <i>Xylomelum occidentale</i> over Open Scrub of <i>Xanthorrhoea preissii</i> , <i>Xanthorrhoea acanthostachya</i> and <i>Persoonia longifolia</i> over Open Low Scrub B of <i>Dasyopogon hookeri</i> over Dwarf Scrub D dominated by <i>Hibbertia hypericoides</i> , <i>Dryandra lindleyana</i> subsp. <i>lindleyana</i> and <i>Calothamnus sanguineus</i> .	This site vegetation type is the widespread upland unit with plentiful Blackwood Plateau characteristics. While species richness is generally lower than areas on the lower slopes, changes in the flora and structure are observable on a fine scale, typically related to soil parameters and disturbance (logging, fire, dieback).
	9 EmChXaXpAlBarmLpBpLp - Forest of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over Low Woodland A of <i>Corymbia haematoxylon</i> over Low Scrub A of <i>Xanthorrhoea acanthostachya</i> and <i>Xanthorrhoea preissii</i> over Dwarf Scrub C of <i>Acacia lateriticola</i> , <i>Banksia armata</i> and <i>Leucopogon pulchellus</i> over Dwarf Scrub D of <i>Banksia bipinnatifida</i> , <i>Calothamnus sanguineus</i> , (<i>Hibbertia glomerata</i> subsp. <i>glomerata</i> , <i>Hypocalymma robustum</i> and <i>Isopogon sphaerocephalus</i>) [on brown sandy loam].	This site vegetation type was separated from SVT8, following the review by Ekologica (2008a), based on the paired presence of <i>Xanthorrhoea acanthostachya</i> and <i>Banksia armata</i> . Its location in the landscape indicates that it may receive subsurface drainage from up-slope.
	10 EmChKaDhXpAl - Open Woodland of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over Open Scrub of <i>Corymbia haematoxylon</i> and <i>Kingia australis</i> over Open Low Scrub A of <i>Dasyopogon hookeri</i> and <i>Xanthorrhoea preissii</i> over Dense Tall Sedges of <i>Anarthria laevis</i> .	This SVT is a minor subset of SVT8 but also shows similarities to SVT12.
Mid and upper slopes and crests	11 EmAfChBgDhHh - Open Woodland of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over Open Low Woodland B of <i>Allocasuarina fraseriana</i> , <i>Corymbia haematoxylon</i> and <i>Banksia grandis</i> over Open Scrub of <i>Dasyopogon hookeri</i> over Dwarf Scrub D dominated by <i>Hibbertia hypericoides</i> .	SVT 11 is a major landform component in the HVN area and consists entirely of a lateritic outcropping running parallel to the scarp on both private property and State Forest. It appears that, at its crest, the vegetation shares similarities with SVT8, but with SVT5 on its eastern margins and SVT4 on its western slopes, i.e. gradations do not seem to be well-defined.
	12 EmCcChBgDhHhSI - Low Woodland A of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over Open Low Woodland B of <i>Corymbia calophylla</i> , <i>Corymbia haematoxylon</i> and <i>Banksia grandis</i> over Low Scrub A of <i>Dasyopogon hookeri</i> over Dwarf Scrub D of <i>Hibbertia hypericoides</i> and <i>Stirlingia latifolia</i> .	This site vegetation type is also associated with laterite outcroppings, but at HVS and the laterite appears to be more weathered/friable and is present as gravel. It contains localised pockets of yellow sands and also occurrences of other sandplain taxa.
	13 EmChBgXpLmHg - Low Woodland A of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over Open Low Woodland B of <i>Corymbia haematoxylon</i> , <i>Banksia grandis</i> and <i>Persoonia longifolia</i> over Low Scrub A of <i>Lambertia multiflora</i> subsp. <i>occidentalis</i> and <i>Xanthorrhoea preissii</i> over Dwarf Scrub D of <i>Hibbertia glomerata</i> subsp. <i>glomerata</i> and <i>Platytheca</i> sp Argyle (G.J. and B.J. Keighery 2008).	This is another mosaic unit, located to the south of HVS on a steep, northwest-facing slope. Soils were mapped as grey sands, brown sandy gravels and laterite and contained several taxa most commonly associated with the Darling Range, including <i>Lambertia multiflora</i> var. <i>darlingensis</i> (P3).
Sandplain unit	14 EmChXoBgRcDnSIHhSwDI - Low Woodland A of <i>Eucalyptus marginata</i> subsp. <i>marginata</i> over Open Low Woodland B of <i>Corymbia haematoxylon</i> , <i>Banksia grandis</i> and <i>Xylomelum occidentale</i> over Open Dwarf Scrub C of <i>Daviesia nudiflora</i> subsp. <i>nudiflora</i> , <i>Ricinocarpos cyanescens</i> and <i>Stirlingia latifolia</i> over Dwarf Scrub D of <i>Hibbertia hypericoides</i> , <i>Synaphea whicherensis</i> and <i>Dryandra lindleyana</i> subsp. <i>lindleyana</i> .	This is the principle vegetation community defined by the deep yellow sands and habitat for the suite of species: <i>Daviesia nudiflora</i> subsp. <i>nudiflora</i> , <i>Ricinocarpos cyanescens</i> and <i>Daviesia elongata</i> subsp. <i>elongata</i> . The edges of the mapped extents include gravelly soils, but floristically and structurally, the vegetation has consistent themes. Additional examples of the community have been identified and mapped in several areas to the south of the mining tenements.

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Vegetation condition

The condition of the native vegetation remaining within the Happy Valley mining tenements was assessed by Bennett and Brearley in 2006/2007 (Bennett 2006, 2007) (Figure 5-3), using the vegetation condition rating scale of Gibson et al (1994) and recorded for each quadrat.

The condition of remnant bushland areas surveyed was in good or better condition (recognising that quadrats were purposefully placed in areas of better condition vegetation). Most of the area could not be rated higher than 3 (very good) as there was clear evidence that the area has been logged and there have been repeated fires.

A total of 11 weed species were recorded during the survey by BEC (Bennett 2006) (Table 5-3), using guidance published by the Department of Conservation and Land Management (CALM 1999). The rating allocated to each weed by CALM is based on three criteria:

- **invasiveness** – ability to invade natural bushland in good to excellent condition or ability to invade waterways
- **distribution** – wide current or potential distribution including consideration of known history of wide spread distribution elsewhere in the world
- **environmental impacts** – Ability to change the structure, composition and function of ecosystems. In particular an ability to form a monoculture in a vegetation community.

Very few weed taxa were recorded from the quadrats, as areas in better condition were selected for the quadrat placement. One weed only is rated as high indicating this is the one that should be targeted for removal, as it will have the greatest impact on the remnant bushland. One is rated as low, all the remainder are rated as moderate.

Table 5-3 Weeds recorded by Bennett (2006), and classified according to CALM (1999)

Scientific name	Common name	CALM (1999) Rating
<i>Romulea rosea</i>	Guildford grass	High
<i>Aira caryophylla</i>	Silvery hair grass	Moderate
<i>Arctotheca calendula</i>	Cape weed	Moderate
<i>Briza maxima</i>	Blowfly grass	Moderate
<i>Briza minor</i>	Shivery grass	Moderate
<i>Hypochaeris glabra</i>	Flat weed	Moderate
<i>Lolium rigidum</i>	Annual rye grass	Moderate
<i>Orobanche minor</i>	Lesser broomrape	Moderate
<i>Ursinia anthemoides</i>	Ursinia	Moderate
<i>Vulpia bromoides</i>	Squirrels tail grass	Moderate
<i>Lotus subbiflorus</i>	Lotus	Low

Phytophthora cinnamomi surveys

The most recent mapping of *Phytophthora cinnamomi* extent in the Proposal site was completed by Glevan Consulting Pty Ltd in August 2008. Approximately forty per cent of the study area was considered unmappable for *Phytophthora* disease (consisting mainly of pasture, Tasmanian blue gum

plantations and some recently burnt remnant native forest). Of the mappable area, approximately fifty five percent has been assessed as infested and forty five percent as uninfested (Figure 5-4). All streams, gullies and riparian zones within the assessment area have been assessed as infested. Many upland ridges and midslope areas are also infested, but more so within the State Forest area adjacent to Gavins Road. The largest sections of uninfested area were found to be in the mid and upper slope areas of remnant forested area of Locations 4485 and 4965.

5.3 IMPACT ON BROAD SCALE VEGETATION COMMUNITIES/ASSOCIATIONS, FLORISTIC COMMUNITY TYPES AND DECLARED RARE AND PRIORITY FLORA

5.3.1 Overview

There are a number of vegetation and flora conservation policy frameworks that apply to the Proposal area as described in Section 5.1:

- Forest Ecosystems, the broad-scale vegetation mapping unit for State Forest used by the Conservation Commission of WA
- Vegetation Associations/Types of the National Vegetation Information System (NVIS) and as mapped for the National Land and Water Resources Audit (www.nlwra.gov.au) by the Western Australian Department of Agriculture and Food (DAFWA)
- Vegetation Complexes of Matisse and Havel (1998) prepared for the Regional Forest Agreement
- Threatened Ecological Communities, as listed by the DEC or under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
- Priority Ecological Communities, are those listed by the DEC as possibly a Threatened Ecological Community but do not meet the listing criteria
- Declared Rare Flora, as listed under the *Wildlife Conservation Act 1950*
- Threatened flora species, as listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999
- Priority Flora, which are those under consideration by the DEC for declaration as Rare Flora, or are rare but not currently threatened
- significant flora, which are defined by the EPA (EPA 2004d) as those flora that are significant for a range of reasons, other than as Declared Rare Flora or Priority Flora
- significant natural areas, as per the criteria applied by the EPA in its assessment of the draft Greater Bunbury Region Scheme (EPA 2003b)
- conservation areas and formal conservation recommendations of the EPA.

The impacts of the Proposal on vegetation and flora at the regional level were assessed against each of these frameworks or criteria, with the exception of the last two dot points, which are addressed in Section 8.

5.3.2 Potential impacts on Forest Ecosystems

Forest ecosystems are the conservation evaluation and management units for the establishment of a CAR reserve system in the State Forests. The units are defined as 'an indigenous ecosystem with an

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overstorey of trees that are greater than 20% crown cover' by a panel convened by the Western Australian RFA Steering Committee, and were developed from the forest associations mapping of Bradshaw et al. (1997) and the vegetation complex and ecological vegetation system mapping of Matiske and Havel (1998). The JANIS (1997) reservation target set for each forest ecosystem is 15% of the pre-1750 extent, although higher targets exist for forest ecosystems recognised as vulnerable or rare and endangered. The 15% target can be contributed to by both formal and informal reserves

The Happy Valley Proposal only affects the Jarrah Blackwood Plateau forest ecosystem. This ecosystem currently covers 281,810 ha on crown land, or eighty-one percent of the pre-1750 distribution. Thirty-seven percent of the ecosystem is reserved in informal and formal reserves (Table 5-4).

A vulnerable forest ecosystem (CCWA 2002) is one which is:

1. Approaching a reduction in areal extent of 70% (compared with the pre-European occurrence) within a bioregional context and which remains subject to threatening processes; or
2. Not depleted but subject to continuing and significant threatening processes which may reduce its extent. The Conservation Commission recommends that, where forest ecosystems are recognised as vulnerable, at least 60% of their remaining extent should be reserved. The Jarrah Blackwood Plateau forest ecosystem is not recognised as vulnerable and is considered by the Conservation Commission to be adequately reserved (2002).

Old growth forest is defined as forest that is ecologically mature and which has been subjected to negligible past disturbance (JANIS 1997). The Happy Valley Proposal site and surrounds contains no significant or mapped examples of old growth forest.

Potential impacts

The Proposal will not have any statistically significant impact on the present extent of the Jarrah Blackwood Plateau forest ecosystem (i.e. less than 0.06%), which is the only forest ecosystem proposed to be disturbed. Importantly, because the Proposal does not include any formal or informal reserve areas, it will not decrease the reservation level of the Jarrah Blackwood Plateau forest ecosystem.

Table 5-4 Reservation level of the Jarrah Blackwood Plateau forest ecosystem within the RFA area

Area description	Area (ha)
Total pre-1750 extent	347,200
Present extent on all lands in the RFA region	281,810
Present extent in all lands vested in the Conservation Commission in the RFA region	269,560
CAR Target (15%)	52,080
Area of ecosystem in CAR informal reserves	6,110
Area of ecosystem in other informal reserves	25,420
Total area of forest ecosystem in current and proposed formal reserves	88,690 (26%)
Total area of forest ecosystem in current and proposed formal and informal reserves	128,650 (37%)

5.3.3 Potential impacts on Vegetation Types

The Department of Agriculture and Food Western Australia (DAFWA) maintains the Native Vegetation Extent and Type dataset for WA, prepared through the National Land and Water Resources Audit (DAFWA-002, Beeston, Hopkins and Shepherd 2002). The dataset is based on the vegetation mapping of Beard and Hopkins, using a consistent protocol and meets national standards. It contains a total of 819 vegetation types (Association-level (V) units, as per NVIS²³), with those within the south-west agricultural area mapped at a scale of 1:250,000. The dataset also includes the extent remaining of each vegetation type, which is a widely used tool for national and regional assessments against retention/representation criteria, such as those of the EPA (2000a).

The two vegetation associations that will be affected by the Proposal (Table 5-5) are both Eucalyptus woodlands. The Jarrah and *Eucalyptus haematoxylon* unit (unit 1181) is the only Whicher Scarp vegetation unit in the DAFWA dataset, and has 8936 ha remaining, or roughly 46% of its original extent. It is considered a low priority for additional reservation by the 2002 State Biodiversity Audit (CALM 2003).

Table 5-5 Impacts of the Proposal on the extent of vegetation associations (DAFWA 2006)

Type	Description	Pre-European Extent	Remaining extent	Remaining extent reserved	Impact of Proposal
1017	Medium open woodland: Jarrah and Marri, with low woodland: Banksia	17529 ha	11336 ha (64.7%)	0 %	40 ha (64.4% remaining)
1181	Medium woodland, Jarrah and <i>Eucalyptus haematoxylon</i> (Whicher Range)	19218 ha	8936 ha (46.5%)	4.3%	101 ha (46.0% remaining)

5.3.4 Potential impacts on Vegetation Complexes

Landform-vegetation complexes (Heddl et al. 1980, Mattiske and Havel 1998) are based on the pattern of vegetation at a regional scale (1:250,000), reflecting the key determining factors of landforms, soils and climate. The Proposal will potentially affect four vegetation complexes (Figure 5-5), which are described below.

Whicher Scarp valleys (WCv)

Described as “Open forest of *Eucalyptus marginata* subsp. *marginata* - *Corymbia calophylla* with some *Xylomelum occidentale* on valleys dissecting escarpment in the humid zone”. Havel (2002) adds that “the understorey is floristically rich” and reports that the vegetation complex is inadequately represented within existing reserves, with only 7% (42 ha) of pre-European distribution reserved. An additional 43% (175 ha) of the pre-European distribution is still represented on Crown land and approximately 40 ha on land owned by the Proponent.

²³The National Vegetation Information System (NVIS) is a comprehensive data system that provides information on the extent and distribution of vegetation types in Australian landscapes and seeks to develop a nationally consistent vegetation information system to support the State, Territory and Commonwealth requirements for vegetation information. (<http://www.environment.gov.au/erin/nvis/index.html>). A Vegetation Association, or NVIS Level 5 description, is based on the dominant growth form, height, cover and species (3 species) for the three traditional strata. (i.e. Upper, Mid and Ground).

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Whicher Scarp uplands (WC)

Described as “Open forest of *Eucalyptus marginata* subsp. *marginata* - *Corymbia calophylla* on escarpment with some *Corymbia haematoxylon*, *Banksia attenuata* and *Xylomelum occidentale* in the humid zone”. This vegetation is relatively restricted within existing reserves with 15% (603 ha) of the pre-European distribution represented. Of the remainder, 1,831 ha occurs on Crown land.

Cartis (Cs)

Described as “low open forest of *Eucalyptus marginata* subsp. *marginata*, *Corymbia calophylla* and *Corymbia haematoxylon* with some *Banksia attenuata* and *Xylomelum occidentale* on escarpment slopes”. This vegetation is poorly represented, with only 20% remaining, of which none is reserved²⁴.

Rosa (Ro)

Described as “Woodland to open forest of *Corymbia calophylla* - *Eucalyptus marginata* subsp. *marginata* - *Xylomelum occidentale* on slopes and tall shrubland of *Agonis linearifolia* in valley floors in the humid zone”. This vegetation is relatively extensively represented within the landscape and is adequately represented within existing reserves, with approximately 3,300 ha within reserves and a further 8,300 ha on Crown land.

Potential impacts on extent

The remaining extent and reservation level of the four vegetation complexes within and surrounding the Proposal site are shown in Table 5-6, along with the reduction in extent associated with the Proposal. The Proposal to clear 142 ha of native vegetation will not take either of the two Whicher Vegetation Complexes below the 30% retention target of the EPA. Additionally, the impact on the remaining extent of the Rosa Vegetation Complex (Blackwood Plateau vegetation) will be negligible.

The Proposal will not affect any formal or informal reserves, so will not affect the EPA reservation target of 10%. However, the reservation target for the WCv Vegetation Complex has not yet been met.

Table 5-6 Area remaining and reservation targets of the EPA for the 4 vegetation complexes within the Proposal site

	Pre-1795 extent (pre-European)	Area remaining (c. 2003/04)	Area reserved (formal and informal)	Proposed clearing (change to extent)
Whicher Scarp valleys (WCv) ^a	599 ha ^a	327 ha (55%) ^a	42 ha (7%) ^a	28 ha (-5%) [9 ha in State Forest]
Whicher Scarp uplands (WC) ^a	4,071 ha ^a	3,035 ha (75%) ^a	603 ha (15%) ^a	109 ha (-3%) [42 ha in State Forest]
Cartis (Cs) ^b	1,458 ha	290 ha (20%)	0	0
Rosa (Ro) ^b	16,514 ha ^b	13,038 ha (79%) ^b	3295 ha (20%)	5 ha (-0%)

a Data from Keighery et al 2008

b Data from BEC 2006

²⁴ The Proponent has previously placed 10 ha of Cartis vegetation under a Conservation Covenant as part of the Gwindinup mining Proposal (EPA 2005b)

5.3.5 Potential impact on Threatened Ecological Communities

Vegetation communities²⁵ are described as ‘Threatened Ecological Communities’ (TECs) if they have been defined by the Western Australian Threatened Ecological Communities Scientific Advisory Committee and found to be Presumed Totally Destroyed (PD), Critically Endangered (CR), Endangered (EN) or Vulnerable (VU). For definitions of TEC categories and criteria refer to English and Blyth (1997) and Department of Environment and Conservation (2007b). Selected plant communities have also been listed as “Threatened Ecological Communities” under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act). The TEC’s at the national level are defined on the Environment Australia website (www.ea.gov.au) and are considered to be critical environmental assets by the EPA (EPA 2006b).

Potential impacts

A search of the DEC database and the EPBC Protected Matters search tool showed no recorded populations of TECs in or surrounding the Happy Valley tenements. Two TECs have been recorded in the wider region, and both are located on the Swan Coastal Plain:

- Shrublands on southern Swan Coastal Plain ironstones (17 km to the south west)
- *Eucalyptus calophylla* woodlands on heavy soils of the southern Swan Coastal Plain (9 km to the north west).

A review of the landforms, soils and vegetation patterns within the Happy Valley mining tenements also confirmed that none of the vegetation communities (Bennett 2006) was comparable to the two TECs.

5.3.6 Potential impacts on Priority Ecological Communities (Preliminary only²⁶)

Possible TECs that are poorly defined and do not meet the requisite survey criteria for assessment are added to DEC’s Priority Ecological Community Lists under Priorities 1, 2 and 3. Ecological communities that are adequately known, are rare but not considered to be threatened, or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. Conservation-dependent ecological communities are placed in Priority 5. Priority Ecological Communities (PECs) may be considered high value (but not critical) environmental assets by the EPA, have no specific legal protection and the inclusion of a community type in the Priority list does not necessarily imply any status as a threatened ecological community (DEC 2008b).

Impacts on listed PECs

This assessment of the potential impacts of the Happy Valley Proposal on PECs listed by the DEC focuses on the communities with identified Whicher Scarp affinities (Table 5-7).

²⁵ Modern definitions view the ecosystem as an energy-driven complex of the biological community (plants, animals, fungi and prokaryotes) and its physical environment and that has a limited capacity for self-regulation (Leuscher 2005). A vegetation community, is more broadly defined by the EPA, is ‘an assemblage of plants at any given locality’ (EPA 2004a)

²⁶ See section 5.2.2 regarding further studies on regional floristic comparisons

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Table 5-7 Description of Whicher PECs and relevance to Happy Valley

Community	Occurrence	Typical species	Affinity with Proposal Area
<i>Eucalyptus haematoxylon</i> - <i>Eucalyptus marginata</i> woodlands on Whicher foothills (1a) – P3	Occurs along the northern edge of State Forest along the base of the Whicher Range.	<i>Eucalyptus haematoxylon</i> <i>Corymbia calophylla</i> <i>E. marginata</i> forests and woodlands, <i>Acacia varia</i> subsp. <i>varia</i> , <i>Agonis grandiflora</i> , <i>Xanthosia pusilla</i>	High for mid and upper slopes due to broadness of FCT. Keighery et al. writes 1a and their C group have high similarity. The affinity of this FCT with the Proposal area is discussed in more detail in the main text.
Southern <i>Banksia attenuata</i> woodlands (21b) – P3	Restricted to sand sheets at the base of the Whicher Scarp, the sand sheets on elevated ridges or the sand plain south of Bunbury.	<i>Banksia attenuata</i> , <i>Eucalyptus marginata</i> , <i>Acacia extensa</i> , <i>Jacksonia</i> sp. <i>Busselton</i> , <i>Laxmannia sessiliflora</i> , <i>Lysinema ciliatum</i> , <i>Johnsonia acaulis</i>	High for lower sandy slopes (<i>B. attenuata</i> dominated). Keighery et al. writes 21b and their B group have high similarity. The affinity of this FCT with the Proposal area is discussed in more detail in the main text.
Central Whicher Scarp Mountain Marri woodland (A1) – P1	Woodlands of grey/whites sands on mid-slopes. 7 quadrats.	<i>Ricinocarpos</i> aff. <i>cyanescens</i> , <i>Hibbertia ferruginea</i> , <i>Platysace filiformis</i> , <i>Conospermum capitatum</i> subsp. <i>glabratum</i> , <i>Thysanotus arbuscula</i> , <i>Schoenus brevisetis</i> , <i>Phlebocarya filifolia</i> , <i>Leucopogon glabellus</i> , <i>Pimelea rosea</i> subsp. <i>rosea</i> , <i>Adenanthos obovatus</i> , <i>Stylidium carnosum</i> , <i>Gompholobium capitatum</i>	Locally high, particularly in areas of pale, damp sands. There is a group of HV quadrats intergraded between FCT A1 and A2, but with also good similarities to FCT B1 (HV2, 7, 10, 11, 22, 34 ²⁷). Two of these quadrats (7 and 22) are situated on the upper lateritic slopes of HVS and are within the margins of the clearing footprint. HV11 is located on the lower slopes (higher affinity to FCT B1) and will be cleared for infrastructure. The affinity of this FCT with the Proposal area is discussed in more detail in the main text.
West Whicher Scarp <i>Banksia attenuata</i> woodland (B2) – P1	Occurs in grey sand in the West Whicher Scarp. Species poor.	<i>Allocasuarina fraseriana</i> , <i>Banksia attenuata</i> , <i>Xylomelum occidentale</i> , <i>Bossiaea praetermissa</i> , <i>Calytrix flavescens</i> , <i>Gompholobium tomentosum</i> , <i>Hibbertia hypericoides</i> , <i>Hovea stricta</i> , <i>Hypocalymma robustum</i> , <i>Kunzea rostrata</i> , <i>Petrophile linearis</i>	Very low. FCT based on 1 quadrat only near Carbanup River. No HV quadrats are floristically comparable to that DEC quadrat, although <i>Agonis flexuosa</i> var. <i>flexuosa</i> was recorded in one of the HV creeklines (no <i>B. attenuata</i> or <i>Allocasuarina fraseriana</i>), which will not be significantly disturbed by the Proposal as a result of the creek buffers.
Central Whicher Scarp Jarrah woodland (C1) – P1	Occurs on coloured sands and laterites on moderate to gentle slopes of the Central Whicher Scarp.	<i>Podocarpus drouynianus</i> , <i>Loxocarya cinerea</i> , <i>Allocasuarina fraseriana</i> , <i>Drosera stolonifera</i> , <i>Amperea ericoides</i> , <i>Thysanotus triandrus</i> , <i>Cyathochaeta equitans</i> , <i>Hibbertia quadricolor</i> , <i>Comesperma calymega</i> , <i>Lepidosperma pubisquamum</i> , <i>Conospermum paniculatum</i> , <i>Acacia preissiana</i> , <i>Hybanthus debilissimus</i>	There are no reference quadrats within the Proposal area (Figure 5-7). Although none of the Happy Valley quadrats are strongly comparable to FCT C1 quadrats, and no weakly comparable quadrats are within the proposed footprint, the DEC believes that there may be examples of C1 FCT at Happy Valley North – this area is considered by the Proponent to be a mosaic of many vegetation types and the DEC position is being further researched.

²⁷ from Appendix 3 Griffin 2008

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Community	Occurrence	Typical species	Affinity with Proposal Area
Whicher Scarp Jarrah woodland of deep coloured sands (C2) – P1	Found scattered through the Central and North Whicher Scarp on midslopes on deep, generally coloured sands rarely associated with laterites.	Common sand taxa including <i>Hypolaena exsulca</i> , <i>Dasyopogon bromeliifolius</i> , <i>Stirlingia latifolia</i> , <i>Petrophile linearis</i> , <i>Melaleuca thymoides</i> and <i>Adenanthos meisneri</i>	Very high, including examples of the ‘tighter’ portion of the group recorded in the Boyanup forest by Keighery et al. (2008). The affinity of this FCT with the Proposal area is discussed in more detail in the main text.
Dardanup Jarrah and Mountain Marri woodland on laterite (C5) – P1	Located on unusual surface of quartzite and laterite in Dardanup forest which is an area where the Whicher Scarp, Blackwood Plateau and Darling Scarp interface. 2 quadrats.	<i>Lomandra whicherensis</i> , <i>Lomandra spartea</i> , <i>Olx benthamiana</i> , <i>Andersonia heterophylla</i> , <i>Hemigenia incana</i> , <i>Acacia varia</i> var. <i>varia</i> , <i>Daviesia angulata</i> , <i>Pimelea preissii</i> , <i>Lomandra brittaniai</i> , <i>Xanthorrhoea acanthostachya</i> , <i>Banksia armata</i> var. <i>armata</i> , <i>Hakea stenocarpa</i> , <i>Stachystemon vermicularis</i> , <i>Lambertia multiflora</i> var. <i>darlingensis</i> , <i>Petrophile striata</i> , <i>Pimelea sulphurea</i>	Very low owing to absence of quartzite soils. Small areas of the Proposal area contain <i>B. armata</i> var. <i>armata</i> (SVT 9, which will not be impacted by Proposal, and HV quadrats within SVT 9 grouped as FCTC3).
Sabina River Jarrah and Marri woodland (F1) – P1	Sabina River alluvial fan where the Sabina River meets the Swan Coastal Plain. 2 quadrats.	Suite of SCP wetland taxa: <i>Mirbelia dilatata</i> , <i>Lomandra pauciflora</i> , <i>Tremandra diffusa</i> , <i>Tremandra stelligera</i> , <i>Trymalium floribundum</i> subsp. <i>trifida</i> and <i>Clematis aristata</i> var. <i>occidentalis</i> , <i>Hovea elliptica</i> , <i>Leucopogon verticillatus</i> , and <i>Darwinia citriodora</i>	Very low. One of the HV quadrats in a creekline (HV2007-05) shared some F-group affinities. Keighery et al. (2008) write that they did not expect to find the FCT elsewhere. Creeklines will be largely protected from the Proposal using creek buffers.
Shrublands of near permanent wetlands in creeklines (G2) – P1	Permanent creeklines on the Whicher Scarp. 1 quadrat on Carbanup River.	<i>Astartea scoparia</i> , <i>Homalospermum firmum</i> , <i>Taxandria fragrans</i> MS, <i>*Anthoxanthum odoratum</i> , <i>Baumea rubingosa</i> , <i>Cyathochaeta teretifolia</i> , <i>Isolepis cernua</i> , <i>Taraxis grossa</i>	Very low. The HV creeklines are not ‘near-permanent’ but do have areas of freshwater seepage on the lower slopes, but on a seasonal basis. The common suite of taxa between the HV creek quadrats and the G quadrats is very small compared to the mismatches.
Swan Coastal Plain Paluslope Wetlands – P1	Wet all year round and found in nearby low-lying areas at the base of the Scarp.	Typical taxa include: <i>Melaleuca preissiana</i> , <i>Taxandria linearifolia</i> , <i>Taxandria fragrans</i> , <i>Melaleuca incana</i> , and <i>Cyathochaeta teretifolia</i> . Other species include: <i>Eucalyptus patens</i> , <i>Homalospermum firmum</i> , <i>Gahnia decomposita</i> , <i>Callistachys lanceolata</i> , <i>Hakea linearis</i> , <i>Melanostachya ustulata</i> , <i>Evandra aristata</i> , <i>Beaufortia sparsa</i> , <i>Callistemon glaucus</i> , <i>Pultenaea pinifolia</i>	While there is no question that the Proposal area does not contain examples of this ecological community, the potential of the Proposal to affect those examples mapped at the base of the Scarp through secondary impacts has been addressed. The Proposal will not influence the regional landforms and aquifers responsible for the wetlands – this has been verified by PB (2008b), and is discussed under the section sub-heading of wetlands (Section 7).

Potential impacts on Community 1a of Gibson et al. (1994)

Effects on reference quadrats

The closest of the thirteen Gibson et al. (1994) quadrats classified as Floristic Community 1a to the Proposal site is KELLY01, which lies immediately to the south of the tenements, therefore no reference sites will be affected by the Proposal. Of the other FCT 1a quadrats, three are to the north of the Proposal area and ten are to the south and west (Figure 5-6).

Effects on comparable quadrats of Keighery et al. (2008)

In their work, Keighery et al. (2008) determined that their C floristic group *Whicher Scarp woodlands of coloured sands and laterites* was virtually equivalent to the Floristic Community 1a. Of the 49 quadrats with that classification (including eleven 1a quadrats²⁸), two are within the Proposal area. The remaining 47 C quadrats are located to the north and south-west of the Proposal area, along the entire length of the Whicher Scarp, including current and proposed conservation reserves (Figure 5-6).

Effects on comparable Happy Valley quadrats

Based on Griffin (2008), 44 of the 61 Bemax quadrats are comparable to the C floristic group of Keighery et al. (2008), indicating that at least 66% of the vegetation within the extended study area possesses many of the characteristics of Community 1a. Of these quadrats, nine are located within (or immediately adjacent to) the Proposal area (Figure 5-7).

Assessment of impact on representation of PEC Floristic Community 1a

No publicly-available information on the spatial extent of the 1a Community is available to make a quantitative assessment of the impact on its representativeness. However, if the sampling conducted by Keighery et al. (2008) and for the Proponent is representative of the vegetation of the Whicher Scarp and the Proposal area respectively, then it can be estimated from the proportionate representation of comparable quadrats from both of those studies that approximately 50% of the upland native vegetation on the Whicher Scarp shares a moderately high level of similarity with the 1a floristic community.

Potential impacts on Community 21b of Gibson et al. (1994)

Effects on reference quadrats

The closest of the fifteen Gibson et al. (1994) quadrats classified as Floristic Community 21b to the Proposal area is KELLY02, which lies immediately to the south of the tenements, so no reference sites will be affected by the Proposal. The other 21b quadrats are widely distributed across both the Whicher Scarp and the Swan Coastal Plain (Figure 5-8).

²⁸ The two other 1a quadrats are more comparable to the A Floristic Group *Whicher Scarp woodlands on grey-white sands*

Effects on comparable quadrats of Keighery et al. (2008)

In their work, Keighery et al. (2008) determined that their B floristic group *Swan Coastal Plain woodlands of grey/white sands* was virtually equivalent to the Floristic Community 21b. Of the 22 quadrats with that classification (including 14 of the 15 original 21b quadrats), none are within the Proposal footprint (Figure 5-8).

Effects on comparable Happy Valley quadrats

Based on Griffin (2008), 11 of the 61 Bemax quadrats are comparable to the B floristic group of Keighery et al. (2008). Of these quadrats, two located within (or immediately adjacent to) the Proposal footprint (Figure 5-9), with one of these (HV07) being classified as a poor match (Griffin 2008).

Impact assessment on representation of PEC Floristic Community 21b

The Happy Valley Proposal has been designed to place a very high priority on minimising the clearing of the sandy foothills where *Banksia attenuata* dominates, due to its links with the Community 21b and to the under-represented Cartis landform-vegetation complex.

In order to estimate the relative impact of the Proposal on the remaining extent of the Southern *Banksia attenuata* woodlands PEC, based on the vegetation and landscape descriptions, a suitable proxy may be the Cartis (Cs) Vegetation Complex (as mapped by Matiske and Havel 1998), which the Proposal area does not intersect.

Potential impacts on Community A1 of Keighery et al. (2008)

Effects on reference quadrats

Seven of the 114 quadrats of Keighery et al. (2008) were classified as FCT 1A (Figure 5-10), being concentrated on the mid-slopes of the central Whicher Scarp, between the Vasse and Abba Rivers. There are no reference quadrats within the northern Whicher Scarp, where the Proposal is situated.

Effects on comparable Happy Valley quadrats

The preliminary regional comparison of Griffin (2008) did not classify any Happy Valley quadrats as being reasonably comparable to the A1 reference quadrats. However, a number of quadrats (Figure 5-11) were intergrade between FCT A1 and A2, but also had good similarities to FCT B1, which is also a grey sand community. Two of these quadrats (HV07 and HV22) are located on the grey sands over laterite on the upper slopes of Happy Valley South and are within the margins of the proposed clearing footprint. A third quadrat, HV11, which is located on the lower slopes and was considered by Griffin (2008) to be most comparable to FCT B1, will be cleared for infrastructure.

Impact assessment on representation of PEC floristic community A1

The potential impact of the Proposal on the distribution of the A1 FCT is difficult to predict at this stage, as the preliminary work by Griffin indicates that this is one of the floristic groups that is likely to be redefined with the addition of new data to the classification dataset (see Section 5.2.2). While no reference quadrats or strongly similar quadrats will be impacted, the potential impacts are the subject of further scientific study by the Proponent.

Potential impacts on Community C2 of Keighery et al. (2008)

Effects on reference quadrats

According to Keighery et al. 2008, eight of their 114 Whicher Scarp quadrats belonged to this FCT. The distribution of the FCT ranged the full length of the Scarp, although most examples were located in the central and northern sectors (Figure 5-13). The C2 FCT quadrats were found across five different soil-landscape units (DAFWA 2006), including two quadrats on sands and clays of the Swan Coastal Plain. Four of the eight quadrats were located on the Whicher Scarp (WC2, Duplex sandy gravels on gentle, smooth lateritic slopes) soil-landscape unit. Two of the eight C2 quadrats (DAVE01 and DAVE02) are located within the Proposal disturbance area.

Effects on comparable Happy Valley quadrats

Griffin (2008) found 19 of the 61 Happy Valley quadrats to be comparable to the C2 FCT (Figure 5-14). Of these, five are located within the Proposal disturbance area, six are located outside of the disturbance area but still within the tenements, on both private and Crown land, and eight are located outside of the tenements on Crown land. Of those quadrats outside of the disturbance footprint, two quadrats (HV01 and HV08) group very closely to the DEC quadrats DAVE01 and DAVE02 (Griffin 2008).

Impact assessment on representation of PEC Floristic Community C2

In the context of assessing the relative impact to the remaining extent of the PEC, Bemax commissioned Ekologica (2009) to conduct a rapid field assessment of known and potential locations of C2 communities, such as DEC quadrats and mapped locales of indicator taxa. The work identified a total of 22 populations along the Whicher Scarp (Figure 5-15), with an estimated total combined area of 294 ha. Based on this mapping of the C2 FCT, the Proposal will require the clearing of 54 ha (~18%), with remaining populations to the north (although small) and south of the Proposal site.

5.3.7 Potential Impacts on listed flora

Declared Rare Flora

One Declared Rare Flora (DRF²⁹) taxa, *Daviesia elongata* subsp. *elongata* (Long-leaved Daviesia, Family Papilionaceae) was identified as occurring within the Proposal area (Bennett 2004a, Bennett 2006, Bennett 2007). The taxa is also listed as Vulnerable³⁰ under the EPBC Act.

Description and taxonomy

Daviesia elongata subsp. *elongata* is a spreading multi-stemmed shrub to 75 cm tall, but with a spread to 1.5m. The leaves are alternate, flat, straight, coriaceous and up to 25 cm long, linear to linear

²⁹ DRF are “Taxa that have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection”, as per the *Wildlife Conservation Act 1950*.

³⁰ Vulnerable taxa are “taxa which are not critically endangered or endangered and are facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria”, as per the Australian *Environment Protection and Biodiversity Act 1999*.

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oblong. Inflorescence is 2-3 flowered, shorter than the leaves. Flowers are yellow - orange in colour with a red keel. Bracts 2, shorter than flowers. Flowering occurs December to February. *D. elongata* subsp. *elongata* is known to be an obligate seeder (germinating after fire). Population numbers decrease after resprouting as seedlings compete for light, moisture and resources.

Daviesia longifolia can resemble *D. elongata* but differs in having an inflorescence of 4-11 flowers (*D. elongata* has 2-4 flowers), yellow standard and wings (*D. elongata* is reddish brown). When vegetative can be mistaken for *Labichea punctata* but *L. punctata* has leaves with a spine tip whereas *D. elongata* has a rounded tip with a small point.

Habitat and biology

The DEWHA species' profile for *D. elongata* subsp. *elongata* (2008) states that the taxa occurs on "grey sandy loam soils in low forest over heath with *Eucalyptus marginata*, *Dryandra squarrosa*, *Banksia sphaerocarpa*, *Stirlingia latifolia*, *Allocasuarina* spp. and *Xanthorrhoea* spp.". Several mapped subpopulations occur within the 'Shrublands on Southern Swan Coastal Plain Ironstones' TEC.

Surveys for *D. elongata* subsp. *elongata* by Bennett and others (Appendix V4) have also located the taxa on a range of other soils, including yellow sand, yellow sand over clay, grey sand and grey sandy loam over laterite. In these surveys, occurrences are typically on flats/low slopes to upper/middle slopes of the Whicher Scarp, in a variety of vegetation assemblages. Targeted searches for the taxon by the Proponent have concentrated on areas of yellow sand.

Typical associated species include *Stirlingia latifolia*, *Hibbertia hypericoides*, *Kingia australis*, *Dryandra lindleyana*, *Adenanthos meisneri*, *Boronia humifusa*, *Dasypogon hookeri*, *Ricinocarpos cyanescens* and *D. nudiflora*.

Distribution of population/s

The DEWHA Conservation Advice for *D. elongata* subsp. *elongata* (2008) makes the following statements in relation to population and distribution:

- known from seven locations (one of which has been split into sub-populations³¹) near Carbanup on the Swan Coastal Plain over an area of 1,442 km² (area of occupancy 3.56 ha)
- species distribution is considered to be fragmented, with considerable distance between populations and there are no translocated subpopulations
- the population estimate (2007) in or near the Proposal area is around 1000 mature plants and appears to be in decline³², although known populations are not considered to be threatened.

The numerous surveys conducted by Bennett (2004a, 2007), Bennett (2006) and Ekologica (2008b, 2009) recorded many thousands of additional plants in multiple populations, mostly outside of the mining tenements (Figure 5-17 and Appendix V4). Three other populations have been recorded much further south than those listed above. The first recorded by A. Webb (pers comm., in Bennett 2008)

³¹ Sub-populations are defined by differences in land tenure, management and location.

³² Numbers of *D. elongata* subsp. *elongata* recorded within and around the Happy Valley tenements have declined since targeted searches were first conducted in 2003.

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from the Butler Block in 1998 (AW) where he recorded many thousands of plants after a fire. A survey of the Yarragadee area by Matiske Consulting Pty Ltd recorded this species from a population at Poison Gully, which is a tributary south of the Blackwood River. The third was from Harrington Forest Block where 3 plants were recorded.

Threats

The main identified threats to *D. elongata* subsp. *elongata* are:

- pressures associated with clearing and disturbance by road and development works
- altered fire regimes
- *Phytophthora cinnamomi*
- invasive weeds.

Potential impacts and proposed management

The potential impact of the Proposal on the population and habitat of *D. elongata* subsp. *elongata* are listed in Table 5-9, using the assessment criteria published by DEWHA (DEH 2006a). Several of the criteria consider the impacts to ‘important populations’ of the taxon, where an ‘important population’ is one that is necessary for a species’ long-term survival and recovery. The importance of the population in the Proposal site in this regard is considered in Table 5-8 and, while the Happy Valley sub-population is only a small part of a much larger local to sub-regional population, it remains the northern-most occurrence of the taxa as yet recorded, despite the (limited) availability of habitat to the north and targeted northward searches by the Proponent. Accordingly, the Happy Valley sub-population may meet one of the criteria to be considered as an important population under the EPBC Act, but only if the distance of 1.6 km to the next closest sub-population is considered genetically significant (Lester et al. 2007). Information on the ecology of *D. elongata* subsp. *elongata* that may assist in determining the significance of this distance is not available, so a conservative approach has been taken in this assessment.

Table 5-8 Consideration of the importance of the Happy Valley (HV) population of *Daviesia elongata* subsp. *elongata* and habitat (derived from DEH 2006a)

Consideration	Response
Are the HV occurrences similar geographically i.e. are they the same local population?	The plants recorded at Happy Valley existed (many are no longer present) as small groups of plants together on the section of the yellow sands/C2 community at Happy Valley South that had been burnt in 1997. All are in State Forest and can be considered as part of the same local population.
Is the HV local population geographically similar to other local populations i.e. is it part of a larger local population?	Approximately 1.6 km to the south of the HV local population is another group of 5 or more local sub-populations, collectively containing 5,000 plants or more. They are also on areas mapped as yellow sands/C2 community and are also in State Forest that was burnt in 1997 (Figure 5-17). Although very similar in geology and vegetation associations, the absence of information on the dispersal ability and range size of <i>D. elongata</i> subsp. <i>elongata</i> and hence the genetic differentiation between the two populations, means a conservative approach should be taken. Accordingly, it is reasonable to consider the HV population as a sub-local population of a significantly larger ‘North Whicher Scarp’ population, spread over at least 4 km of the mid-slopes of the Whicher Scarp, and up to 7 km.
Is the HV population identified in any recovery plans as an important population?	There is no specific recovery plan for <i>D. elongata</i> subsp. <i>elongata</i> .

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Consideration	Response
Is the HV population a key source for either breeding or dispersal?	The HV population is not limited by habitat (it has been found occupying less than a third of the suitable habitat at the site) and is considered to be more a reflection of a sporadic disturbance history (the plant is a post-fire (or other disturbance) coloniser, sprouting from the soil seed-bank). Accordingly, seed resources in undisturbed areas may also represent breeding potential.
Is the HV population necessary for maintaining genetic diversity?	There is no information on the dispersal ability and range size of <i>D. elongata</i> subsp. <i>elongata</i> and hence the genetic differentiation between the HV sub-local population and other sub-local populations to the south.
Is the HV population near the limit of the species' range?	The HV sub-local population is the northern-most recorded population by a distance of roughly 1.6 km.

In terms of provenance-correct propagative material, the Happy Valley sub-population includes seed resources contained in the topsoil of other areas of suitable habitat that are currently unpopulated. The Proposal will only affect ~50% of the suitable habitat within the tenements and a range of targeted mining and rehabilitation actions have been developed to reduce the potential impact of the disturbance on the sandplain habitat and population. These actions include:

- pre-clearing collection of seeds and cuttings (including block translocation), targeting locally significant and recalcitrant taxa
- stripping topsoil in two layers (0 – 50 mm and 50 – 200 mm) for separate management
- reserving the original subsoils to a depth of 0.7 m (which are mineralised) to retain natural soil properties
- direct and seasonal returning 90% of the topsoil within the same dry season (November – April) for that proportion of habitat within State Forest.

These measures are aimed at keeping the level of disturbance to the soil profile to a minimum and to restore those hydrogeologic, physical and chemical properties of the soils and soil profile to an overall state as close as possible to that which existed prior to mining. Other rehabilitation outcomes, such as monitoring for species' recovery after mining (including areas where dieback is known to be present), its lifecycle and responses to fire, will be generally applicable to the long-term management of *D. elongata* subsp. *elongata*, including within the Proposal area, after rehabilitation is complete. The assessment of the significance of the potential impact on *D. elongata* subsp. *elongata* in Table 5-9 has included these and other mitigation measures, consistent with the DEWHA guidelines.

Overall, the assessment confirms that to clear several hundred plants³³ (Bennett 2004b, using 2003 data) over an area of 32 ha, or approximately half, of the local population's suitable habitat, will have a local but reversible impact on the Happy Valley sub-population given its recruitment in rehabilitation. The Proposal will disturb 50% of the habitat of the species within the Proposal area but is unlikely to have a significant effect on the local North Whicher Scarp population which will not be significant.

³³ Note that this number has decreased significantly since 2004, due to the commonly observed decline in populations following germination (D. Brearley pers. Comm. and as noted in DEWHA species profile.

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Table 5-9 Assessment of significance of potential impact: *Daviesia elongata* subsp. *elongata* (Vulnerable)

Criteria	Assessment information
Will Proposal lead to a long-term decrease in the size of an important population(1)?	The current extent of the HV population appears strongly related to disturbance history (fire and tracks), is observed to be declining in numbers and only occupies less than a third of the local habitat considered suitable for the taxa, by virtue of soils and species that are often associated with it. While the Proposal will impact on the known HV populations of <i>D. elongata</i> subsp. <i>elongata</i> , it will only impact on ~50% of the suitable HV habitat in the Proposal area. Additionally, avoidance measures and rehabilitation prescriptions are expected to produce a net <i>increase</i> in numbers of plants after mining.
Will Proposal reduce the area of occupancy of an important population?	The area of occupancy for the HV population in the Proposal area is estimated at 60 ha, of which 32 ha (~50%) will be affected. The approximate area of potential occupancy for the larger 'North Whicher' population is estimated as ~200 ha, based on geology, geography and vegetation. The Proposal has placed a high priority on the return of this habitat suitable to the re-establishment of pre-disturbance diversity and structure.
Will Proposal fragment an existing important population into two or more populations?	The HV population is the northern-most extent of <i>D. elongata</i> subsp. <i>elongata</i> and will not be fragmented. No occurrences of <i>D. elongata</i> subsp. <i>elongata</i> have been recorded in two small areas of suitable habitat located to the north.
Will Proposal adversely affect habitat critical to the survival of a species?	Approximately 32 ha of the 133 ha mapped (local) extent of the yellow sands Site Vegetation Type will be disturbed by the Proposal. Advanced rehabilitation measures have been committed to by the Proponent to enhance rehabilitation success of that community type, including sacrificing the top 0.7 m of the soil profile to preserve subsoil properties and 90% direct and seasonal return of topsoil.
Will Proposal disrupt the breeding cycle of an important population?	The Proposal will disturb the soil seed-bank for about half of the habitat for the HV population in the Proposal area, based on suitable habitat. Measures such as direct and seasonal return of topsoil and pre-clearing collection of seed and cuttings should minimise this disruption.
Will Proposal modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?	The managed impacts to 32 ha of habitat suitable for <i>D. elongata</i> subsp. <i>elongata</i> as part of the Proposal will not be sufficient to affect the survivability of the taxa in the local North Whicher Scarp population.
Will Proposal result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat?	The impact of invasive weeds on habitat for <i>D. elongata</i> subsp. <i>elongata</i> generally, is considered to be a threat to the species and impacts may become significant during post-fire re-establishment. Although invasive weeds already exist in some sections of the Proposal area, there will be a strong management focus on ensuring weed numbers are controlled across the site and in rehabilitated areas.
Will Proposal introduce disease that may cause the species to decline?	<i>D. elongata</i> subsp. <i>elongata</i> is considered to be susceptible to <i>Phytophthora cinnamomi</i> , although this has not been confirmed ³⁴ . Dieback already exists in the Proposal area and the Proponent has committed to stringent and industry standard hygiene controls, including segregation of soils and biological materials.
Will Proposal interfere with the recovery of the species?	There are no recovery plans or programs in place for <i>D. elongata</i> subsp. <i>elongata</i> . It is expected that the rehabilitation outcomes of the Proposal will substantially increase the knowledge of the response to the species to disturbance, disease and fires, which will all be relevant to future recovery actions.

Priority flora

A number of Priority Flora species have been identified to occur within and surrounding the Happy Valley mining tenements. Their details and likelihood of occurrence are described in Table 5-10.

³⁴ *D. elongata* subsp. *elongata* has been mapped in areas where the presence of *P. cinnamomi* has been confirmed at HVS, particularly along tracks.

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Table 5-10 Priority flora potentially in Happy Valley proposed footprint (see footnote on risk ranking)

Priority Flora	PX	Habitat	Likelihood of presence	Rank
<i>Acacia flagelliformis</i>	P4	Prefers moisture-gaining situations on sandy soils, but may also contain loams and/or gravels. Observed in valleys, creek beds and roadside drains in surrounding areas	One of six occurrences recorded in tenements is within footprint.	1
<i>Acacia inops</i>	P3	Uncommon shrub of sumplands of the Margaret River Plateau and Yelverton (Poole Swamp) area (Keighery et al. 2008), not recorded in Whicher surveys. Habitat preference is black peaty sand, clay surrounding swamps, creeks.	Not recorded in HV surveys. The preference for swampy areas with wet sands greatly reduces the likelihood of the Proposal affecting this taxon, as these areas will be well-protected within creek buffers.	4
<i>Acacia semitrullata</i>	P3	Preferred habitat is sandplains and swampy areas, where it grows on white/grey sand, sometimes over laterite and/or clay. Keighery et al. (2008) lists the taxon as having a distinct habitat preference (sands) with disjunct populations along the Whicher Scarp.	Recorded by ESM on lower sandy slopes (Gwindinup). Not recorded in Happy Valley (HV) tenements. The preference for swampy areas with wet sands greatly reduces the likelihood of the Proposal affecting this taxon, as these areas will be well-protected within creek buffers.	4
<i>Andersonia ferricola</i> MS	P1	Described by Webb et al (2006) as a 'Busselton ironstone endemic', i.e. that its distribution is centred upon the ironstone landform. Keighery et al (2008) confirms that populations have been identified in the Argyle forest laterites.	Recorded in 3 BEC quadrats located in or close to creeklines. Floristically similar quadrats (at 20 group) are also associated with creeklines. All those in proximity to footprint are in creek buffers and will not be affected.	3
<i>Aotus cordifolia</i> (Swamp Aotus)	P3	Prefers peaty soils and swamps, Augusta to Bullsbrook. Closest records are Camp Gully Rd and Brilliant Rd (brown moist loam on road verge – Paluslope wetland).	Not recorded in HV tenements. Potentially may occur in creek buffer zones. Considered very low likelihood of disturbance.	4
<i>Aponogeton hexatepalus</i>	P4	Aquatic herb with preference for freshwater ponds, rivers and claypans. Closest record is Capel.	Not recorded in surveys despite targeted searches of creeklines. If present, will be protected by creek buffers. Considered very low likelihood of disturbance.	4
<i>Boronia humifusa</i>	P1	Recorded in gravelly clay loam over laterite and also sandy soils associated with lateritic outcropping, loamy or clayey sand or gravel, usually associated with Jarrah – Marri forest. Keighery et al. (2008) states it is a North Whicher endemic, which is locally common but restricted. Herbarium records include Perth foothills.	Widespread across the HV tenements, typically on the laterite ridges and crests, but also on the deeper yellow and grey sands of HV South and North, respectively. Occurs in 9 of the 14 site vegetation types and is a common taxon (i.e. 50 – 75% occurrence) within the C2 floristic community of Keighery et al. (2008). High risk of local disturbance.	1
<i>Boronia tenuis</i>	P4	Habitat preferences include laterite, stony soils and granites. Records include Moora, Kalamunda, Boddington and Yallingup. Mostly damp sites. Not recorded by Keighery et al. (2008).	Recorded in two quadrats (HV10 and HV25), both of which are well upslope and downslope of the footprint. Considered unlikely to be on sandy midslopes but could be present on ridges of Loc 215.	2
<i>Caustis sp. Boyanup</i>	P1	Habitat preference is white or grey sand in association with Banksia or Banksia/Jarrah woodland and has been recorded from the Whicher Scarp, Donnybrook and as far east as Kojonup and Albany, where it is recorded as locally abundant. Keighery et al. (2008) states there are 3 known populations in the Whicher Scarp: the Boyanup forest (the most northern population), Argyle forest, and the Whicher National Park (most southern population). The taxon was only recorded in a single quadrat of that study.	<i>C. sp. Boyanup</i> was not found in any of the Happy Valley quadrats. Bennett (2004a) conducted a targeted search for the plant and found a single population along the verges of Hyder Road, south of the Happy Valley mining tenements. It is not considered to be at risk from the Proposal.	4

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Priority Flora	PX	Habitat	Likelihood of presence	Rank
<i>Dillwynia</i> sp. Capel	P1	Littered grey loamy sand, rocky soils. Valleys, rangelands. Whicher Scarp/Blackwood Plateau. Not recorded by Keighery et al. (2008). Not recorded in any other studies.	Not recorded during site surveys. Presumably associated with upland areas owing to Blackwood Plateau affinities (recorded at Nannup, Pemberton, Donnybrook), which will not be disturbed to any great extent by the Proposal. Considered very low likelihood of disturbance.	4
<i>Franklandia triaristata</i>	P4	White or grey sand. Boyanup, Happy Valley and Abba forest blocks (Keighery et al. 2008). Other records to Jarrahwood, Capel and Argyle, including two Whicher surveys conducted for Iluka (Mattiske 2006, 2009).	Reported by Bennett from 1 location downslope of HVS footprint. Potential for presence on lower sandy slopes along western edge of HVS and areas of HVN is considered to be reasonably moderate.	2
<i>Hemigenia rigida</i>	P1	Habitat preferences are sandy soils and lateritic gravelly soils on hillslopes, granite outcrops, flats and ironstone ridges. Records extend from north of Perth to Walpole.	Recorded in four of the Happy Valley quadrats (and twice by Ekologica), none of which are within the proposed disturbance area or its proximity. These sites are associated with the upland lateritic crests and flats or the upper slopes of creeklines (moisture shedding) and are not replicated within the mining area. Considered very low likelihood of disturbance.	3
<i>Hypolaena robusta</i>	P4	Found on white sand north of Perth and Geraldton sandplains. Not recorded by Keighery et al. (2008) or Mattiske (2006, 2009). No records south of Perth.	Recorded in creekline HVN (2007-01). Not located in other creeks, but may be present. Ranking is elevated to reflect the possibility of a new population being present in or around the mine area.	2
<i>Logania wendyae</i>	P1	Habitat includes brown clay to sandy clay and lateritic gravel. Believed to be restricted to the northern Whicher Scarp (Keighery et al. (2008), with the authors noting that specimens have not been located south of the Argyle Forest.	The plant is locally common in the areas of the Happy Valley tenements associated with the lateritic uplands and gravelly mid-slopes. Approximately one-third of its recorded occurrences across the proposal site will be disturbed.	1
<i>Lomandra whicherensis</i> (formerly <i>L. sp. Dardanup</i>)	P1	Newly described species normally found along lateritic or quartzite ridges under low woodlands of <i>C. haematoxylon</i> . Currently known from Dardanup, Boyanup and Argyle forests on the Whicher Scarp and near Collie (Keighery et al. 2008) and recorded in 5 quadrats.	Recorded from two quadrats at HVN, one upslope from the footprint on laterite and one to the west on the laterite ridge on Gavins Rd. Considered low likelihood of disturbance as laterite ridges and crests will not generally be disturbed but may occur in remnants at HVN (Loc 215).	2
<i>Platytheca anasima</i>	P2	Habitat preference is sandy soils and gravel along creeklines or in areas of impeded drainage, endemic to Whicher Scarp (Keighery et al. 2008). Not recorded by Mattiske 2006, 2009).	Recorded in 8 plots including outside of HV tenements. One of the plots may be affected by mine.	1
<i>Pultenaea skinneri</i>	P4	Associated with winter-wet depressions/margins of basin wetlands. Recorded from Kemerton east to Collie and south to the Blackwood Plateau. Recorded by Keighery et al. (2008) in Abba block.	Not recorded in any of HV studies. Although no wetlands in project area, there are areas of damp sands on upper flats and lower slopes, both of which are largely excluded from mining, as will be creek buffers. Considered very low likelihood of disturbance.	4
<i>Rhodanthe pyrethrum</i>	P3	Habitat preference is clay, sandy clay associated with winter-wet depressions, clay pans, swamps. Distributed from Albany to Bullsbrook. Not recorded by Keighery et al. (2008) or Mattiske (2006, 2009).	Not recorded in any of HV studies. Although no wetlands in project area, there are areas of damp sands on upper flats and lower slopes, both of which are largely excluded from mining, as will be creek buffers. Considered very low likelihood of disturbance.	4
<i>Stenanthemum sublineare</i>	P2	Habitat preference is white sands, including coastal. Disjunct populations in Perth, Augusta and Albany. Not recorded by Keighery et al. (2008) or Mattiske (2006, 2009).	Recorded from one quadrat on Bassendean Sands to NW of HVS deposit outside of footprint. Only impact to this landform is access road and specific search will be conducted prior to construction. Considered very low likelihood of disturbance but ranked as high due to regional significance.	2

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Priority Flora	PX	Habitat	Likelihood of presence	Rank
<i>Stylidium barleei</i>	P3	Habitat includes grey, white or brown sand over laterite, in upland areas including Eucalyptus woodland and Allocasuarina shrubland. It endemic to the southwest and has been found between Margaret River, Nannup and south of Busselton. Keighery et al. (2008) recorded the species in the Treeton Forest and the Whicher National Park.	One of the two recorded locations lies less than 10 m from the edge of the HVN footprint. All measures will be taken to protect the quadrat from disturbance, however, it is considered to be at high risk. Floristically, the two quadrats have been assigned as the C3 community type, which is widespread in the area. The mosaic of soil and vegetation patterns at HVN includes several small areas where suitable habitat may occur, both within and outside of the proposed footprint. Considered high likelihood of disturbance.	1
<i>Stylidium striatum</i>	P4	Brown clay loam over laterite. Hill-slopes. Jarrah/Marri forest, Wandoo woodland. Majority of records Darling Scarp and Plateau (Beverly, Boddington) but also Capel and Boyanup. Recorded at Yoganup by Mattiske in 2006 but not at Tutunup in 2009. Recorded from 3 sites by Keighery et al. (2008) but not mentioned in the text.	Not recorded in any surveys of HV tenements or surrounds. However, may be present across the area in low numbers.	2
<i>Synaphea hians</i>	P3	Present on sandy soils and rises, with populations are found between Collie, Busselton and Cranbrook. A population recorded for the Treeton forest by Keighery et al. (2008).	Not recorded in any surveys of HV tenements or surrounds. However, may be present across the area in low numbers.	2
<i>Synaphea polypodioides</i>	P3	Newly described species recorded in Dardanup, Boyanup and Argyle (Gavins Road) forest by Keighery et al. (2008), but not in quadrats. Habitat preference is Light brown loam, red-brown sandy loam, gravelly, brown sandy clay over laterite. In undulating areas.	Not recorded in any surveys of HV tenements or surrounds. However, may be present across the area in low numbers.	2
<i>Tetrateca parvifolia</i>	P3	Relatively uncommon species recorded in open jarrah forest from Yallingup to Capel to Collie, on lateritic sands. Recorded from a single quadrat of Keighery et al. (2008) on lower central slopes. Recorded at Gwindinup by Bennett (2005), also on mid slopes in <i>E. marginata</i> , <i>C. haematoxylon</i> open woodland. Not found in Mattiske studies.	Not recorded in any surveys of HV tenements or surrounds. However, may be present across the area in low numbers.	2
<i>Villarsia submersa</i>	P4	Aquatic perennial herb, in freshwater 0.05-0.6 m deep. Pools, lakes, swamps, winter-wet depressions, claypans. Several records from Boyanup area.	Not recorded in HV tenements. Unlikely to occur in creeks or buffer zones. Considered very low likelihood of disturbance.	4

RISK RANKINGS: 1 Confirmed within footprint; 2 Potentially within footprint; 3 Unlikely to be found in footprint but recorded in surrounding area; 4 Unlikely to be found in footprint and not recorded in surrounding area.

Potential impacts and proposed management

For each of the Priority flora in the first and second rankings of Table 5-10, the importance of the population that will or may be impacted is assessed using the description of an important population used by DEWHA (DEH 2006a). According to that description, an important population is one that is necessary for a species' long-term survival and recovery and may include populations identified as such in recovery plans and/or that are:

- key source populations for either breeding or dispersal
- populations that are necessary for maintaining genetic diversity
- populations that are near the limit of the species range.

***Acacia flagelliformis* (P4)**

Acacia flagelliformis was not recorded in any of the Happy Valley plots or relevés, but was mapped as several small and discrete occurrences by ESM (1999) and Bennett (2001). ESM noted it was uncommon in the study area (Happy Valley and Gwindinup tenements) and typically occurred in valleys, creek beds and roadside drains. One of the occurrences mapped by Bennett on Loc 215 will be partially disturbed by the Proposal.

The plant is considered as widely distributed across the Whicher Scarp (e.g. Keighery et al. 2008, Mattiske 2006 and 2009), southern Swan Coastal Plain (e.g. EPA 2003b, HGM 2002) and Blackwood Plateau (Donnybrook and Nannup). Accordingly, the occurrence that will be impacted by the Proposal is not considered an important population or a significant part of an important local population or sub-population.

Rehabilitation advice

Plants will be targeted for seed collection prior to disturbance. Good regeneration can be expected from most *Acacia* spp. with timely return of topsoil.

***Boronia humifusa* (P1)**

Boronia humifusa was widely recorded across the Proposal area (39 occurrences by ESM and Bennett), being present in most Site Vegetation Types (SVTs). The Proposal will disturb six of the recorded occurrences.

Keighery et al. (2008) recorded *B. humifusa* in the Argyle, Happy Valley and Abba forest blocks, describing the taxa as 'poorly reserved' and with distinct habitat preferences, being locally common in upland open jarrah forest. Preference for areas of impeded drainage (shallow laterite/loam and creeks) seemed apparent from Happy Valley records.

Rehabilitation advice

B. humifusa is known to respond to physical disturbance. Direct and seasonal return of topsoil and direct seeding following topsoil replacement should produce outcomes.

***Boronia tenuis* (P4)**

The preferred habitats of *Boronia tenuis* includes laterite, stony soils and granites in areas from Moora, Kalamunda, Boddington and Yallingup. Most recorded occurrences are damp sites. Recorded in two quadrats at Happy Valley, neither of which will be disturbed by the Proposal. However, the vegetation at one of the plots (HV10) is similar to that of the lateritic ridges on Loc 215. Consequently, there is potential for the taxa to be present within the Proposal area.

B. tenuis was not recorded by Keighery et al. (2008) or by other Whicher studies conducted by Iluka. Note that Griffin (2008) changed *B. tenuis* to *B. defoliata* (not a listed taxon) in his reconciliation of the Happy Valley and DEC datasets.

Rehabilitation advice

The regeneration of *B. tenuis* has not been specifically studied, although good results have been obtained for other *Boronia* species using smoke water to treat seeds and topsoil prior to replacement.

***Franklandia triaristata* (P4)**

The preferred habitat of *Franklandia triaristata* includes white or grey sand within the Boyanup, Happy Valley and Abba forest blocks (Keighery et al. 2008). Other specimens have been recorded at Jarrahwood, Capel and Argyle, including two in Whicher surveys conducted for Iluka (Mattiske 2006, 2009).

Rehabilitation advice

This species was reported by Bennett from one location downslope of the footprint. The potential for its presence on lower sandy slopes along western edge of HVS and areas of HVN is considered to be moderate as areas associated with the Cartis complex vegetation (grey sands on lower slopes) has been avoided. As a member of the Proteaceae family it is expected that regeneration will occur naturally following appropriate topsoil management and return. *Hypolaena robusta* (P4)

***Hypolaena robusta* (P4)**

Hypolaena robusta has been previously recorded on white sand north of Perth and Geraldton sandplains. Not recorded by Keighery et al. (2008) or Mattiske (2006, 2009). No records south of Perth.

Recorded in creekline HVN (2007-01). Not located in other creeks, but may be present. Ranking is elevated to reflect the possibility of a new population being present in or around the mine area.

Rehabilitation advice

Hypolaena robusta is not common within the project area, restricted to a single site at a creekline which will not be disturbed by mining operations. Disturbance to creeklines in this area will be restricted to access corridors only. Where this does occur, there will be prior assessment of the proposed crossing by a qualified botanist to determine if any plants of *Hypolaena robusta* are present, with alternative crossing points demarcated if possible in the instance that plants are identified. Appropriate topsoil handling will ensure plant recruitment is maximised post disturbance.

***Logania wendyae* (P1)**

*Logania wendyae*³⁵ is described as a decumbent, dwarf shrub, growing to 17 cm. Flowers are white – blue and are present in October. Habitat includes brown clay to sandy clay and lateritic gravel. Believed to be restricted to the northern Whicher Scarp (Keighery et al. (2008), with the authors noting that specimens have not been located south of the Argyle Forest.

L. wendyae is locally common in the areas of the Happy Valley tenements associated with the lateritic uplands and gravelly mid-slopes (predominantly Site Vegetation Types 8 and 9, but also 2, 5, 11 and 14). Some of the locations had been previously disturbed (roadside). The quadrats where *L. wendyae* was recorded all share similarities with the Floristic community type C3: Whicher Scarp Jarrah and Mountain Marri woodland on laterites (Keighery et al. 2008), which will not be affected by the Proposal to any great extent. Approximately one-third of its recorded occurrences across the Proposal area will be disturbed.

Rehabilitation advice

There is no information on the biology or rehabilitation of *L. wendyae* available at this time. The taxon has been placed on the seed collection list, so seed will be collected from any plants that are present prior to clearing. Additionally, the mapped occurrences within the mine footprint are in the Whicher and Yellow Sandplain rehabilitation management areas (refer to the draft Integrated Mining and Rehabilitation Plan), which have minimum commitments for the direct and seasonal return of topsoil of 50% and 90% (State Forest areas) respectively. The presence of *L. wendyae* along disturbance boundaries indicates that the taxon may respond well to rehabilitation efforts, provided all measures to protect the abiotic and biotic qualities of the soil profile are properly implemented.

L. serpyllifolia, which is taxonomically very similar to *L. wendyae* (Keighery et al 2008), has been successfully rehabilitated by the Proponent at its Jangardup minesite (Bennett 2004b), using direct seeding and block translocation.

***Lomandra whicherensis* (P1)**

Lomandra whicherensis is a newly described species, normally found along lateritic or quartzite ridges under low woodlands of Mountain Marri (*Corymbia haematoxylon*). It is known from populations in Dardanup, Argyle and Boyanup Forests and also Collie area (Keighery et al. 2008). *L. whicherensis* was recorded in two of the Happy Valley North quadrats³⁶, one upslope from the footprint on laterite and one to the west on the laterite ridge on Gavins Rd. While the mineral deposits are not associated with these landforms, they will be affected by vegetation clearing for infrastructure, particularly in Loc 215. Consequently, there is some potential for *L. whicherensis* to be disturbed by the Proposal.

Rehabilitation advice

Being a newly described species, it is not surprising that there is no available information on the rehabilitation or regeneration of *L. whicherensis*. Bemax has successfully regenerated other *Lomandra*

³⁵ Also described as *Logania* sp. nov. (GJK 15234) in Keighery, Keighery and Gibson (2008) and as *Logania connii* in Bennett 2004a and 2006.

³⁶ Originally recorded as *L.* sp. nov.

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species at its minesites at Yarloop and Jangardup, using nursery cuttings and block translocation. Prior to clearing, those landforms on Loc 215 that are considered to be suitable habitat for *L. whicherensis* will be surveyed and any populations marked for translocation and/or the collection of cuttings or other propagative material.

***Platytheca anasima* (P2)**

Platytheca anasima is a newly described species, arising from the survey work done by Keighery et al. (2008) and is endemic to the Whicher Scarp. It is a slender erect or straggling shrub that grows 0.6 to 1.5 m high. Flowers are blue to purple, leaves are ovate. The taxon is distributed across the foothills, drainage flats and mid-slopes of the Happy Valley South tenements, on both private land and State Forest. No occurrences have been recorded within the Happy Valley North tenements. Only one of the seven occurrences will be affected by the Proposal. The quadrats within which it has been recorded are located across several Site Vegetation Types and share similarities with the A floristic group and the C3 floristic community type of Keighery et al. (2008). The taxon appears reasonably well distributed across the local site, in habitats that will be largely unaffected by the Proposal. Therefore it is not expected that the Proposal will impact significantly on *P. anasima*.

***Stenanthemum sublineare* (P2)**

Stenanthemum sublineare is an erect shrub to 10 cm high, with green flowers appearing October to December. Its habitat includes white sands, typically coastal, and has a known distribution from Bullsbrook north of Perth to Albany, but only from very few records.

The single recorded occurrence is on the edge of degraded bushland on Loc 4485 Gundagai Rd, within the Happy Valley South tenements. The Proposal has been redesigned to avoid the quadrat.

***Stylidium barleei* (P3)**

Stylidium barleei, the Tooth-leaved Triggerplant, is a rosette perennial herb of 10 to 45 cm high, with white flowers that occur October to December. One of the two recorded locations of *S. barleei*, HV29, lies less than 10 m from the proposed disturbance boundary of the Happy Valley North mine. All measures will be taken to protect the quadrat from disturbance, however, it is considered to be at high risk.

Floristically, the two quadrats (the other being HV 32) have been assigned as the C3 community type, which is widespread in the area. The mosaic of soil and vegetation patterns at Happy Valley North includes several small areas where suitable habitat may occur, both within and outside of the proposed footprint. Accordingly, there is only a very low level of risk that the Proposal will significantly impact on the local population of *S. barleei*.

Rehabilitation advice

S. barleei has been listed as a priority for seed collection in the Happy Valley Rehabilitation Plan. While numerous *Stylidium* spp. have been successfully rehabilitated by Bemax and other mining companies in W.A., specific research will be conducted to ensure that *S. barleei* and *S. striatum* (below) can join that list.

***Stylidium striatum* (P4)**

Stylidium striatum (Fan-leaved Triggerplant, synonymous with *Stylidium rigidifolium*) can be found on brown clay loam over laterite on hill-slopes of the Jarrah/Marri forest and Wandoo woodland. The majority of records of the species are in the Darling Scarp and Plateau (e.g. Beverly, Boddington) but has also been recorded at Capel and Boyanup. *S. striatum* was recorded at Yoganup by Mattiske in 2006 but not at Tutunup in 2009. The plant was recorded at three sites by Keighery et al. (2008) but not mentioned in the text of the report as a significant species.

S. striatum was not recorded in any of the Happy Valley studies, but has the potential to be present in low numbers.

Rehabilitation advice

As with *S. barleei*, *S. striatum* will be subject to targeted seed searches and for further research.

***Synaphea hians* (P3)**

Synaphea hians has a recorded habitat preference for sandy soils and rises, with populations found between Collie, Busselton and Cranbrook. A population (1 quadrat) was recorded in the Treeton forest block by Keighery et al. (2008). *S. hians* was not recorded by any of the Happy Valley surveys. While it may be present in the Proposal area, any presence will be minimal and localised. Subsequently, any potential impacts are not expected to impact on the distribution or diversity of *S. hians*, as the site is not at the extents of its considerable range.

***Synaphea polypodioides* (P3)**

Synaphea polypodioides is a newly described species³⁷, being recorded in light brown loam, red-brown sandy loam, gravelly, brown sandy clay over laterite, typically in undulating areas, from the Dardanup, Boyanup and Argyle (Gavins Rd) forest blocks. Keighery et al. (2008), who did not record any *S. polypodioides* within their quadrats, recommended that the species be upgraded to Priority 1, based on the small area from which it has been recorded. *S. polypodioides* was not recorded in any of the Happy Valley studies, however it may be present in low numbers throughout the tenements, as they are located in the same Boyanup State Forest that Keighery et al. (2008) recorded their individuals.

***Tetratheca parvifolia* (P3)**

Tetratheca parvifolia is a relatively uncommon species recorded in open jarrah forest from Yallingup to Capel to Collie, on lateritic sands. It was recorded from a single quadrat of Keighery et al. (2008) on lower central slopes. *T. parvifolia* was also recorded at Gwindinup by Bennett (2006), also on mid slopes in *E. marginata*, *C. haematoxylon* open woodland. However, the plant was not recorded in any of the Happy Valley studies, nor by Mattiske in their surveys of Iluka tenements.

There is potential for *T. parvifolia* to occur in low numbers in the Proposal area, owing to the presence of lateritic sands and mixed *E. marginata*, *C. haematoxylon* open woodland. However, the overall abundance and distribution of the plant is highly unlikely to be determinably affected.

³⁷ Previously known as *Synaphea* sp. Donnybrook (B.J. Lepschi and T. Lally 3111)

5.4 IMPACT ON SITE VEGETATION TYPES AND FLORA

The potential impacts of the Happy Valley Proposal on site vegetation types and flora of the immediate area were assessed considering the following (from EPA 2006c):

- extent and conservation values of (local) vegetation structural units
- vegetation condition
- total flora, including significant flora.

In addition, any conservation recommendations or relevant observations made by consultants to the project or other stakeholders were also considered.

5.4.1 Potential impacts on Site Vegetation Types (structural units)

Potential impacts

The impacts of the Proposal on the mapped extent of the Happy Valley site vegetation types are shown in Table 5-1. Initial mapping showed the Proposal to have a relatively high (55% reduction in local occurrence) impact on SVT 14, which is a yellow sands community most associated with the DRF taxa *Daviesia elongata* subsp. *elongata*. Further investigations were commissioned (Ekologica 2008b) to map the extent of this community in areas to the south of the mining tenements, where Bennett 2006 and 2007) had recorded populations of *D. elongata* subsp. *elongata*. This additional mapping has indicated that only about 24% of currently mapped extent of this community will be affected.

None of the site vegetation types will have more than 70% of their mapped extent affected by the Proposal. The largest reduction in local occurrence of any site vegetation types is anticipated to be 42% for SVT1 and 53% for SVT12. The conservation attributes of both of these units are described in Section 5.4, with SVT1 being considered locally unique but in very poor condition (due to *Phytophthora cinnamomi* infestation) and supporting only low numbers of significant taxa, while SVT12 is a restricted unit on gravels that contains characteristics of SVT8 (laterite) and SVT14 (yellow sand) on potentially less dry upland slopes of the Proposal site.

Proposed management

Nine out of the fourteen SVT in the local area will be affected to some extent by the Proposal. For the purposes of rehabilitation planning, they will be grouped into three management units based on topsoil properties, soil profile and floristic conservation values:

- Kingia unit on upper flats and crests with soils dominated by laterite (SVT 8 and 11)
- Whicher unit on the mid-slopes, with a mosaic of sandy topsoils and vegetation types (1,2, 4, 5, 7 and 12) but a typical shallow soil profile
- Yellow Sandplain unit at Happy Valley South, with deep yellow and pale brown sands over laterite and loams and supporting a very diverse range of sandplain taxa, including DRF (14)
- the three units are described and shown in the draft Integrated Mining and Rehabilitation Plan (IMRP). Topsoils and subsoils will be managed separately for each unit, with further demarcation required for dieback management as well
- the outcomes for the rehabilitation of the most conservation-significant unit (SVT14) will be enhanced by the following Proponent management actions:

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- will not process the upper soil profile (top 0.7 m) for the area mapped as SVT14 to recover heavy mineral thereby maximising the retention of natural soil properties
- return at least 90% of the topsoil for the yellow sandplain unit within State Forest within the same season as its removal (period November - April)
- recreate the top 5 m of the soil profile using unprocessed sandy overburden with similar properties to the original subsoils to ensure the soil hydrologic conditions that favour the conservation significant taxa are retained (after Groom 2004).

Additional rehabilitation actions are described in the draft IMRP will also be implemented.

5.4.2 Potential impacts on local vegetation condition

This assessment applies to the potential of the Proposal to affect detrimentally on the condition of vegetation, i.e. structural integrity, vigour, etc., in areas immediately surrounding the Proposal.

Environmental aspects associated with the Proposal that may affect vegetation condition include:

- earthworks or mine pit construction causing disturbance of hydrological processes (surface water and groundwater), resulting in changes to moisture availability to individual plants or communities
- mining operations/ vehicle movements causing the introduction of, or increase in the rate of spread of invasive weed species potentially affecting the abundance/occurrence of some native species
- mining operations/ vehicle movements causing the introduction of, or increase in the rate of spread of dieback disease *Phytophthora cinnamomi* potentially reducing the number of species in vegetation communities
- introduction of ignition sources leading to an increase in the frequency or severity of uncontrolled bushfires potentially affecting vegetation community structure and composition and fauna habitat value
- dust emissions resulting in fall out potentially smothering individual plants.

Disruption to surface hydrology by earthworks

The vegetation most susceptible to this aspect will be riparian vegetation that grows in association with the creeklines that cross the Proposal area as this vegetation is reliant on a particular surface water or soil water regime. Bennett (2007) mapped vegetation condition along the creeklines as varying from Excellent to Good, as many areas have been affected by dieback, logging and grazing. The actual extent of riparian vegetation on each side of the watercourses is very limited (less than 10 m), with dryland taxa dominating (Bennett 2007 and Keighery et al. 2008).

The Proposal will avoid impacts to vegetation along creeklines by maintaining a 30 – 50 m disturbance buffer, depending on creekline. The buffers represent a minimum mining/stockpile setback, although creek crossings for roads and pipes will need to be constructed.

Potential impact and proposed management

The Proposal will effectively isolate the disturbance area from the streams for the duration of mining and the early stages of rehabilitation through the retention of buffers and directing runoff into the mining operations area away from watercourses. This diversion water will however, has the potential

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to limit catchment yield. The ephemeral nature of the watercourses (Section 7 shows that they do not flow every year) and sandy soils of the catchment that limit surface runoff infer that the temporary reductions in catchment yield from the Proposal should have little impact on riparian vegetation.

Management actions to further protect and enhance the condition of the vegetation within the riparian buffers include:

- infill planting with seedlings of plant taxa that are common to the environment in the area
- removal and rehabilitation of creek crossings, using suitable plant taxa.

Disruption to groundwater hydrology and soil moisture levels by earthworks and mine pit construction

Vegetation surrounding the proposed disturbance footprint may be affected detrimentally as a result of:

- groundwater drawdown leading to decreased availability of groundwater, if the vegetation is groundwater dependent and if the water table is affected sufficiently to cause a response
- increased infiltration of water leading to the waterlogging of soils
- excavation of soil resulting in increased evaporative soil moisture losses within or near the root zone.

Potential impact and proposed management

The first two environmental effects are considered very unlikely occurrences on other than a local scale given the absence of a permanent watertable within or below the vegetation root zone (PB 2008b, Section 7). Soil surveys (e.g. ESM 1999) and the occurrence of moist-sand plant taxa (Keighery et al. 2008) do however, support the observation by Parsons Brinkerhoff that, on a seasonal basis, local surface saturated or semi-saturated conditions may occur in the area as a result of shallow clay and/or laterite layers in the Kingia and Rosa landforms. None of the wet soil areas identified during surveys were larger than 100 m across and excavations to the base of the sandplain types on the Whicher Valley (WC and WCv) landforms in late spring showed any evidence of saturation.

The small scale of these features (less than 1 or 2 ha) makes it impossible to apply models to usefully predict the extent of groundwater impacts (Oracle 2003) and management controls are limited to adaptive responses, including:

- monitor for changes in vegetation health
- liaise with DEC and/or specialist consultants
- rehabilitate affected areas following mining.

The extent of the impact associated with soil moisture losses caused by excavation within the root zone of larger plant forms depends on the hydraulic transmissivity of the soil, which varies across the Proposal area from sands to sandy loams. The effects however, on vegetation reliant on perched water systems within the vicinity of the mine are not expected to be significant given that vegetation will be cleared from the edges of the excavation to a minimum of 20 m for mine safety reasons.

Spread of invasive weeds by earthworks and vehicle movements

The collective work of Bennett and Brearley (Bennett 2006, 2007) identified 11 weed species, including one considered of high importance (Guildford grass *Romulea rosea*). Most weeds outside of cleared areas were identified along the edges of native vegetation, particularly alongside roads and tracks.

Potential impact and proposed management

The Proposal will be managed to minimise the risk of introduction and spread of weeds through the implementation of controls as part of the site Environmental Management System (EMS) and as described in the proposed Integrated Mining and Rehabilitation Plan (IMRP). Controls include:

- not placing topsoil stockpiles from pasture areas directly adjacent to native vegetation
- avoiding placing native vegetation soil stockpiles on pasture areas, unless strict hygiene measures are implemented
- assessing routinely rehabilitation areas for weeds and periodic spot spraying.

Dieback spread by earthworks and vehicle movements

Dieback has been mapped across the mining tenements (private property and State Forest) and is quite widespread, with over 50% of vegetated areas being infested.

Potential impact and proposed management

The Proposal is a high-risk operation with regards to the spread of dieback pathogen in infested soils and stringent controls (actions) will be implemented through the EMS and as described in the IMRP, such as:

- restricting access to uninfested areas
- diverting stormwater runoff to the process water circuit
- implementing vehicle hygiene procedures for moving between areas of different dieback status
- demarcating vegetation materials, topsoil and subsoils based on dieback status.

Bushfires from introduced ignition sources

The vegetation in the State Forest areas of the Happy Valley tenements was last burnt in a controlled fuel reduction burn by DEC in 1997. There have been no uncontrolled fires in the area since that time.

Potential impact and proposed management

The greatest period of risk of mining operations causing a bushfire is during the clearing stages, which are typically carried out in the summer – autumn months. Clearing will be controlled through the company EMS, with the Proponent implementing best practices measures (actions), such as:

- fit all vehicles with fire extinguishers
- make available permanently, medium-scale fire-fighting equipment on-site, such as a trailer-mounted water tank and pump

- prohibit hot work (naked flames/sparks) without prior assessment and a hot work permit issued
- liaise with DEC and local bushfire brigades
- maintain firebreaks
- training of all site personnel in fire control and prevention.

Dust fallout from dust emissions

Dust can be generated by various aspects of the mining process such as clearing, earthmoving and haulage. Dust may have physical effects on plants such as blockage and damage to stomata, shading, abrasion of leaf surface or cuticle and cumulative effects (e.g. drought stress on already stressed species). Vegetation located close to dust sources is more likely to be subject to such impacts.

The Proponent will apply dust management measures, such as the application of water to dust-prone surfaces and limiting the movement of vehicles on unsealed roads to mitigate dust impacts generally.

5.4.3 Potential impacts on other significant flora (other than Declared Rare and Priority Flora)

Several floristic investigations of the Whicher Scarp (Bennett 2004a; Keighery et al. 2008, Keighery, Keighery and Gibson 2008) have identified additional flora species that are considered to be of conservation significance for one or more of the following reasons:

- a recently recognised taxa
- significance due to geographical locations e.g. southern or northern limit of their known geographical location
- poorly reserved and/or uncommon to the area
- local endemism with less than 100 km range
- taxa with distinct habitat preference
- a relictual species
- a morphological or genetic variant of the taxa.

About 256 flora species of significance were identified in the region by these authors, 36 of which occur within the Proposal area (Table 5-11). Appendix V3 summarises the reasons for significance and the distribution within the Proposal area, Whicher Scarp and within Western Australia. The full list of significant taxa and the locations where they have been recorded in and around the Proposal site are presented in the Appendix. Site vegetation types 14, 8, 2 and 3 are perhaps the more floristically significant, having respectively 17, 15, 11 and 11 significant taxa recorded within their bounds.

Proposed management

The Proponent will implement a number of best practice rehabilitation measures that will address the potential impacts to significant taxa that are likely to be disturbed by the Proposal. Such measures include:

- minimum targets for the direct and seasonal return of topsoil in different rehabilitation management units

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- constructing the returned soil habitat to be similar as possible to the pre-mining profile
- using provenance-correct seed and other propagative plant material
- involving local plant nurseries in the propagation of seedlings of conservation significant species for replanting following rehabilitation
- controlling spread and introduction of weed and dieback
- minimum targets for diversity and abundance of flora on rehabilitated areas.

The results of the search are presented in Table 5 - 24. Those taxa considered to be potentially impacted to some extent by the Proposal are:

- *Dampiera linearis* (locally common)
- *Hibbertia acerosa* (locally common)
- *Hibbertia huegelii* (locally common)
- *Hibbertia lasiopus*
- *Hypolaena exsulca* (locally common).

These taxa are mostly widespread across the Proposal area and a variety of vegetation associations. They are addressed specifically in the Mining and Rehabilitation Plan.

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Table 5-11 Significant flora species (as listed by Keighery et al. 2008) that have been recorded in Happy Valley studies

Species	Reason for significance (Keighery et al 2008)	Typical Habitat	Local distribution (Site Vegetation Types)	Regional distribution	Potential impact of Proposal
<i>Acacia mooreana</i>	Northern range-end of the Dardanup Reserve on the Whicher Scarp	Mainly sandy soils, often over laterite. Swampy areas and along drainage lines	14 and creeklines	SW: JF, SWA, WAR	2 out of 14 separate occurrences/sub-populations will be affected by Proposal. Priority for seed collection (as seeds and seedlings).
<i>Agonis flexuosa</i> var. <i>flexuosa</i>	Restricted distribution; uncommon in the area; distinct habitat preference	Calcareous soils, sand, loam and clay, granite. Near-coastal areas	3	SW: ESP, GS, JF, SWA, WAR	Recorded on lower sandy (Cartis) slopes. Will not be disturbed by Proposal.
<i>Allocasuarina thuyoides</i>	Populations disjunct from their natural range; restricted distribution; uncommon in the area	Sandy soils, clay. In heath on lateritic foothills and sandplains	4 (HV11)	ER: COO; SW: AW, ESP, GS, JF, MAL, SWA	Recorded on lower sandy slopes. Mine access road has been moved to avoid quadrat.
<i>Banksia armata</i> var. <i>armata</i>	Populations disjunct from their natural range; restricted distribution; uncommon in the area; distinct habitat preference	Gravelly to sandy soils, laterite. Granite outcrops, breakaways, hills, ridges, undulating plains	9 (dominant taxa)	SW: AW, ESP, GS, JF, MAL, SWA, WAR	SVT is outside of mine footprint (upper slopes). No risk of determinable impact to taxa.
<i>Banksia sphaerocarpa</i> var. <i>sphaerocarpa</i>	Northern range-end; populations disjunct from their known geographic range	Sandy soils over laterite, laterite, lateritic gravel. Geraldton to Albany	4, 6 (two quadrats)	SW: AW, ESP, GS, JF, MAL, SWA, WAR	Recorded on lower sandy slopes. Mine access road has been moved to avoid impact.
<i>Cheilanthes austrotenuifolia</i>	Populations disjunct from their known geographic range; poorly reserved; uncommon in the area; distinct habitat preference	Red to brown, sandy to clayey loam. Exposed rocky areas, granitic outcrops. Very widely distributed (> Aust)	Not recorded. May be present in creeklines (Keighery et al. 2008)	N: NK, OVP; ER: CAR, COO, CR, GAS, GD, GSD, MUR, PIL, YAL; SW: AW, ESP, GS, JF, MAL, SWA, WAR	Creeklines predominantly protected by exclusion buffers. Negligible impact, if any.
<i>Craspedia variabilis</i>	Populations disjunct from their known geographic range; uncommon in the area	Grey, red/brown or black sand, lateritic soils. Seasonally wet flats, granite outcrops, slopes	1 quadrat on SVT 8 (Kingia vegetation)	SW: AW, ESP, JF, SWA, WAR.	Not recorded within footprint. Impact of proposal on Kingia landform is minimal.
<i>Cyathochaeta avenacea</i>	Morphological and genetic variant	White, grey or brown sand, lateritic loam. Peaty swamps	Recorded at three locations along creeklines	SW: ESP, GS, JF, SWA, WAR	Creeklines predominantly protected by exclusion buffers. 1 of 3 records outside of tenements. Negligible impact, if any.
<i>Dampiera linearis</i>	Morphological and genetic variant	Sandy or clayey soils, laterite. Plains, stony ridges, seasonally wet flats	5, 2, 8, 10, 14 (11 quadrats)	ER: COO; SW: AW, ESP, GS, JF, MAL, SWA, WAR	Locally common across both sites on range of land/veg units. 4 of 11 quadrats affected. Priority for seed collection for rehabilitation using direct seed/seedlings. Some local impact possible until rehabilitation is effective.

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Species	Reason for significance (Keighery et al 2008)	Typical Habitat	Local distribution (Site Vegetation Types)	Regional distribution	Potential impact of Proposal
<i>Darwinia vestita</i>	North-western range-end; poorly reserved; uncommon in the area	White, grey or yellow sand, laterite. Stony hillsides, sandplains, granite outcrops, coastal areas, swamps	11 (1 quadrat)	SW: AW, ESP, JF, MAL, SWA, WAR	Quadrat (HV34) is well-removed from footprint but similar vegetation will be cleared on Loc 215. Potential local impact only.
<i>Dasyogon hookeri</i>	Northern range-end; distinct habitat preference; relictual species	Grey or black sand, sandy gravel, sandy clay, often wet	5, 11, 7, 2, 8, 3, 10, 14 (31 quadrats)	SW: JF, SWA, WAR	Dominant on mid-slope and upland lateritic units. Unlikely to respond well to rehabilitation on mined areas due to changes in hydrology but will be targeted for seedlings. Potential small-scale, local impact.
<i>Daviesia divaricata</i> subsp. <i>divaricata</i> MS	Populations disjunct from their known geographic range; uncommon in the area; distinct habitat preference	Sand, limestone, laterite. Woodlands, low open heath, roadside sandplain, gentle slopes. Yallingup to Eneabba	8, 6 (5 quadrats)	SW: AW, GS, JF, SWA	One plant recorded within mine footprint. All other records outside of tenements. Priority for seed collection. Potential minor impact on local abundance.
<i>Daviesia nudiflora</i> subsp. <i>nudiflora</i>	Southern range-end; Populations disjunct from their known geographic range; uncommon in the area; distinct habitat preference; morphological variant	Sandy and clayey soils, often on laterite. Undulating low rises	2, 12, 8, 14 (8 quadrats)	ER: COO; SW: AW, ESP, GS, JF, MAL, SWA	2 of 9 local occurrences/sub-populations will potentially be impacted by proposal. Priority for seed collection. Expected to recolonise well from seed and topsoil.
<i>Eremaea pauciflora</i> var. <i>pauciflora</i>	Populations disjunct from their known geographic range; uncommon in the area; distinct habitat preference	White, grey, yellow or brown sand, sandy clay, gravel, granite, laterite. Undulating flats, hillslopes, plateaus, floodplains	2, 3, 6, 14 (7 quadrats)	ER: COO; SW: AW, ESP, GS, JF, MAL, SWA	Located mainly on the upper lateritic crests and ridges and also the lower sandy foothills. Only one occurrence potentially affected. Priority for seed collection. Negligible local impact anticipated.
<i>Hakea cyclocarpa</i>	Significant populations in reference to the Whicher Scarp; distinct habitat preference	Sand, clay, gravel, laterite. Perth to Nannup	1, 8, 9, 14 (15 quadrats)	SW: JF, SWA, WAR	Locally dominant taxa. Priority for seed collection. Widely rehabilitated. Negligible potential impact.
<i>Hakea stenocarpa</i>	Populations disjunct from their known geographic range; uncommon in the area; significant populations in reference to the Whicher Scarp	Gravelly sand or clay over laterite	11 (1 quadrat)	SW: AW, GS, JF, SWA	Not recorded within footprint. Priority for seed collection. Potential impact considered negligible.
<i>Hibbertia acerosa</i>	Populations disjunct from their known geographic range; uncommon in the area; significant populations in reference to the Whicher Scarp	Sandy or gravel soils, laterite, granite. Kalbarri to Dunsborough to Esperance	1, 5, 7, 12, 8, 9, 14 (19 quadrats)	SW: AR, ESP, GS, JF, MAL, SWA, WAR	Locally common across a range of sandier vegetation types. Associated with DRF <i>Daviesia elongata</i> subsp <i>elongata</i> and C2 FCT. High priority for seed collection and direct and seasonal return of topsoil. Potential impact negligible.
<i>Hibbertia huegelii</i>	Southern range-end; populations disjunct from their known geographic range; uncommon in the area; significant populations in reference to the Whicher Scarp	Sandy soils, lateritic gravelly soils. Common in sandplains north of Perth	1, 5, 11, 7, 2, 4, 8, 6, 14 (23 quadrats)	SW: AW, GS, JF, SWA	Present in low numbers across numerous vegetation types. Expected to respond well to direct and seasonal return of topsoil and other treatments. Located south of footprint. Minor potential impact on local abundance.

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Species	Reason for significance (Keighery et al 2008)	Typical Habitat	Local distribution (Site Vegetation Types)	Regional distribution	Potential impact of Proposal
<i>Hibbertia lasiopus</i>	Northern range-end; populations disjunct from their known geographic range; uncommon in the area; significant populations in reference to the Whicher Scarp; poorly reserved	Gravelly lateritic soils	7, 14 (2 quadrats)	SW: AF, JF, SWA	1 of 2 quadrats will be impacted (HVS). Search will be conducted for additional plants in footprint and targeted for translocation or collection of propagative material to establish seedlings for replanting. Potential local impact if unable to regrow.
<i>Hibbertia mylnei</i>	Populations disjunct from their known geographic range; uncommon in the area; significant populations in reference to the Whicher Scarp	Lateritic sand or gravel. Hills, breakaways, ridges	14 (4 quadrats)	SW: AW, GS, JF, SWA	1 of the quadrats will be cleared for access and infrastructure at HVS. The remaining quadrats are outside of the impact zone. Rehabilitation will include seedlings. Negligible potential impact as not southern most records of range.
<i>Hyalosperma demissum</i>	Southern range-end; populations disjunct from their known geographic range; uncommon in the area; significant populations in reference to the Whicher Scarp	Shallow soils over granite, lateritic soils, clay loam. Winter-wet areas, granite slopes, sandplains	1 (1 quadrat)	ER: COO, GAS, MUR, YAL; SW: AW, ESP, GS, JF, MAL, SWA	Not recorded in mine area. Not specifically included in Rehabilitation Plan. No potential impact expected.
<i>Hypolaena exsulca</i>	Morphological variant	Grey or black sand. Sometimes in winter-wet depressions	1, 5, 11, 7, 2, 4, 8, 3, 6, 14 (32 quadrats)	SW: AW, ESP, GS, JF, NAL, SWA, WAR	Locally common to dominant. Targeted for rehabilitation from cuttings, root division or translocation. Previously rehabilitated by Bemax and other mines. Potential minor local impact.
<i>Johnsonia acaulis</i>	Significant populations in reference to the Whicher Scarp; distinct habitat preference; morphological variant	White, grey or lateritic sand	5, 4, 6 (4 quadrats)	SW: ESP, JF, MAL, SWA, WAR	Recorded on grey sandy foothills and midslopes. No recorded occurrences within footprint. Unlikely to be affected by Proposal.
<i>Johnsonia lupulina</i>	Distinct habitat preference; endemic taxa that extends well south of the Whicher Scarp	Grey or black peaty sand, lateritic gravel. Dunes, roadsides, damp locations. Throughout Whicher Scarp	9, 14 (3 quadrats)	SW: ESP, JF, SWA, WAR	Locally uncommon. 1 quadrat on lower slopes will be impacted. 1 quadrat is outside of the mining tenements. Priority for seed collection. Has been successfully rehabilitated in past by Proponent. Potential impact to taxa is negligible.
<i>Lambertia multiflora</i> var. <i>darlingensis</i>	Southern range-end; disjunct from their known geographic range; poorly reserved; significant populations in reference to the Whicher Scarp; distinct habitat preference	Deep white-yellow sands or loamy, clayey or gravelly soils, laterite, granite. Flats, gorges, base of scarp, rocky hills, plateaus, roadsides	13 (1 quadrat)	SW: JF, SWA	Sole recorded occurrence is located south of tenement in State Forest. Not considered to be under threat from Proposal.
<i>Lomandra spartea</i>	Southern range-end; disjunct from their known geographic range; significant populations in reference to the Whicher Scarp; distinct habitat preference; uncommon in the area	Lateritic soils	2, 8, 9 (3 quadrats). Locally common on lateritic uplands and crests	SW: AW, JF, SWA	No recorded occurrences within footprint. May be present on crests of Loc 215 to be cleared for infrastructure. Recorded to south so not range end. Will be rehabilitated from seedlings collected from provenance material. Potential impact to taxa is negligible.

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Species	Reason for significance (Keighery et al 2008)	Typical Habitat	Local distribution (Site Vegetation Types)	Regional distribution	Potential impact of Proposal
<i>Paragonis grandiflora</i> MS	Southern range-end; significant populations in reference to the Whicher Scarp	Stony, gravelly soils, brown clay, sandy clay, laterite, granite. Plateaus, hillsides, valleys, along tracks. Dardanup and Argyle forests, Harvey to Perth	8, 13, 9 (9 quadrats). Locally common on lateritic uplands and crests	SW: GS, JF, SWA	1 quadrat potentially affected. May also be present on crests of Loc 215. Recorded occurrences to south. Potential impact to taxa is negligible.
<i>Petrophile striata</i>	Populations disjunct from their known geographic range; uncommon in the area; significant populations in reference to the Whicher Scarp	Gravelly sandy soils, laterite, granitic soils, clay. Coastal plains, sandplains	8, 9 (2 quadrats). Upper sandy slopes of drainage lines	SW:AW, GS, JF, SWA	1 quadrat potentially affected by Proposal. Will be rehabilitated using seedlings from provenance stock. Recorded occurrences south, east and north. Potential impact to taxa is negligible.

5.5 SUMMARY OF POTENTIAL IMPACTS AND MANAGEMENT

5.5.1 Potential broad/regional scale impacts

The Proposal has been assessed using the regional conservation frameworks identified in Section 5.3.1, and it is likely that the Proposal will:

- sit across the boundary of the Swan Coastal Plain (SWA) and Jarrah Forest IBRA Bioregions and also the boundary of the Regional Forest Agreement study area and the Swan Coastal Plain portion of the System 1 region
- reduce the extent remaining of the Jarrah Blackwood Plateau forest ecosystem (JANIS 1997) by between 0.05 and 0.06%
- reduce the extent remaining of the “Medium open woodland: Jarrah and Marri, with low woodland: Banksia” (1017) vegetation type (DAFWA-002) by 0.3%, with 11,296 ha (64.4%) remaining
- reduce the extent remaining of the “Medium woodland: Jarrah and *Eucalyptus haematoxylon* (Whicher Scarp)” (1181) vegetation type (DAFWA-002) by 0.5%, with 8,835 ha (46.0%) remaining
- reduce the extent remaining of the Whicher Scarp valleys (WCv) vegetation complex (Mattiske and Havel 1998) by 5%, with 299 ha (50%) remaining
- reduce the extent remaining of the Whicher Scarp uplands and slopes (WC) vegetation complex (Mattiske and Havel 1998) by 3%, with 2926 ha (72%) remaining
- reduce the extent remaining of the Rosa (Ro) vegetation complex (Mattiske and Havel 1998) by an indeterminable amount (~0.04%), with 13,033 ha (79%) remaining
- not affect any listed Threatened Ecological Communities
- reduce the extent remaining, but not the distribution of, the Priority Ecological Communities 1a, 21b and C2, and other recorded occurrences are shown to exist outside of the Proposal area (based on preliminary studies and subject to ongoing investigation)
- contain recorded occurrences of the Declared Rare Flora *Daviesia elongata* subsp. *elongata* (also listed as Vulnerable under the EPBC Act), but the potential impact on the local population will not be not significant, with additional and larger sub-populations recorded 1.6 km to the south of the Proposal area
- contain recorded occurrences of two Priority 1 flora (*Boronia humifusa* and *Logania wendyae*), a Priority 2 flora (*Synaphea petiolaris* subsp. *simplex*), three Priority 3 flora (*Acacia semitrullata*, *Stylidium barleei* and *Synaphea whicherensis*) and a Priority 4 flora (*Evandra aristata*)
- be adjacent to other recorded occurrences of Priority flora, including two Priority 1 flora (*Andersonia ferricola* and *Hemigenia rigida*).

These potential impacts will be mitigated by the implementation of the IMRP, which is aimed at restoring a range of functional plant habitats and communities that are as close as possible to their pre-disturbance properties.

The performance of the Proposal against other regional conservation frameworks is described in Section 8 of the ERMP.

5.5.2 Potential local scale impacts

In terms of locally significant vegetation and flora, as described, the Proposal will:

- not take any local vegetation community (SVT) below the 30% threshold of its mapped extent
- improve the rehabilitation outcomes for SVT14, which is associated with the yellow sandplain habitat type, such as foregoing recovery of mineral from the sands of the upper 0.7 m of the soil profile and direct and seasonal return of topsoil, with a 90% minimum target for State Forest areas
- include the retention and enhancement of creek buffers to reduce impacts to surface water hydrology
- not result in wide-scale dewatering and unlikely to cause significant impacts to local vegetation, due to clearing around pit edges
- be unlikely to introduce new invasive weed species to the site and will include measures to control those weeds already present
- implement controls to limit the Proposal's potential to increase the spread of dieback infestation (the area is already 50% infested)
- implement the IMRP (see below), which includes best practice measures (and beyond) and performance criteria for the re-establishment of conservation significant taxa.

5.6 VEGETATION AND FLORA MANAGEMENT COMMITMENTS IN DETAIL

5.6.1 Mine planning

Natural vegetated features of the Proposal area have been prioritised for preservation in the mine planning process to reduce impacts on the landscape. The priority features (in order of importance) considered in this process are:

1. Dieback-free areas.
2. Drainage lines that flow down from the Scarp and wet areas.
3. Areas with Cartis landform characteristics (i.e. *Banksia attenuata* woodlands on grey sands on lower slopes).
4. Yellow sandplain community (SVT14).
5. Vegetation mapped as the Whicher Valleys (WCv) vegetation complex.

The mine plan, as presented in this ERMP, includes the following measures (actions):

- mine sequentially infested and uninfested areas and provide for the separate stockpiling of infested and uninfested topsoils and subsoils (including shallow overburden to the root depth)
- establish a mining separation distance of 30 m from the creeks on Loc 4965 and 50 m from the creek on Loc 215 and the State Forest (Happy Valley North) except at road crossings
- relocate the plant site (which will be shared with the Gwindinup South mine) from the Cartis landform to the Whicher Scarp (WC) landform

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- return the natural upper profile underlying areas of yellow sandplain vegetation type (SVT14) at Happy Valley South by sacrificing the top 0.7 m of mineralised ore
- accelerate the removal of ore from the southern half of Happy Valley South and backfill rapidly to enable the direct and seasonal return of topsoil from the yellow sandplain vegetation type.

This last measure will require double-handling of ore and other soil materials, the importation of suitably sandy overburden from Gwindinup South mine to replace the stockpiled ore and tails and an increased project footprint to accommodate the tails and fines dams that would normally be constructed on the backfilled areas.

These measures are more fully described in the draft IMRP.

5.6.2 Integrated Mining and Rehabilitation Plan

The Proponent has prepared a Integrated Mining and Rehabilitation Plan (IMRP), which describes the management actions to be implemented prior to, during and post mining of the Happy Valley Mineral Sands Project, necessary to:

- ensure that the gross value of the project area's social, economic and environmental assets at the completion of the project at least matches that of the pre-mining landscape
- integrate mining and rehabilitation schedules to maximise associated environmental outcomes
- maximise the use of rehabilitation resources available on site
- ensure that populations of any significant flora and vegetation communities are not compromised by the mining project
- adopt controlled approaches towards the management of existing threatening processes such as dieback, weed control, fire and feral animals.

The IMRP includes measures/management actions to:

- reconstruct soil profiles that are as close to the pre-mining condition as possible, by using three different standard profiles for specified areas, including topsoils
- restrict the use of mine tails within at least the top 5 m for vegetated areas and address soil compaction
- maximise the direct (same season) return of topsoil (some topsoil from the Kingia units at Happy Valley North that cannot be direct and seasonal returned will be used to assist in the revegetation of nearby old quarries)
- use provenance-correct seeds and seedlings when re-establishing vegetation, including material collected prior to clearing
- translocate recalcitrant species
- control the spread of dieback and weeds
- demonstrate the vegetation is moving towards a self-sustaining state, including capacity to regenerate following burning.

The IMRP includes review mechanisms to ensure that rehabilitation techniques are kept up to date with community and government expectations and industry best performance benchmarks and adapted

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according to monitoring results and rehabilitation progress. The plan also includes an implementation performance table to assist in the implementation of the plan. The core commitments of the IMRP are listed in Table 5-12.

Previous rehabilitation performance of the Proponent

Independent expert review

Bemax has commissioned the environmental consultants URS (2008), specifically Dr Sam Ward, to conduct an independent review of the rehabilitation practices and outcomes of its mines with native vegetation rehabilitation, namely: Yarloop, Ludlow and Jangardup (Shire of Nannup). The review is provided as Appendix V5 and is summarised below.

The review is built around a brief assessment of the rehabilitation challenges and expected outcomes at the proposed Happy Valley site. It also touches on the difficulties of ascertaining if a rehabilitated system is, or is heading towards, a sustainable, resilient and productive system.

The review states that, in light of these difficulties in ascertaining progress in rehabilitation, it becomes critical to ensure that the preconditions for a sustainable system exist. At a minimum, this requires that there is a diverse flora and a reconstructed soil profile that is stable and able to supply the nutrients and water required by the different rehabilitation types as they develop and mature. The depth of the soil profile on rehabilitated mines must be similar to the pre-mining profile and there should be an absence of impeding layers that are not present in the pre-mining profile. The reconstructed soils should have similar physical and chemical properties to the pre-mining soils. For sand mines, the most important physical property that determines the soils ability to store and release water and nutrients is the proportion of silt and clay sized particles.

The capacity of the Proponent to address these challenges and to commit to the critical needs of successful rehabilitation was reviewed, as per EPA guidance on rehabilitation (2006c). The review describes the novel techniques developed by Bemax as well as the adoption of broader best practice measures. Consistent with the advice of the reviewer, many of these developments related to the reconstruction of soil profiles as similar as possible to pre-mining profiles. The commitment and capacity of the Proponent was found to be sufficient, if it continued, to obtain maximum outcomes for the Happy Valley rehabilitation.

Outcomes from the Ludlow mining proposal

Rehabilitation by the Proponent of the native vegetation removed as part of the Ludlow mining project (Cable Sands 2002) has already produced impressive outcomes since rehabilitation commenced in 2004. For example, native species richness (NSR) for annual rehabilitation blocks has ranged between 30 species and 57 species for the three rehabilitation years. Lowest NSR has been recorded for the 2005 trial rehabilitation area, where a full suite of rehabilitation taxa was not available at the time of trial establishment. NSR for the 2006 rehabilitation block was likely reduced by drought conditions experienced during the first year (approximately half of the annual rainfall received in 2006). Highest NSR was recorded for the 2007 rehabilitation block, where a full rehabilitation mix was seeded and planted with average annual rainfall recorded over the following months. Mean native plant density ranges between 6.08 – 14.56 plants/m² for the three rehabilitation stages, with expected trends evident for the earliest rehabilitation block (2005) over four assessment years.

Native revegetation cover for the 2005 rehabilitation block averages between 83 – 101% at 30 -40 months of age. The 2006 rehabilitation block averages 44% cover at 25 months, and 2007

rehabilitation block averages 30% at 15 months. Native cover is developing rapidly and excluding weed species actively up to 40 months of age (D. Brearley, pers comm.).

5.7 PREDICTED ENVIRONMENTAL OUTCOME

Studies by the Proponent show that the Happy Valley Proposal will not cause the level of representation of any vegetation community to fall below the 30% threshold adopted by the EPA (2000a), including Priority Ecological Communities (based on preliminary studies and subject to ongoing investigations). The impacts to conservation significant plant taxa will not be significant, both by virtue of the relative scale of the Proposal on local populations and by the best rehabilitation measures to be implemented and the record of rehabilitation at other sites in the region by the Proponent. The Proposal has been modified to exclude mining from creeklines and riparian vegetation within the creek buffers.

In regards to the DRF *Daviesia elongata* subsp. *elongata*, the Proposal will be limited in its impact to the northern Whicher population of the species to the northern-most subpopulation.

The condition of the Proposal area is already compromised by large areas of *Phytophthora cinnamomi* infestation, exacerbated by previous gravel extraction and uncontrolled access to the area by the general public using a network of local tracks. The Proponent has committed to high-level hygiene measures to combat the spread of weeds and of *P. cinnamomi* through its proposed operations and to the revegetation of the abandoned quarries and tracks.

A detailed Integrated Mining and Rehabilitation Plan has been prepared, including rehabilitation objectives and proposed completion criteria. The plan addresses the complexity of the different landforms and vegetation and includes actions to maximise rehabilitation resources and outcomes, including direct topsoil return of 40% and 90% for State Forest areas of Whicher and Sandplain communities. Measures such as these will ensure that critical and significant taxa, such as *D. elongata* subsp. *elongata*, will have the best opportunity to re-establish self-sustaining populations. The plan has also been assessed against the expectations of the EPA, as described in Guidance Statement No. 6 (EPA 2006b) and the rehabilitation capacity of the Proponent has also been externally verified (Appendix V5).

5.7.1 Potential residual impacts

Following assessment of the factor of vegetation and flora, the Proponent predicts the following effects on the environmental values may occur as a result of the implementation of the Proposal:

- vegetated pit areas that will experience extensive disturbance to the soil profile (67 ha), there may be:
 - a change in landform, and hence vegetation, heterogeneity
 - a shift towards freer-draining (sandplain) habitat, which may affect taxa on rehabilitated areas with a preference for damp sands
- 155 ha of native vegetation that will be disturbed, potentially leading to:
 - a decrease in the structural diversity of the vegetation in rehabilitation areas, until natural processes (disturbance/regeneration) are re-exerted
 - a decrease in floristic diversity and productivity, which may or may not be permanent in the local area

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- a change in vegetation structure and floristics to an extent that the community descriptions may be altered, thus reducing representativeness of existing communities
- a moderately increased risk of dieback and weeds being spread into currently uninfested areas.

The significance of these residual impacts and measures proposed for their off-setting are discussed more in Section 11 of the ERMP.

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Table 5-12 Outline of the Proponent's commitments aimed at reducing, mitigating and/or offsetting impacts to vegetation communities and flora

Environmental objective	Potential inherent impact	Management commitment
To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvements in knowledge	Impact on restricted riparian habitats and vegetation	Retain a 30 m buffer from mining around the creeks on Loc 4965, Happy Valley South, and 50 m mining buffer around the creek on Lot 215 and State Forest, Happy Valley North.
	Impact on vegetation other than that absolutely necessary for Proposal to proceed (i.e. avoidable impacts)	Limit clearing in State Forest to pits and buffers, infrastructure corridors, access roads and vegetated topsoil stockpiles. Limit clearing of native vegetation generally, where alternatives exist. Demarcate clearly disturbance boundaries.
	Loss or reduction in value of rehabilitation resources	Prior to clearing, collect seed and cuttings required for propagation and store appropriately. Segregate topsoil on vegetation type and dieback status. Strip upper topsoil in 50 mm layer and lower topsoil in a 150 mm layer. Strip in dry conditions, where practicable. For Yellow sandplain management unit, strip a further 0.5 m of subsoil to specifically re-use in same strata in restored profile. Minimum commitment for direct return of topsoil for Whicher vegetation management unit in State Forest is 50% and 90% for Yellow sandplain unit in State Forest (direct return = November – April). Native vegetation topsoil that cannot be directly returned will be stockpiled to maximum height of 1 m and will be shaped and ripped to encourage germination. Where suitable, topsoil from HVN (Kingia) will be used to revegetate abandoned gravel pits in State Forest areas of the tenements.
	Loss or severe alteration of abiotic factors that are responsible for establishing/maintaining floristic diversity and productivity	Recreate upper soil profiles (top 5 or 6 m) using prescriptions developed as part of IMRP and that are consistent with landscape position and adjacent environments. Use only native soils (i.e. not mine tails) in top 5 m of profiles in areas to be restored to native vegetation. Deep-rip and contour surfaces to minimise soil compaction and reinstate natural drainage patterns. Verify soil profile reconstruction with test pits and soil tests in each mining stage.
Vegetation that is re-established differs markedly, in terms of diversity, abundance and community composition, to pre-disturbance values	Control threat of dieback spread and weeds at all stages of mining and rehabilitation. Block translocate vegetation supporting dense ground covers dominated by sedges to improve re-establishment of recalcitrant taxa. Translocate individual plants of recalcitrant or slow growing plants. Direct seed prepared rehabilitated areas with native species mix, predetermined based on rehabilitation objectives, seed quality, germination rates and feedback from monitoring and investigations.	

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Environmental objective	Potential inherent impact	Management commitment
		<p>Replant nursery seedlings (from seeds, cuttings, root divisions and tissue culture) at density >1000 plants/ha.</p> <p>Target tree density > 1000 tree species/ha.</p> <p>Conservation taxa (as identified in IRMP) abundance and diversity > 60% of pre-mining (based on plot data) within 15 months of rehabilitation.</p> <p>Weed presence in rehabilitated areas will be no greater than in State Forest control sites.</p> <p>Meet or exceed rehabilitation targets for trees, diversity, cover of understorey for each of the management units at set intervals, as described in IMRP.</p>