GMA Mining Australia

Mining Tenement M70/204 Supporting Documentation for Native Vegetation Clearing Permit Application

Contents

1. Introduction

1.1 Project Description

GMA Garnet Pty Ltd (GMA) is a wholly-owned subsidiary of Garnet International Resources Pty Ltd. GMA owns and operates the garnet mineral sand mining, and processing operations in the Mid-West Region, Port Gregory, Western Australia.

GMA proposes to clear up to 284.86 hectares (ha) of native vegetation (over 10 to 15 years) for ore extraction and related mining activities (i.e. haul road, access tracks, stockpiles) within mining tenement M70/204 (the project). The area to be cleared herein referred to as the application area (Figure 1).

A clearing permit for the proposed expansion within M70/204 is required under the Environmental Protection (Clearing of Native Vegetation) Regulation 2004 and the Environmental Protection Act 1986 (EP Act), which contains provisions that protect native vegetation while allowing the approved clearing activities.

This document comprises the following:

- A description of the proposed works
- The locality of the application area.
- Details regarding the vegetation assemblages and fauna.
- An assessment of the proposed expansion against the Ten Clearing Principles.
- The proposed environmental management requirements.

1.2 Clearing footprint design

The project will require clearing of no more than 284.86 ha of native vegetation, equivalent to the Beard Vegetation Association (BVA) 17 (Figure 2). Vegetation within the application area was rated from Completely Degraded to Good (Figure 3).

Legend

- NVCP Application Area
- Osprey nest 100 m buffer
- 50 m Orchid Habitat Exclusion Zone
- Mining Tenement

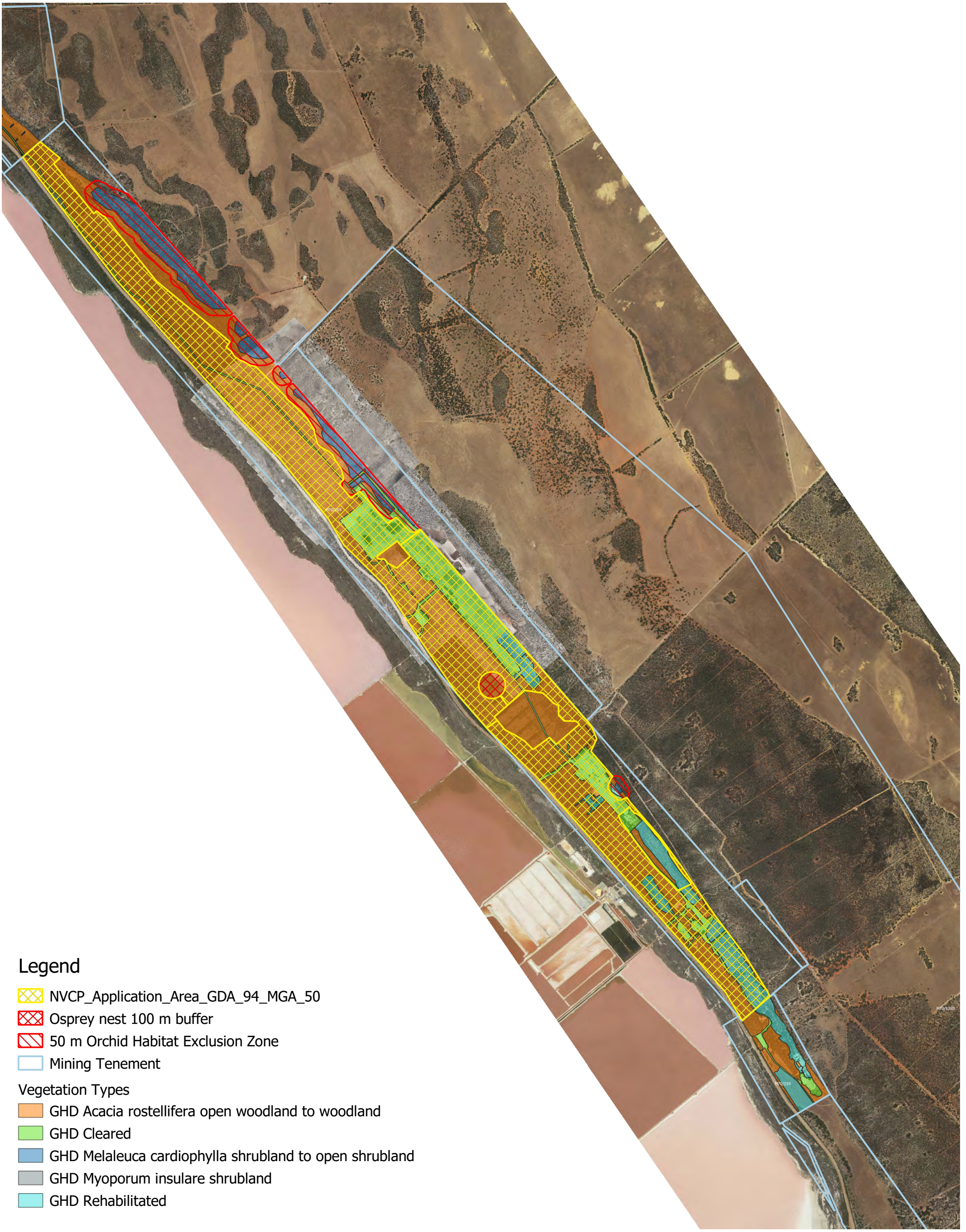
0 500 1000 m

Map Project: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50
Datasource: GHD (2020)

N

Imagery Source: Landgate 2017, GMA Imagery 12/2019 and 3/2020

Figure 1:
GMA Garnet Pty Ltd
NVCP Application Area



Legend

- NVCP_Application_Area_GDA_94_MGA_50
- Osprey nest 100 m buffer
- 50 m Orchid Habitat Exclusion Zone
- Mining Tenement

Vegetation Types

- GHD Acacia rostellifera open woodland to woodland
- GHD Cleared
- GHD Melaleuca cardiophylla shrubland to open shrubland
- GHD Myoporum insulare shrubland
- GHD Rehabilitated

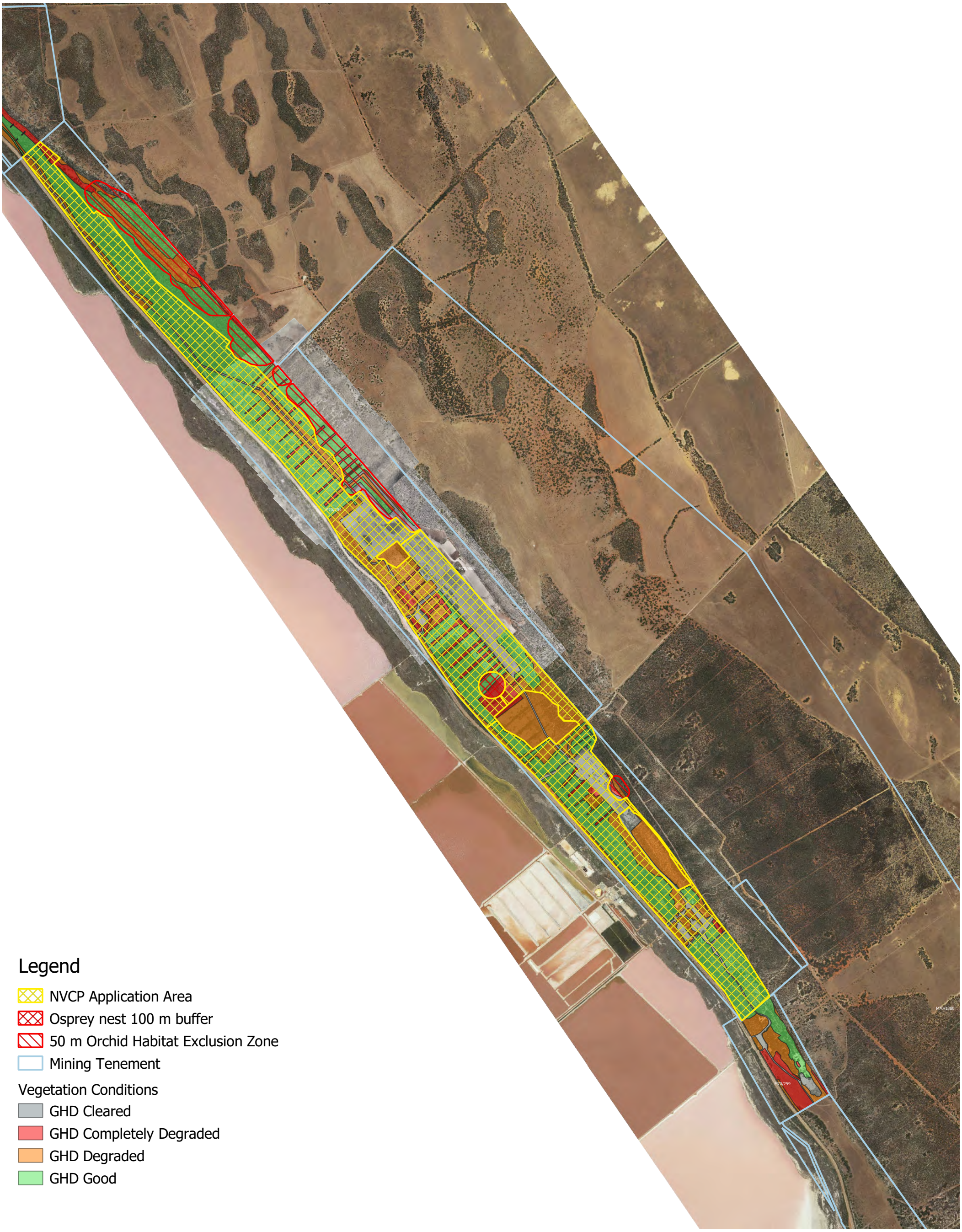
0 500 1000 m

Map Project: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50
Datasource: GHD (2020)

N

Imagery Source: Landgate 2017, GMA Imagery 12/2019 and 3/2020

Figure 3:
GMA Garnet Pty Ltd
NVCP Application Area
Mapped Vegetation Types



Legend

- NVCP Application Area
- Osprey nest 100 m buffer
- 50 m Orchid Habitat Exclusion Zone
- Mining Tenement

Vegetation Conditions

- GHD Cleared
- GHD Completely Degraded
- GHD Degraded
- GHD Good

0 500 1000 m

Map Project: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50
Datasource: GHD (2020)

N

Imagery Source: Landgate 2017, GMA Imagery 12/2019 and 3/2020

Figure 3:
GMA Garnet Pty Ltd
NVCP Application Area
Mapped Vegetation Condition

2. Overview of existing environment (GHD 2020)

GHD (2020) completed a detailed vegetation and flora survey, and reconnaissance fauna survey of the three mining tenements M70/204, M70/259 and M70/1330 (collectively referred to as the survey area) in December 2019. The biological report is provided in Appendix A. The desktop component of the report is detailed in the below sections.

2.1 Bioregional

This region comprises of sandy earth of an extensive undulating and lateritic sandplain mantling Permian to Cretaceous strata. This region occurs within the southern end of the Carnarvon Basin and the northern end of the Perth Basin, with exposed areas of Permian/Silurian siltstone and Jurassic sandstones mostly overlain by sandplains, alluvial plains and coastal limestone. The vegetation consists primarily of proteaceous heath with *Banksia* -York gum woodlands on alluvial plains and *Acacia* scrub on limestone (GHD 2020).

2.2 Geology and landforms

The application area is located within the Tumblagooda Sandstone, which is characterised by sandstone, with minor siltstone and granulate to pebble conglomerate. Most of the survey area is located on the Tamala North Land System, described as low hills with relict dunes and some limestone outcrop, which forms a coastal band 3 to 7 km wide. Parts of the western boundary of the survey area is located within the Grey Land System, described as riverbeds, terraces and alluvial flats, includes dissected margins of relic alluvial plains (GHD 2020). The topography of the application area ranged from 4 metres to 34 metres above sea level (Figure 4).

2.2.1 Soil characteristics of M70/204

Soils within M70/204 were brown to orange sands (GHD, 2020). The plate below illustrates the soil profile of the current mining area at Lynton.

The average topsoil depth observed across the Lynton deposit through mining and exploration drilling is relatively shallow at between 0.2m to 0.4m. The soil depth varies from a few centimetres above limestone cap rock up in the east, to potentially 1m in areas towards the west. The soil is sandy and porous with a similar texture to the underlying paleo-dune sand and in profile the darker brown/orange soil colour grades into the lighter yellow/light brown/beige of the underlying sand.

Beneath the top soil, a weathering profile extends to a depth generally between 0.5m to 2.0m. This zone characterised by an increase in fine calcareous material and contains nodules of calcium carbonate cemented sand. The base of the weathering zone varies from 0.5m to 2m and defined by a calcium carbonate nodule rich horizon. In some instances, this horizon has cemented into a discontinuous lense/pod of limestone up to 0.5m thick. The paleo-dunes are shell fragment rich, and it is weathering/dissolution of the shell fragments that provide calcium carbonate for precipitation into secondary nodules and limestone layers.

A characteristic of the local soil is the relatively high concentration of garnet mineral sand. The garnet is concentrated in the soil profile by weathering effects. Lighter minerals are blown or washed away over time whereas the heavy garnet mineral is left behind.

Description	Representative photograph
The photograph depicts the underlying soil profile in the eastern area of the mine pit. This soil comprises limestone underlying shallow pale brown sands.	
The photograph depicts the underlying soil profile in the eastern section of the active mining area. Cemented pale brown sands are overlying calcium carbonate nodules and some limestone.	

Legend

- NVCP Application Area
- Osprey nest 100 m buffer
- 50 m Orchid Habitat Exclusion Zone
- 2 m Contours
- Mining Tenement

0 500 1000 m

Map Project: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50
Datasource: Landgate Topography

N

Figure 4:
GMA Garnet Pty Ltd
NVCP Application Area
Topography

1.1. Hydrology

2.2.2 Groundwater

The Department of Water and Environmental Regulation (DWER) Perth Groundwater Map indicates the survey area is within the Gascoyne Groundwater Area (GHD 2020).

2.2.3 Surface water

There are no watercourses or wetlands located within the application area. The closest watercourse is the Hutt River, which is located approximately 4 km south of the application area and flows west into the ocean (GHD 2020).

The Hutt Lagoon, located directly west of the application area, is listed as a wetland of national importance on the Directory of Important Wetlands in Australia (DIWA) (DEC 2009). Hutt Lagoon is a macroscale elongate sumpland aligned northwest to southeast, parallel to the coast. It neighbours macroscale elongate floodplains (to the northwest and southeast) that include more than twenty microscale elongate sumplands such as Utcha Swamp (Jaensch 1992). Water supply for the Hutt Lagoon derives from direct precipitation, surface inform from several minor creeks and seepage of groundwater (DEC 2009).

1.2. Biological survey results

2.2.4 Vegetation and flora

The desktop results of the GHD (2020) Biological survey indicates that the application area comprises one vegetation association (table below). Remnant vegetation within the application area was mapped as Beard Vegetation Association (BVA) 371 and described as Low forest; *Acacia rostellifera*. Vegetation association directly adjacent to application area was mapped as BVA 17 and described as Shrublands; *Acacia rostellifera* thicket

The current extent of vegetation association Greenough_371 is below the 30% retention target of the pre-clearing size at all levels except LGA shown in the table below. Greenough_17 is greater than 30% of its pre-European extent at State, IBRA regional and sub-regional, and Local Government Authority (LGA).

Pre-European Vegetation Extent Association	Pre-European (ha)	Current extent (ha)	Remaining pre-European extent (%)
Greenough_17			
State	76,633.84	67,605.49	88.22
IBRA Bioregion: Geraldton Sandplains	54,078.08	45,159.85	83.51
Sub-IBRA: Geraldton Hills	49,605.04	42,016.28	84.70
LGA: Shire of Northampton	49,549.89	41,939.33	84.64
Greenough_371			
State	32,816.04	3,499.60	10.66
IBRA Bioregion: Geraldton Sandplains	32,807.53	3.499.10	10.67
Sub-IBRA: Geraldton Hills	32,807.53	3,499.10	10.67
LGA: Shire of Northampton	5,749.92	2,142.08	36.94

One vegetation type was mapped within the application area – *Acacia rostellifera* open woodland to woodland with brown to orange sands. The vegetation type mapped in low-lying and middle to upper slopes of the survey area and aligns with BVA 17 (*Acacia rostellifera* dense thicket at 6 m in height, principal species comprise of *Alyogyne cuneiformis*, *Pimelea floribunda* and *Melaleuca cardiophylla*).

BVA 371 (Acacia low forest) located on some flats north of the Hutt River and is a taller version of the *A. rostellifera* thicket exceeding 10 metres in height, and it is very dense. The *Acacia rostellifera* seems to be a pure stand of that species (Beard and Burns 1976). Beard and Burns (1976) t*he Vegetation of Geraldton Area Western Australia, Map and Explanatory Memoir* is provided in Appendix B.

Rehabilitation areas were also recorded within the application area and contain fragmented vegetation resembling the *Acacia rostellifera* open woodland to woodland vegetation type (GHD 2020).

The vegetation condition within the application area ranged from good to completely degraded. Some of these areas have appeared to have undergone historical clearing (exploration) and rehabilitation in some areas (GHD 2020).

*2.2.1 **Conservation ecological communities***

GHD (2020) desktop searches did not identify Threatened Ecological Communities within 10 km of the application area. Two Priority Ecological Communities PECs were identified within 10 km of the application and these include:

- *The Kalbarri Ironstone Community* (P1) – 8 km east of the application area.
- *Shrubland of the Northampton Area, dominated by Melaleuca species over exposed Kockatea shale* (Priority 1 – PEC) – 5 km southeast of the application area.

No PEC or TECs were delineated from the biological survey.

*2.2.2 **Flora***

Sixty-four flora taxa (including subspecies and varieties) representing 26 families and 50 genera were recorded from the survey area during the field survey.

Conservation significant flora

A review of the *NatureMap,* EPBC PMST and purchase DBCA database indicate the potential presence of 48 conservation significant flora occurring within 10 km of the application area (GHD 2020).

No Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) or Biodiversity Conservation Act 2016 (BC Act) or Department of Biodiversity Conservation and Attraction listed flora were recorded within the survey area.

The likelihood of occurrence assessment post-field survey concluded three species considered possible to occur, five species unlikely to occur, and 40 species highly unlikely to occur in the survey area. The species considered possible to occur within the mapped vegetation type of the application area included *Anthocercis intricata* (P3) and *Balladonia aervoides* (P3) (GHD 2020).

GHD (2020) recorded a potential habitat for *Caladenia bryceana* subsp. *cracens* adjacent east of the clearing application area.

*2.2.3 **Environmentally Sensitive Areas***

One Environmentally Sensitive Area (ESA) was identified 200 metres west of the application area (GHD 2020).

*2.2.4 **Fauna***

GHD (2020) recorded thirty-one fauna species during the biological survey, including 21 bird, 8 mammal and 2 reptile species. Of these, 24 are native and seven introduced/feral.

Conservation significant fauna

A review of the *NatureMap*, EPBC PMST and purchase DBCA database indicate the potential presence of 35 conservation significant fauna occurring within 10 km of the application area (GHD 2020).

No Threatened fauna listed under the EPBC Act and/or BC Act or Priority fauna species listed by the DBCA were recorded during the survey. The Eastern Osprey (*Pandion cristatus*) listed as Migratory and Marine under the EPBC Act and International Agreement under the BC Act were recorded during the survey but outside the application area.

Of the 35 conservation significant fauna identified in the desktop searches:

- One species was present (*Pandion cristratus* (Osprey) – Migratory and Marine listed))
- Two considered likely to occur.
- The remaining species are considered unlikely or highly unlikely to occur.

An Osprey nesting site was recorded outside the application area and in the south-western portion of M70/204. A 100 m buffer was applied to the nesting site (GHD 2020).

3. Summary of Key Findings

The application area is situated on a moderate slope with the topography varying from10 m to 36 m above sea level. One vegetation type (*Acacia rostellifera* open woodland to woodland) was mapped within the application area and closely aligned with BVA 17. The soil of the application area described as a brown to orange sands with underlying limestone nodules.

A comparison of the mapped BVAs indicates that the vegetation structure, topography, soil type and underlying geology closely aligns with BVA 17. BVA 17 flora community comprises *Acacia rostellifera thicket* dense shrub community reaching 6 m or more in height. Principal species include *Alyogyne cuneiformis*, *Pimelea floribunda* and *Melaleuca cardiophylla* occurring on black soil overlying limestone (GHD 2020).

BVA 371 characterised by *Acacia rostellifera* exceeding 10 m in height and is very dense and seems to be a pure stand of the species (*Acacia rostellifera)* occurring on some black clay bottomland soils (Beard and Burns, 1976).

The vegetation condition of the application area ranged from good to completely degraded, with much of the understorey comprising high weed cover (GHD 2020).

GHD (2020) did not record any conservation significant flora within the application area. However, a Likelihood of Assessment post-field assessment for flora indicated that *Anthocercis intricata* (P3) and *Balladonia aervoides* (P3) considered possible to occur within the application area. A previous survey undertaken by GHD have not recorded *Balladonia aervoides*; however, *Anthocercis intricata* (P3) was recorded by GHD (2019) sandy loam overlying limestone with M70/1380. Potential habitat for *Caladenia bryceana* subsp. *cracens* which is an EPBC Act listed Vulnerable/BC Act flora mapped directly adjacent north of the application area.

4. Assessment of the Ten Clearing Principles

4.1 Principles

An assessment of the proposed clearing action against the ten clearing principles, as outline in Schedule 5 of the EP Act provided in the table below. The assessment of the ten clearing principles indicates the following:

- The proposed clearing may be at variance with Principle (e) – the desktop assessment identified one Beard Vegetation Associations 371 that intercepts the application area. Vegetation association BVA 17 mapped directly adjacent to the application area. BVA 371 is underrepresented with less than 30% remaining at a State, IBRA and sub-IBRA level. BVA 17 is considered well represented with greater than 80% remaining at all levels. GHD (2020) delineated one vegetation type from the application area and comparison of this vegetation type, soil type and geology with Beard Vegetation Association descriptions, indicates that vegetation type is equivalent to BVA 17.

Clearing Principle	Assessment	Conclusion
Principle (a) – Native vegetation should not be cleared if it comprises a high level of biological diversity.	The application area is in the Geraldton Hill sub-region of the Geraldton Sandplains IBRA. One Beard Vegetation Association has been mapped in the application area BVA 371. BVA 17 has been mapped directly adjacent to the Application Area. The extent of the pre-European extent vegetation remaining for BVA 17 is greater than 80% at all levels. The extent of remaining for BVA 371 is 10.66 to 10.67% at a State, IBRA, Sub-IRA level. At an LGA level 36.9% of native vegetation extent remains. However, mapping results from vegetation and flora survey conducted by GHD (2020) only described one vegetation type (*Acacia rostellifera* open woodland to woodland) within the application area. The vegetation type describe is consistent with BVA 17. Sixty-four flora taxa (including subspecies and varieties) representing 26 families and 50 genera recorded from the survey area during the field survey. This total comprised 49 native taxa and 15 introduced flora taxa. The species diversity ranged was 14 taxa per 100 m^2. As such, the species diversity is comparatively lower than that known within a 10 km radius, as according to *NatureMap* 455 flora taxa have been recorded (GHD 2020). The application area is not within a TEC or PEC. Two priority flora species considered to potentially occur in the application area based on available range and habitat type. No threatened flora taxa considered to occur within the application area. The application area is good to completely degraded vegetation condition. The application area has been subject to historical grazing and clearing. Therefore much of the understorey comprises weeds. No Threatened or Priority Flora was recorded within the application area. A total of 31 fauna species were recorded within the broader survey area. Of these, 24 are native, and seven introduced. One Migratory/Marine listed EPBC Act fauna species – *Pandion cristratus* (Osprey) was recorded nesting outside the application area. A 50 metre buffer has been implemented	The proposed clearing not at variance with this Principle.

Clearing Principle	Assessment	Conclusion
	around the nesting site to ensure clearing will not impact on the nesting site (Figure 3).	
Principle (b) – Native vegetation should not be cleared if it comprises the whole or a part of, or is necessary for the maintenance of, a significant habitat for fauna indigenous to Western Australia.	The EPBC Act PMST, *NatureMap* and DBCA Threatened and Priority Flora databases identified the presence/potential presence of 48 conservation significant flora taxa within 10 km of the survey area. Of these two were considered as likely to occur including *Apus pacificus* (Fork-tailed Swift) and *Falco peregrinus* (Peregrine Falcon). One Migratory/Marine listed fauna species *Pandion cristatus* (Osprey) nesting site was recorded within the south-western portion of the mining tenement. A 100-metre buffer has been implemented around the nesting site to ensure clearing will not impact on the nesting site (Figure 3).	The proposed clearing is not at variance with this Principle.
Principle (c) – Native vegetation should not be cleared if it includes, or is necessary for the continued existence of, rare flora.	No Threatened (Declared Rare) flora are considered to possibly occur within the application area (GHD 2020) potentially. GHD (2020) recorded a potential habitat for *Caladenia bryceana* subsp. *cracens* adjacent east of the clearing application area. A 50 m was implemented between the suitable habitat and application area.	Removal of native vegetation within the application area is considered not at variance with this Principle.
Principle (d) – Native vegetation should not be cleared if it comprises the whole or a part of, or is necessary for the maintenance of, a threatened ecological community.	There are no known TECs within the application area. Also, the vegetation type mapped within the application area is considered not to be representative of the TEC or PEC (GHD 2020).	The proposed clearing is considered not at variance with this Principle. No threatened ecological communities were recorded within the application area.
Principle (e) – Native vegetation should not be cleared if it is significant as a remnant of native vegetation in an area that has been extensively cleared.	One vegetation type was recorded within the application area. A comparison of vegetation type with Beard Vegetation Associations mapped within the application area. Broader survey area, indicates that vegetation type 1 closely aligns with BVA 17 (*Acacia rostellifera* dense thicket at 6 m in height, principal species comprise of *Alyogyne cuneiformis*, *Pimelea floribunda* and *Melaleuca cardiophylla*). In contrast, BVA 371 (Acacia low forest) which is a taller version of the *A. rostellifera* thicket exceeding 10 metres in height. It is very dense, and seems to be a pure stand of that species (*A. rostellifera)* (Beard and Burn 1976).	The proposed clearing may be at variance with this clearing principle.

Clearing Principle	Assessment	Conclusion
	The current extent of vegetation association Greenough_17 is greater than 30% of its pre-European extent at State, IBRA regional and sub-regional, and LGA levels. Clearing of native vegetation within the application area will not permanently reduce the extent of pre-European extents, as the application area is returned to pre-mining vegetation assemblages following the Mine Closure Plan and Notice of Intent conditions.	
Principle (f) Native vegetation should not be cleared if it is growing in, or in association with, an environment associated with a watercourse or wetland.	There are no watercourses within the application area. The nearest watercourse is the Hutt River, located 4 km south of the application area (GHD 2020). There are no wetlands within the application area. The nearest wetland is the Hutt Lagoon which is located approximately 200 metres from the application area (GHD 2020).	The proposed clearing is considered not at variance with this Principle. No watercourses or wetlands were recorded within the application area.
Principle (g) Native vegetation should not be cleared if the clearing of the vegetation is likely to cause appreciable land degradation	The deep sands of the area have a high to very high wind erosion risk. However, GMA's generally undertakes clearing activities before winter and progression rehabilitation. GMA adopted the following vegetation clearing approach using a raised blade technique to remove vegetation. Pre-winter clearing allows rain to penetrate the soil, preserving rootstock and encourages vegetation cover on the ground to combine with the soil. This controls erosion until rehabilitation commences.	The proposed clearing is not considered at to be at variance with this Principle.
Principle (h) Native vegetation should not be cleared if the clearing of the vegetation is likely to have an impact on the environmental values of any adjacent or nearby conservation area.	There are no conservation areas within the application area. The nearest reserve is Utcha Well, which is located approximately three kilometres north of the application area. There is no direct linkage between the reserve and application area; therefore, it is unlikely that clearing will have an impact on the environmental values of the nearby reserve. Also, the clearing proposed is temporary and returned to pre-mining vegetation assemblages as per the Mine Closure Plan and Notice of Intent conditions.	The proposed clearing is not considered at to be at variance with this Principle.
Principle (i) Native vegetation should not be cleared if the clearing of the vegetation is likely to cause	The clearing is not considered likely to alter the quality of surface or groundwater within the application area. Mining operations are above the groundwater table as per Mine Closure Plan and Notice of Intent. Also, the	The proposed clearing is not considered at to be at variance with this Principle.

Clearing Principle	Assessment	Conclusion
deterioration in the quality of surface or underground water	water table is too deep (greater than 16 m bgl) to support root systems of any species (URS 2013).	
Principle (j) Native vegetation should not be cleared if clearing the vegetation is likely to cause, or exacerbate, the incidence or intensity of flooding.	Clearing of native vegetation is not expected to cause or exacerbate the incidence or intensity of flooding. The application area occurs on sandy soils which are not prevalent to flooding events.	The proposed clearing is not considered at to be at variance with this Principle.

5. Environmental management

Vegetation clearing management measurement is undertaken as per the Mine Closure Plan for Port Gregory Mine Site, some of the measures include:

- Clearing and access control measures such as demarcation of the clearing boundary.
- Weed control.
- Sequential clearing to allow fauna to abscond.
- Dust control.
- Implemented a 100-metre buffer has implemented at the location of the recorded migratory listed Osprey nesting site (the buffer area is shown in Figure 3).

6. Reference

GHD (2020) *Lynton Mine Expansion Biological Survey.* Unpublished. Prepared for GMA Garnet

URS (2013) *Hose Mine Hydrological Assessment.* Unpublished. Prepared for GMA Garnet.

Appendix A. Lynton Mine Expansion Biological Survey

Submitted as part of CPS 8825/1

Appendix B. The Vegetation of the Geraldton Area Western Australia

With best wishes from the authors.

VEGETATION SURVEY OF WESTERN AUSTRALIA

THE VEGETATION OF THE

GERALDTON AREA

WESTERN AUSTRALIA

MAP AND EXPLANATORY MEMOIR

1:250,000 SERIES

by J.S. Beard & A.C. Burns
assisted by Anne Z. Parker

Vegmap Publications
Perth
1976

September-October 1973 and again in 1974 with a final visit in April 1975. The vegetation map was compiled at the end of 1974 and shows original natural vegetation as inferred to exist prior to European settlement. Aerial photomosaics at a scale of 1 inch to 1 mile (1 : 63,360) were utilised but as the greater part of the Geraldton district had been cleared for agriculture prior to the photography, eliminating vegetation patterns, much reliance was placed on the geological map. The original plant communities could usually still readily be assessed from roadside relics and their correlations with soil, topography, landform and geology observed. Boundaries could then legitimately be assumed from the geological map particularly as this indicates superficial deposits rather than the solid geology over substantial areas. This method was only found to break down on the "sandplain" or Tertiary plateau surface where the decreasing rainfall inland parallel to the coast leads to progressive change in vegetation without accompanying change in the geology. In this case boundaries were determined from aerial photography and ground observation. On the Greenough flats agricultural use has proceeded for so long and so intensively that no reliable vestige of the original vegetation remains, and the mapping there was worked out from general inference.

The vegetation map was drawn onto a topographic base provided by the Department of National Development, Canberra. Concepts in the classification of vegetation, nomenclature and other aspects of procedure have been dealt with in earlier work (Beard 1969, Beard and Webb 1974).

DESCRIPTION OF THE AREA

CLIMATE

There are numerous rainfall recording stations in the southwest half of the Geraldton map and very few in the northeastern half. The heaviest rainfall in the region is found near the west coast where a narrow tongue of comparatively high rainfall extends as far as the northern border of the map. It runs along the steeply rising land, roughly parallel with the west coast and about 16 km from it as far north as Northampton, but approaches the coast north of the mouth of the Hutt River.

The 300 mm isohyet runs very approximately from the southeast corner to the northwest corner of the region, dividing it in halves. In the western half, rainfall increases rapidly from 300 mm to 500 mm near the coast. East of the 300 mm isohyet, the decrease in rainfall with distance from the coast is less rapid, reaching as low as 200 mm on the eastern edge of the northern border. The rainfall pattern in the southern half is more involved due to the greater variation in topography.

The network of temperature-recording stations in the region is less complete. There are no such climatological data for the northeastern half of the map. The only three temperature-recording stations are Geraldton, Mullewa and Chapman Research station. Temperature in the summer is generally high and in the early part of the year the maximum in a large part of the region is higher than in the north of the State, in the tropics. The average ranges from 29°C (85°F) on the coast to 38°C (100°F) in the

TABLE

Meteorological Data Kept at Geraldton Met. Office 1942-1975

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total or Mean
Rainfall (mm)													
Average	7	12	12	27	74	119	100	65	28	20	8	5	477
Highest monthly	53	131	67	100	282	286	243	131	81	109	47	59	286
Lowest monthly	0	0	0	1	0	34	34	32	0	0	0	0	34
Av. No. rain days	2	2	3	6	10	15	15	15	9	7	4	2	88
Temperature °C													
Mean Maximum	31.6	32.2	30.6	26.7	24.0	20.6	19.4	19.8	21.6	24.5	27.1	29.9	25.7
Mean Minimum	18.7	19.1	17.5	14.9	12.6	11.2	9.2	8.7	8.8	10.9	13.7	16.7	13.5
Relative humidity %													
9 a.m.	48	48	52	59	64	78	78	75	67	54	47	46	60
3 p.m.	45	42	43	45	46	59	57	57	53	48	45	45	49

northeast. Winter temperatures are seldom low enough to affect crops and pastures adversely. Occasional frosts do occur.

Most rain is received in the six month period May to October. The growing season is, on the average, four months per year.

Distribution of summer rainfall is very different from annual and winter patterns. High averages are found in the far inland districts in the southeast where they exceed 96 mm, while lows are in the coastal area to the far northwest at less than 50 mm. Farming is the main occupation in the southern part of the region, while towards the centre it gives way to pastoral activity.

Winter rainfalls are generally reliable, while summer rainfalls are more sporadic as evidenced by the large discrepancy between the averages and median rainfalls - the median falls being considerably lower and in some cases nil.

Evaporation is lowest in winter and amounts to 50 mm to 75 mm in both June and July. The annual total reaches 2400 mm (95") on the eastern border and exceeds 2150 mm (85") in two-thirds of the region. In the lower south-east coastal region evaporation is less than 508 mm (20").

The annual distribution of rainfall and annual fluctuation in temperature have been plotted on the ombrothermic diagram in Fig. 1 for Geraldton. The period when the monthly rainfall is too small to be effective is given by the proportion of the graph where the rainfall curve is below the temperature curve. In this case there are eight dry months, placing the area in the Dry Warm Mediterranean classification. The Geraldton data represents the coastal, high winter rainfall area. Mullewa,

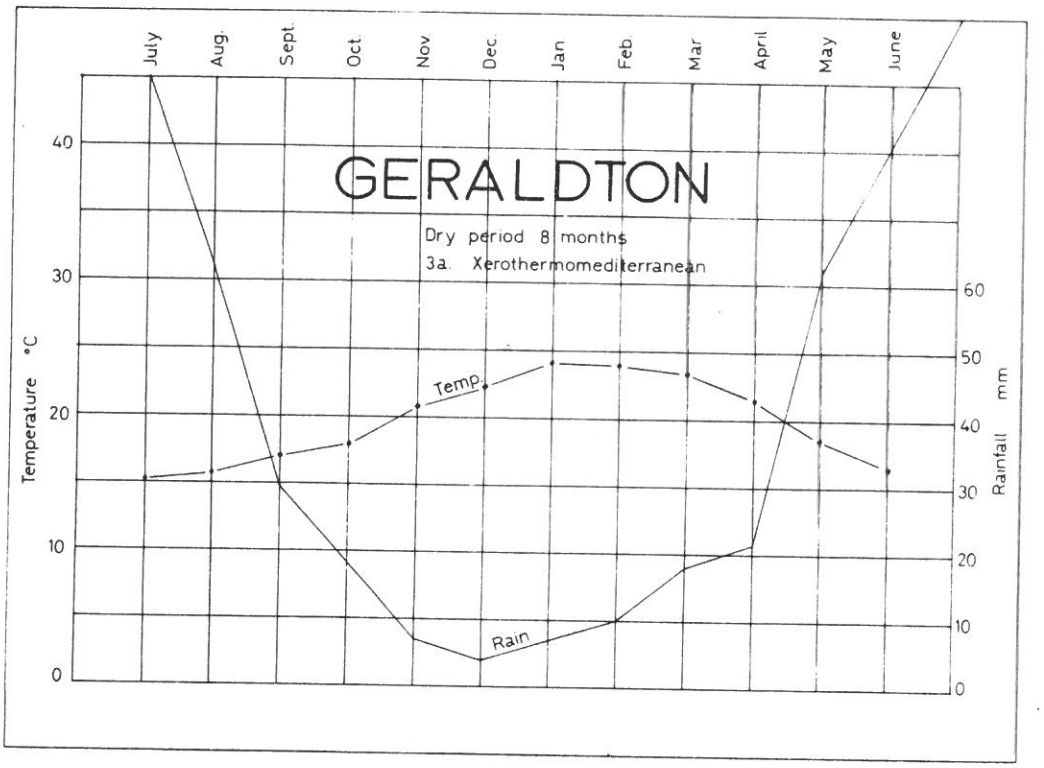


FIG. 1 Seasonal rainfall and temperature diagram for Geraldton

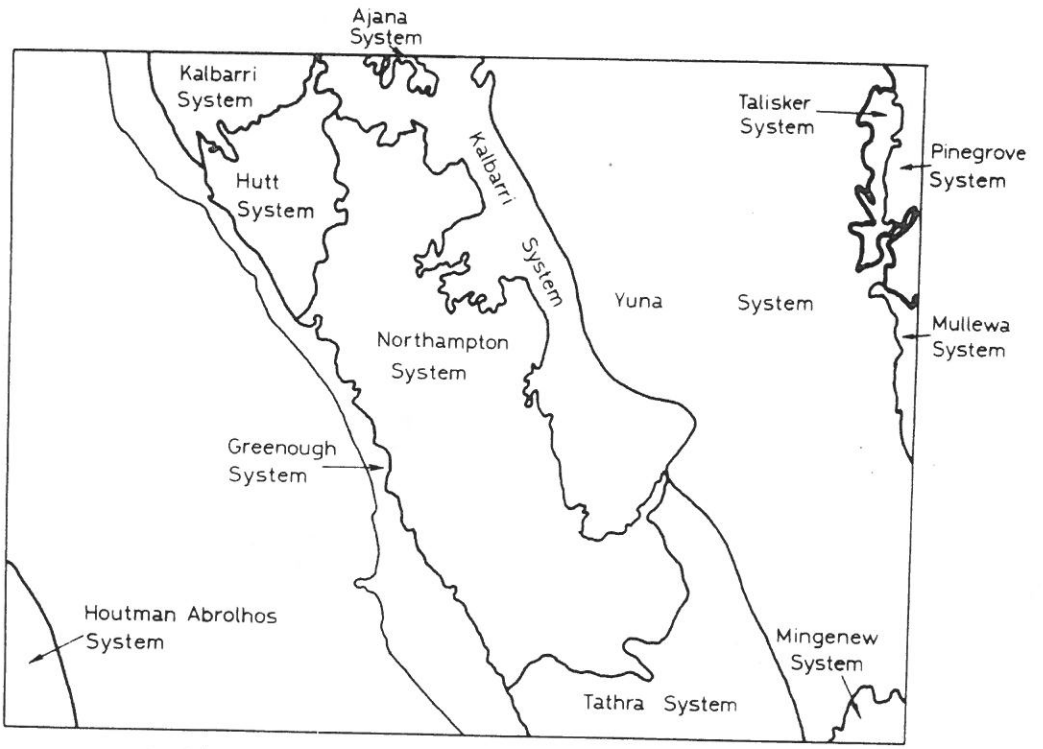


FIG. 2 Vegetation systems in the Geraldton area

almost du
border of
coast and
dry month
classific
1957).

GEOLOGY

The
Playford

Clo
indicated
Western Au
very ancie
some alter
of the cor
the Archae
which once
which ther
and accumu
sedimentat
area seems
and denuda
Northamptc
side with
an island
covered by

The
metamorpho
igneous or
large intr
Perth Basi
glacial or
Cretaceous

Sub
continuous
structural
There is n
in the Gera
that the Da
once a cont
buried at
probably fo
plain and p
fall and te
strong pedo

SOILS

The Geraldton area is included in the CSIRO soil Map (Northcote *et al.* 1967) from which the following information is derived.

The coastal soils run in a narrow strip parallel to the coast coinciding with the coastal sand dune and limestone formations. Those closest to the coast are calcareous sands in coastal dune formations with a uniformly textured profile darkened by organic matter on the surface. The soils just inland are siliceous sands in undulating dune formations underlain by aeolianite which is exposed in places. This soil has similar texture and surface organic matter to the calcareous sands.

In a large area, just inland of these coastal soils around Geraldton itself, are found soils formed of deep coherent sands characteristic of riverine plains, terraces and pans with shallow, stony sands and sandy loams.

The hills of the Northampton block have hard-setting loamy soils with red clayey subsoils. There are two types: one with an unbleached A_2 horizon and acid reaction trend and one with a sporadically bleached A_2 horizon and a neutral reaction trend.

In the northwest corner of the Victoria Plateau, just inland from the coastal soils is an area of leached sand soils in a gently undulating sand plain with occasional low laterite residuals. The majority of the Victoria Plateau area is mapped as yellow sand soil with weak pedologic development. These soils have an earthy fabric below the A horizon and are normally underlain by laterite at depth. Red earth soils are found along the river drainage systems which cross the Plateau. These are chiefly neutral to alkaline red earth soils underlain at shallow depths by a red-brown hardpan.

The laterite is visible in large areas where the sand has been stripped away and in outcrops around the edges of breakaways where the plateau has been dissected. The sand is normally less than 3 m thick, but has been redistributed in many places, accumulating in low areas up to 15 m thick. The laterite is about 1.5 m - 3.0 m deep and rests on a zone of highly weathered rock about 15 m thick. The laterite developed on an already dissected landscape with a relief comparable to that of today.

HUMAN INFLUENCES

Most of the map area is now occupied by wheat and sheep farms, as the favourable climate and soil conditions with the availability of water have encouraged extensive use of the land for pastoral and agricultural purposes. The native vegetation has been largely removed from these properties with the exception of the roadside reserves and drainage areas where many native plants persist. The flora on the sand plains of the Victoria Plateau has been more extensively preserved. The vegetation cover of the islands has remained relatively undisturbed. Reserves for conservation of fauna and flora are discussed in a later section.

DESCRIPTION OF THE VEGETATION

PLANT FORMATIONS

The plant communities mapped are classified primarily by physiognomy into formations which may be subdivided into associations according to floristic composition. The formations found in this district are eight in number, with 20 units distinguished on the vegetation map, as follows:

A. LOW FOREST

1. *Low forest* of *Acacia rostellifera*, on some black clay bottomland soils.

B. WOODLAND

2. *Sclerophyll Woodland*, occupying red loam soils, generally on bottomland sites. Three species are distinguished which associate variously, *Eucalyptus loxophleba*, *E. salmonophloia* and *Casuarina huegeliana*.

C. SHRUBLAND

3. *Scrub with scattered trees*. Open shrubland (scrub) generally of Acacia, with scattered emergent trees too sparse to qualify as woodland, the shrub layer being dominant. Three associations are mapped:

   (a) Jam *(Acacia acuminata)* scrub with scattered York gum *(Eucalyptus loxophleba)*, on Proterozoic rocks of the Northampton Block.

   (b) Mallee and wattle scrub (various *Eucalyptus* and *Acacia* spp.) with scattered eucalypts *(E. loxophleba* and *E. oleosa)*, on red bottomland soils on the Victoria Plateau.

   (c) Bowgada *(Acacia ramulosa)* scrub with eucalypts *(E. oleosa)* and cypress pines *(Callitris columellaris)* on similar soils to (b) under lower rainfall.

4. *Thicket*. Dense shrub formation generally on shallow sandy soils. Five associations are mapped, all variants of the widespread *Acacia-Casuarina-Melaleuca* alliance.

   (a) *Acacia-Casuarina* thicket on red sand plain inland.

   (b) *Acacia-Melaleuca* thicket on outcrop of Windalia radiolarite.

   (c) *Acacia rostellifera* thicket on black soil on limestone.

   (d) *Melaleuca cardiophylla* thicket on thin rocky soil on limestone.

   (e) Mixed thicket with *Melaleuca* and *Hakea* dominant on steep slopes on Jurassic rocks.

5. *Scrub*. Open shrub formation, under drier conditions than the thicket, still normally on sandy soil. Four associations have been mapped:

   (a) *Acacia-Banksia* scrub on red sand over coastal limestone.

   (b) Bowgada *(Acacia ramulosa)* scrub on a sandstone outcrop on the Victoria Plateau.

   (c) *A. ramulosa-A. murrayana* scrub on residual lateritic sand plains of the Darling Plateau.

(d) Mixed wattle scrub principally of *A. grasbyi*, *A. ramulosa*, *A. acuminata* and *A. sclerosperma* on red sandy loam overlying granite on the Darling Plateau.

6. *Open Scrub.* Still more open scrub formation, of *Acacia ligulata*, on recent poorly consolidated coastal dunes.

7. *Scrub-heath.* A sparse to open tall shrub community in which species of Proteaceae are prominent, with a dense heath ground layer mainly of Myrtaceae on leached sand soils. Three different associations are mapped:

(a) Scrub heath coastal association, on bleached or yellow sandplain within about 40 km of the coast.

(b) Scrub heath inland association, on yellow sandplain inland of (a) on the Victoria Plateau.

(c) Scrub heath southern association on bleached lateritic sandplain, replacing (a) in the south under higher rainfall.

D. SUCCULENT STEPPE

8. *Succulent steppe* comprises semi-succulent saltbush *(Atriplex)* and succulent samphire *(Arthrocnemum)* communities. These are halophytes and grow on saline flats. Mapped as (a) saltbush and samphire, (b) teatree and samphire.

PHYSIOGNOMY

The structure and growth forms of all the formations appearing here have been fully described and illustrated in earlier works, principally in the memoirs accompanying the Boorabbin-Lake Johnston and Newdegate-Bremer Bay maps (Beard 1969, 1972) so that it would be needlessly repetitious to deal with them again here. Brief details will be given in the text. They have been illustrated previously by means of measured profile diagrams, Dansereau diagrams and photographs.

CLASSIFICATION: MAPPING NOTATION AND FORMULAE

The communities mapped are classified in three categories each expressed by a code-letter, the resulting three letters, two small letters and a capital being combined into a triplet formula which is used as a mapping notation and is known as the Beard-Webb formula, from Beard and Webb 1974. The classification is as follows:

(1) *Physiognomy of dominant stratum* (capital letters)

T	Tall trees > 25 m tall	G	Bunch grasses
M	Medium trees 10-25 m tall	H	Hummock grass (spinifex)
L	Low trees < 10 m tall	F	Forbs
S	Shrubs > 1 m tall	X	Lichens and mosses
Z	Dwarf shrubs < 1 m tall	C	Succulents

(2) Floristic (small letters) Dominant genus.

a *Acacia*
c *Casuarina*
e *Eucalyptus*
m *Melaleuca*
k Halophytes *(Atriplex, Maireana*, etc.)
t *Triodia*
x Heterogeneous (mixed or other)

(3) *Density* (small letters) of canopy cover. Projective foliage cover as defined by Specht (1970).

d Dense canopy. Projective foliage cover > 70%
c Mid-dense canopy. P.f.c. 30-70%
i Incomplete canopy - open, not touching. P.f.c. 10-30%
r Rare but conspicuous. P.f.c. < 10%
b Barren, vegetation largely absent. P.f.c. negligible.
p Scattered groups. No definite foliage cover.

The actual formulae are written with the floristic category first, then the capital for physiognomy, finally density, resulting in such combinations as eMc,aLi, meaning respectively a Eucalypt-dominated medium height mid-dense tree community or forest, and an Acacia-dominated low open tree community or woodland. The floristic letter stands for a genus. It may be extended to nominate species of the genus by the addition of subscript numbers, e.g. e_6, a_9. (See list below of species designated in mapping).

The relevant classification formulae for the Geraldton map are as follows. Those in the Beard-Webb column appear on the vegetation map. They are contrasted in the adjacent columns with the parallel world systems of Küchler (1949) and Dansereau (1951).

Vegetation unit	Beard-Webb formula (Beard-Webb 1974)	Küchler formula (Küchler 1949)	Dansereau formula (Dansereau 1951)
Low forest	aLc	Blc	Tleaxc
Sclerophyll woodland	eMi	Bmli.szt	Tmeaxi.Fmleaxb
Scrub with scattered trees	eMr.aSi	Bmr.si	Tmeaxp.Fteaxi
Thicket	aSc	Bsc	Fmejaxc
Scrub	aSi	Bsi	Fteaxi
Open scrub	aSr	Bsr	Fteaxb
Scrub heath	xSZc	Bszc	Fteaxi.Fmeaxc
Succulent steppe	kCi	Bzik.Oik	Fljaki

List of species designated in mapping:

a, a_n = *Acacia*, general or numerous
a_9 = *A. ramulosa* W.V. Fitzg. (bowgada)
a_{19} = *A. acuminata* Benth. (jam)
a_{20} = *A. murrayana* F. Muell. ex Benth. (sandplain wattle)
a_{21} = *A. ligulata* Cunn. ex Benth.

a_{23} = *A. rostellifera Benth.*
b = *Banksia* spp.
c = *Casuarina* or *Callitris*
c_5 = *Casuarina huegeliana* Miq.
e = *Eucalyptus*, general
e_6 = *E. loxophleba* Benth. (York gum)
e_8 = *E. salmonophloia* F. Muell. (Salmon gum)
e_{22} = *E. oleosa* F. Muell.
h = *Hakea pycnoneura* Meissn.
k_1 = *Atriplex vesicaria* Moq.
k_3 = *Arthrocnemum* and other samphires
m = *Melaleuca megacephala* F. Muell. in formula mhSc, *M. uncinata* in amSc, *M. thyoides* in mSi.kCi.
m_3 = *M. cardiophylla* F. Muell.
x = Heterogeneous. x_2, x_3, x_4 distinguish different associations.

VEGETATION SYSTEMS

A vegetation system consists of a particular series of plant communities recurring in a catenary sequence or mosaic pattern linked to topographic, pedological and/or geological features (Beard 1969). A vegetation system is a subdivision of a botanical district, as the latter is of a botanical province. Twelve systems can be recognised in the Geraldton district as listed below and shown also in Fig. 2. The following list shows their position in topographic units and in botanical districts and provinces.

Vegetation System	Topographic unit	Botanical district	Botanical Province
Houtman Abrolhos	Houtman Abrolhos	Irwin	Southwestern
Greenough	Coastal belt	"	"
Northampton	River drainage systems	"	"
Hutt	"	"	"
Ajana	"	"	"
Mingenew	"	"	"
Kalbarri	Victoria Plateau	"	"
Tathra	"	"	"
Yuna	"	"	"
Talisker	"	Austin	Eremaean
Pinegrove	Darling Plateau	"	"
Mullewa	"	Irwin	Southwestern

The botanical districts and provinces are in the sense of Diels (1906), Gardner and Bennetts (1956). Vegetation mapping for the first time affords precise boundaries for them. In his account of the vegetation of the area, Speck (1958) also used a vegetation system approach but as his work was less detailed, not based upon aerial photography, and recognised only five Systems in the district instead of twelve, it has not been possible to utilise his basis. The same names have been retained for the Northampton and Greenough Systems which correspond to two of Speck's.

The descriptions of vegetation which follow are taken system by system for convenience.

1. THE HOUTMAN ABROLHOS SYSTEM

The natural history of East and West Wallabi Islands, the two largest in the Houtman Abrolhos, was very thoroughly described by Storr (1964). The present writer has only visited Beacon Island and flown over some of the others. It appeared unnecessary to extend the vegetation map to take in all of these islands as was done by the authors of the geological map (Playford *et al.* 1970) as there would be relatively little to show. Storr *(ibid.)* published a map of the physiographic divisions of the two Wallabi islands which are correlated with vegetation types. The scale of this is 1 inch to 1 mile (1 : 63,360).

The islands are based upon a broad rock-flat composed mainly of old coral reefs which were planed in an earlier cycle of erosion to a level of 30-60 cm above present sea level. This base is partly overlain by beds of younger limestone 1-3 m thick forming the "pavement" limestone of Storr's map, and by dunes of calcareous sand, some consolidated, some unconsolidated.

According to Storr the dominant plant on the dunes is *Spinifex longifolius* together with *Atriplex isatidea, Salsola kali, Senecio lautus* and *Poa caespitosa*. Shrubs include *Olearia axillaris, Acanthocarpus preissii* and *Myoporum insulare*. The basal rock platform is mostly overlain by shellgrit which on West Wallabi supports a saltbush and samphire community with *Atriplex paludosa* dominant, replaced by *Arthrocnemum halocnemoides* in low-lying areas. Associated plants include *Threlkeldia diffusa, Senecio lautus, Frankenia pauciflora* and *Olearia axillaris*. On East Wallabi there are thickets of *Diplolaena dampieri* and *Alyxia buxifolia* instead, which may be due to difference in soil, the covering of shell grit being less extensive on East Wallabi, or to the activities of mutton birds whose burrows riddle the area on West Wallabi.

The pavement limestone supports a thicket 1-2.5 m tall with a fairly rich flora including *Pittosporum phillyraeoides, Diplolaena dampieri, Grevillea argyrodendron, Spyridium globulosum, Exocarpos aphyllus, Capparis spinosa, Pimelea microcephala, Sarcostemma australe, Olearia axillaris* and *Beyeria viscosa*. Also commonly present are *Dianella revoluta, Acanthocarpus preissii* and *Hibbertia subvaginata*.

The vegetation of consolidated dunes on East Wallabi is similar whereas on West Wallabi it is impoverished and consists of little but *Nitraria schoberi* and the introduced succulent *Gasoul crystallinum*. This is attributed to the presence of guano on West Wallabi where it was formerly mined. On the consolidated dunes of East Wallabi, Storr found a thicket of windswept *Eucalyptus oraria*, covering about 3,000 sq. metres, but no more than 1-2.5 m in height.

A list of 130 species was given by Storr comprising the flora of these islands.

2. THE GREENOUGH SYSTEM (Speck 1958)

The Greenough System is associated with the coastal limestone and extends along the coast from Kalbarri to Dongara. The limestone belt varies in width and elevation, also in topography including abrupt rocky ridges, more gentle soil-covered areas, alluvial flats and lagoons. On the seaward side it is covered with a mantle of Recent, poorly consolidated or still mobile dune sands. North of the Hutt River the limestone belt is 6-7 km wide, high and rocky mostly but with some alluvial flats and the Hutt Lagoon (a salt lake cut off from the sea by recent dunes) in the lowest portions. From the Hutt River to the Chapman the belt is 4 km wide, lower and more gentle with sandy soils, and the beach dunes are quite narrow. South of the Chapman the limestone belt spreads out again to a width of 12-13 km and there are two alluvial plains, the "front flats" and the "back flats", bounded by limestone and lime-sand ridges. The two plains are divided by a broad belt of weathered and sand-covered limestone with some rocky ridges; this formation occurs also in patches along the eastern edge of the inner plain, while recent partly mobile and partly consolidated dunes divide the outer plain from the sea.

The general catenary sequence, of which not all members may invariably be present, is of *Acacia rostellifera* and *Melaleuca cardiophylla* thickets on rocky ridges, *Acacia-Banksia* scrub on sand-covered limestone and *Acacia rostellifera* low forest on the alluvial flats. *Acacia ligulata* open scrub is typical of the recent dunes.

The *Acacia rostellifera* thicket is a dense shrub community reaching 6 m or more in height. Principal species comprise *A. rostellifera, A. ligulata, A. scirpifolia, A. xanthina, Eucalyptus eudesmioides* and *E. oleosa* (both as mallees), and *Melaleuca cardiophylla* among the large dominant shrubs, with *Alyogyne cuneiformis, Calothamnus quadrifidus, Grevillea biformis, Labichea* sp., *Helichrysum* sp. *Hibiscus huegelii, Pimelea floribunda* and *solanum simile* among smaller plants. There is no definite small shrub layer. In the rockiest and steepest places *Melaleuca cardiophylla* assumes dominance as more or less sole species. On the other hand deeper and more sandy soil leads to a thinning out of the thicket and appearance of *Banksia prionotes, B. victoriae, Acacia spathulata* and *Grevillea leucopteris,* a transition to the Acacia-Banksia scrub.

South of Geraldton *Melaleuca huegelii* joins *M. cardiophylla* in its niche, and additional species recorded in the *A. rostellifera* thicket have been *Bursaria spinosa, Chamelaucium uncinatum, Diplolaena dampieri, Melaleuca ? leiopyxis* and *M. ? undulata.*

In the *Acacia-Banksia* scrub the principal dominants are *A. rostellifera* and *B. prionotes,* which attain 5 m in height but do not form a closed community. The soil is a red sand overlying limestone. Associated species noted include, among large shrubs: *Acacia scirpifolia, A. xanthina, Banksia attenuata, B. menziesii, Bursaria spinosa, Dryandra sessilis, Eucalyptus dongarraensis, Grevillea biformis, Gyrostemon ramulosus.*

Smaller shrubs and ground plants: *Acacia spathulata, Conostylis aculeata, Grevillea argyrophylla, Hibbertia* aff. *hypericoides, Lechenaultia linarioides, Melaleuca ? undulata, Scholtzia umbellifera, Stylobasium spathulatum* and a number of grasses and sedges.

The *Acacia* low forest which is seen on some flats north of the Hutt River is really a taller version of the *A. rostellifera* thicket, exceeding 10 m in height. It is very dense, and seems to be a pure stand of that species. Creeks are lined by *Eucalyptus camaldulensis* and *Casuarina obesa*. On the alluvial flats south of Geraldton no trace of the original vegetation remains even on roadsides as the area has been intensively farmed for well over a century. Even individual native plants are few, and limited to occasional *Acacia rostellifera* on roadsides, and *Eucalyptus camaldulensis* around waterholes and soaks. These trees are usually windswept, leaning over away from the south wind and in extreme cases virtually decumbent. So extraordinary is their shape that they are a source of wonder and treated as a tourist attraction. The popular impression that the trees have been bent over by the wind is not strictly correct. Wind is indeed responsible for their form but has acted by killing the buds on the windward side of the tree, by desiccation or deposition of salt spray during gales, so that the tree is only able to grow on the leeward side and extends itself in that direction. Strong southerly winds are a feature of the dry summer.

It is believed from consulting Messrs. Tom McNeece and Fred Morrell, two old identities in the district (A.C. Burns, pers. comm.), that some areas on the Greenough were originally treeless but most were covered with dense thickets of Acacia which were cleared by hand by the early settlers to prepare farmland; also the bark was used for tanning. Other species on the front flats were *Melaleuca lanceolata* and *M. rhaphiophylla, Eucalyptus camaldulensis* and *E. dongarraensis*. On the back flats where the soil is lighter it is believed that there were patches of *E. loxophleba* and of Banksia scrub.

By analogy with the alluvial flats further north where a native vegetation still exists, the former cover of the Greenough Flats has been mapped as *Acacia rostellifera* low forest with a few scattered *E. camaldulensis*. Speck (1958) believed that it was *E. camaldulensis* woodland but we disagree.

The Hutt Lagoon consists mainly of bare salt flats but it is vegetated with samphire round the margin for some 100 m.

The coastal dune vegetation in this System has been studied by Sauer (1965) who included an illustration (his Fig. 10) of a transect at Grey's Bay near Geraldton. *Spinifex longifolius* and *Atriplex isatidea* are the sand-binders above high-water mark. The latter plus *Salsola kali* and *Threlkeldia diffusa* occupy the foredune, joined by *Scirpus nodosus, Olearia axillaris* and *Myoporum insulare* a little further inland. *Carpobrotus aequilaterus* and *Acacia rostellifera* appear on inner dunes. Present as scattered, stunted shrubs in the active dunes, *A. rostellifera* forms dense

groves on the stable inner dunes. At some stage north of Geraldton *A. rostellifera* is replaced in this habitat by the closely similar species *A. ligulata*. The coastal dunes at Port Gregory were examined by the writer. Here *Spinifex longifolius* and *Carpobrotus aequilaterus* are the beach colonisers, succeeded by *Acacia ligulata* (or *rostellifera*), *Olearia axillaris* and *Scaevola crassifolia* forming an open scrub. On the sheltered inland side of the dunes *Lechenaultia linarioides* and *Myoporum ascendens* were also recorded.

3. THE NORTHAMPTON SYSTEM (Speck 1958)

Named from the old mining town of Northampton which lies in a characteristic portion of the area, this system comprises the dissected country west of the Victoria Plateau and sloping down to the coast, in which the plateau surface has been largely removed exposing undulating country on rocks of the Northampton Block. Residuals of the overlying Jurassic rocks still remain as isolated flat-topped hills or mesas with remnants of the original plateau sandplain on their summits. These mesas form the Moresby Range north and east of Geraldton, a well-known and conspicuous feature of the district. There is therefore a well-marked catenary sequence, scrub heath of the "coastal association" on the mesa tops, *Melaleuca-Hakea* thicket on the Jurassic sediments (usually forming steep scarp slopes) and *Acacia acuminata* scrub with *Hakea* and scattered *Eucalyptus loxophleba* on the lower undulating country on Proterozoic granites and granulites. Scattered *Eucalyptus camaldulensis* occur on drainage lines but never so densely as to form woodland.

SCRUB HEATH, "coastal association"

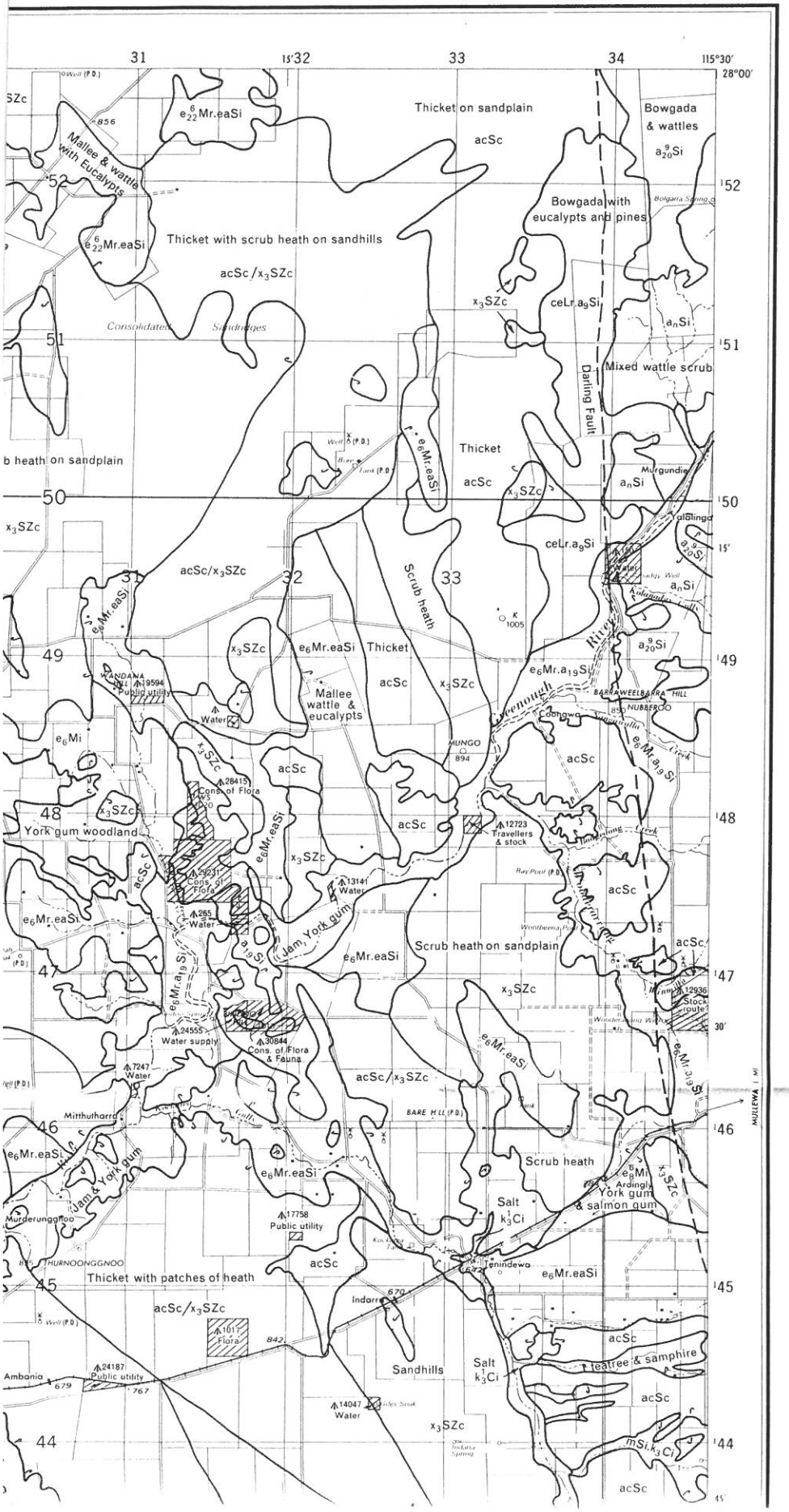
As mapped this unit comprises at least two types, the one on laterite, the other on sand. On laterite the composition was noted: *Gastrolobium oxylobioides* (locally very abundant), *Casuarina campestris* (abundant), *Dryandra ashbyi* (abundant), *Isopogon divergens* (frequent), other species *Baeckea grandiflora, Bossiaea eriocarpa, Calothamnus quadrifidus, Hakea cristata, H. trifurcata, Halgania sericiflora, Hibbertia* aff. *hypericoides, Melaleuca radula, Patersonia* sp., *Verticordia chrysantha, Xanthorrhoea preissii. Nuytsia floribunda* is seen in draws, as a small tree. The stature and density of this assemblage varies from heath to thicket according to the time elapsed since the last fire. The sand community on the other hand will grow taller and more open and is a true scrub heath. Components include *Banksia attenuata, B. menziesii, B. prionotes, Acacia rostellifera, Dryandra sessilis, Casuarina humilis, Conospermum stoechadis, Eremaea beaufortioides, Gastrolobium spinosum, Hibbertia* aff. *hypericoides, Lachnostachys* sp., *Nuytsia floribunda, Petrophile* sp. The sand is white and bleached.

MELALEUCA-HAKEA THICKET

Again, at least two communities are included in this unit, the one with *M. megacephala* and *H. pycnoneura* dominant and the other with

REFER TO THIS MAP AS: **SH 50-1**

VEGETATION SERIES



KEY

This map shows original natural vegetation

Woodland

eMi	Sclerophyll woodland e_6 = *Eucalyptus loxophleba* (York gum) e_8 = *E. salmonophloia* (Salmon gum) c_5 = *Casuarina huegeliana*

Low forest

a_{23}Lc	*Acacia rostellifera* low forest

Scrub with scattered trees

e$_6$Mr.a_{19}Si	Jam scrub with scattered York gum
e_{22}^{6}Mr.eaSi	Mallee & wattle with scattered eucalypts
ceLr.a_9Si	Bowgada with eucalypts and cypress pines

Thicket

acSc	*Acacia-Casuarina* thicket
amSc	*Acacia-Melaleuca* thicket
a_{23}Sc	*Acacia rostellifera* thicket
m_3Sc	*Melaleuca cardiophylla* thicket
mhSc	Mixed thicket, *(Melaleuca, Hakea)*

Scrub

abSi	*Acacia-Banksia* scrub
a_9Si	Bowgada *(A. ramulosa)* scrub
a_{20}^{9}Si	*A. ramulosa & A. murrayana* scrub on sandplain
a_nSi	Mixed wattle scrub

Open scrub

a_{21}Sr	*A. ligulata* open scrub

Scrub heath

x_2SZc	Scrub heath coastal association
x_3SZc	Scrub heath inland association
x_4SZc	Scrub heath on lateritic sandplain

Succulent Steppe

mSi.k_3Ci	Teatree & samphire
k_3^1Ci	Saltbush & samphire

Crown Reserves

Salt Lake

Drift sand

LEGEND

(P.D.) indicates position doubtful
(I.D.) indicates photo interpretation doubtful

Highway; built-up area

Road, sealed surface first class; route marker

Road, sealed surface second class; mileage

Road, loose surface all weather first class

Road, loose surface all weather second class