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Busselton, Margaret River, Augusta: land capability study

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BUSSELTON
MARGARET RIVER
AUGUSTA

land capability study

By P.J. Tille and N.C. Lantzke
DEPARTMENT OF AGRICULTURE - WESTERN AUSTRALIA
Cover:
Aerial view of Wilyabrup area showing vineyards, rolling countryside and the Indian Ocean.
A NATIONAL SOIL CONSERVATION PROGRAM FUNDED PROJECT

BUSSELTON
MARGARET RIVER
AUGUSTA
land capability study

By P.J. Tille and N.C. Lantzke

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Photography: P.S. Eyres

Land Resources Series No. 5
November 1990
Department of Agriculture
Baron-Hay Court
South Perth 6151
Western Australia
ISSN 1033-1670
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National Library of Australia
Cataloguing-in-Publication entry
Tille, P.J. (Peter John, 1961—
Busselton, Margaret River, Au-
gusta land capability study

Bibliography.
ISBN 0 7309 3782 8
1. Land use—Western Australia—
Augusta—Margaret River
(Shire).
2. Land use—Western Australia—
Busselton (Shire).
3. Land use, Rural—Western Aus-
tralia—Augusta—Margaret
River (Shire).
4. Land use, Rural—Western Aus-
tralia—Busselton (Shire).
5. Land capability—Western Aus-
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River (Shire).
6. Land capability—Western Aus-
tralia—Busselton (Shire).
I. Lantzke, N.C. (Neil Clifton),
1963 -
II. Western Australia. Dept. of
Agriculture.
III. Title (Series: Land Resources
Series; No. 5).
333.7317099412
© Chief Executive Officer of the
Western Australian Department of
Agriculture 1990
The study was done to ensure that information on the area's land resource, and its capability, is available for land use planning. This information will assist planners to make decisions which can allow for the optimal development of the land while avoiding land degradation or land use conflicts.

A map showing the distribution of land units defined according to soil type, topography, drainage and wind exposure was prepared at a scale of 1:50,000. From this map a smaller scale, less detailed land systems map was drawn.

Land capability, the ability of land to sustain a specific use without undesirable on-site or off-site effects, has been assessed by comparing the requirements of a number of land uses with the physical attributes of the land units mapped. Land capability has been assessed for the following land uses:

- grazing
- viticulture
- market gardening
- orchard crops
- forestry

For each of the units, the physical limitations for housing on small rural lots have been assessed.

The results of the study are presented in three sections.

- The land systems section gives a general overview of the area and its capabilities by describing and discussing the 15 land systems identified.
- The section on land uses discusses the physical requirements of each use and describes the distribution of areas capable of sustaining that use.
- The appendices can be used as a map key: Appendix 1 describes each land unit, Appendix 2 gives the capability ratings for each land unit, and the physical limitations for housing on small rural lots are listed for each land unit in Appendix 3.

More than 70% of the area has a high capability to sustain grazing, while about half the area has a high capability for forestry.

The portion of the area which is good horticultural land is much smaller and ranges between the 5%, which is capable of sustaining market gardens, and the 15% capable of sustaining vineyards. Much of this area may not be available for these uses because of conflicting land uses or limited water availability. The horticultural industry is very important, producing about a third of the total agricultural income in 1989. Without careful planning, there may not be the land resources for this industry to expand to full potential.

Many coastal dunes are prone to wind erosion and clearing vegetation in these areas should be avoided. Without careful land use planning, water erosion is likely to occur on some slopes.

It is not the purpose of our work to dictate land use. Information is provided which needs to be combined with other data before decisions are made as to land use.
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Funding from the National Soil Conservation Program is gratefully acknowledged
This study was done by the Western Australian Department of Agriculture with funding from the National Soil Conservation Program. It has contributed towards the Leeuwin—Naturaliste Region Study co-ordinated by the State Planning Commission. The aim was to identify and provide for the needs of development, the community and conservation in the area.

A simplified description of soils and landforms of the area and their agricultural potential has been described by Tille and Lantzke (1988). Further detailed information on the land resources of the area and the methodology used to assess their land capability (Tille and Lantzke, 1990) was used in the preparation of this report.

This publication, together with the accompanying maps, provides information for use by Government Departments, Shire councils, planning consultants, landholders and the general public.

The purpose of this study was to provide information for land use planning on a regional scale. Although our report will serve other uses, caution must be exercised to avoid inappropriate usage.

This study embraces the Shires of Busselton and Augusta—Margaret River, which occupy an area known by planning authorities as the Leeuwin-Naturaliste Region (State Planning Commission 1987). The area has undergone changes since the early 1970s which have resulted in rapidly increasing pressures on the land resource and land use conflicts.

Once a somewhat depressed dairying district (Roberts 1944), the Leeuwin-Naturaliste area is now considered to be one of the most desirable locations in the State. There has been a large increase in the number of tourists visiting the area and a rapid growth in the demand for land for retirement, holiday and hobby farms. An expanding horticultural industry, mainly vineyards and market gardens, has developed. Great pressures have resulted for development and the subdivision of rural land.
Location: The area surveyed (Figure 1) is located on a distinctive anvil shaped promontory that forms the south-western extremity of Australia. It is bounded on three sides by ocean; Geographe Bay in the north, the Indian Ocean in the west and the Southern Ocean to the south. To the east the area adjoins a large block of State Forest.

The area surveyed was 2,710 km² and included all the freehold land in the Busselton and Augusta—Margaret River Shires. Also included were:
- areas of National Park, State Forest and vacant Crown Land surrounded by freehold land
- a small portion of Capel Shire bounded in the north-east by the Capel River and in the south by the Boyanup—Busselton railway
- a small portion of Nannup Shire east of the D'Entrecasteaux National Park and south of the block of State forest

Physiography: The area is divided into five physiographic regions (Figures 2 and 3).

1. The Swan Coastal Plain is a flat to gently undulating plain formed on Quaternary marine, alluvial and aeolian sediments. It is about 15 km wide and extends eastward from Dunsborough, along the coast of Geographe Bay and northwards beyond the boundary of the area.
**Geological cross-section of the Leeuwin-Naturaliste area**

**Climate:** The area has a Mediterranean climate with warm to hot, dry summers and mild, wet winters. The rainfall is generally higher and more reliable than in most other areas of the South-West Province, and ranges between 850 and 1200 mm per annum. Most rain falls between April and October, with heaviest falls during the winter months from June to August.

The area is surrounded on three sides by ocean and this has a moderating effect on temperature. Generally, it has a milder climate than most of the South-West Province, and does not experience the extremes of heat and cold that are common elsewhere.

Possible climatic change, because of the Greenhouse Effect, should be considered. The predicted increasing temperatures and decreasing rainfall in the South-West Province would have an effect on agricultural production. The Greenhouse Effect may also influence the area's relative agricultural importance on a State-wide basis. In addition, there are predictions of sea level rises which could have a major impact on low lying coastal areas, particularly around Geographe Bay.

**Land use:** The first European settlers (Molloy, Bussells and about ten other individuals and families) in the area arrived at Augusta in 1830, making it one of the first areas to be settled in the State. Although large areas remain uncleared, it has a long history of agricultural development.

The grazing of dairy cattle and other stock has always been the basis of agriculture, with forestry and fishing also considered important industries. The Group Settlement Scheme, which began in the early 1920s, led to a major expansion of agriculture, primarily in the form of dairying. By the 1970s, the relative importance of dairying had decreased, with greater numbers of beef cattle and sheep being grazed. Dairying remains the most profitable of the grazing industries and the area contains about one-third of the State's dairy farms.

Although there has been a horticultural industry based on potato production since 1839 (Jennings 1983), a major expansion in horticultural production has taken place since the mid 1970s. By 1987/88, such industries, which only occupied around 1% of the total area used for agriculture, contributed more than about a fifth of the total gross value of agricultural production (Table 4).

The first commercial vineyard was planted in 1967 and there was a six-fold increase in the number of hectares planted to vines between 1975 and 1988. The area now has a reputation for producing high quality table wines and grows over a quarter of the State's wine grapes.
Since the mid 1970s, production of vegetable crops other than potatoes has become important. New orchard crops such as kiwi fruit, avocados and pecan nuts began to be established in the 1980s.

The main mining activities in the area have been the extraction of mineral sands on the Swan Coastal Plain and small scale construction materials extraction throughout the area. In the 1990s sand mining activities are likely to increase on the Swan Coastal Plain, and a major sand mining project at Scott River has been proposed.

Another major change to take place since the mid-1970s has been the influx of visitors to the area who are attracted by the mild climate, spectacular coastal scenery, vineyards, caves, forests, pleasant rural atmosphere and numerous recreational opportunities.

By the 1980s, income from tourism was greater than from agricultural industries (Table 1). As a result, there has been an increasing demand for land for tourist developments and a need to preserve the natural features which are one of the area’s main attractions. Together with the development of tourism, there has been a 30% increase in population between 1976 and 1986. Many people live on small rural lots, while others own blocks which are used only on weekends and holidays. The demand for these small lots has placed pressure on agricultural land.

### Table 1. Predicted growth of population and industries for the Shires of Busselton and Augusta-Margaret River

<table>
<thead>
<tr>
<th></th>
<th>1984/85</th>
<th>2004/2005*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>15,230</td>
<td>24,800</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>43</td>
<td>65</td>
</tr>
<tr>
<td>Mining</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Fishing</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Tourism</td>
<td>48</td>
<td>87</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Retail/wholesale</td>
<td>14</td>
<td>25</td>
</tr>
<tr>
<td>Construction</td>
<td>25</td>
<td>45</td>
</tr>
<tr>
<td>Forestry</td>
<td>6</td>
<td>19</td>
</tr>
</tbody>
</table>

*These are forecasts taken from the *Economic profile of the Leeuwin-Naturaliste region* (ACIL 1987).
Using the information

The results of the study are for
the information of land use plann-
ers and the general public. There
are three main groups of informa-
tion in this publication.

1. An overview of the area, its land
resources and capability is given
in the land systems section. In
this section, 15 land systems are
identified and the distribution of
the land units within them are
described with the aid of block
diagrams. Wherever the land
units are mentioned in the text,
their map symbols are shown in
parentheses. A description of
current (1990) land use on the
land system is followed by a
brief discussion of its land capa-
bility for various uses.

2. Information concerning particu-
lar land uses is in the land uses
section. Each of the six land uses
covered are discussed sepa-
rately. A brief description of the
current land use, and its defini-
tion as used in the capability
assessment, is given. The physi-
cal requirements of the use are
then discussed. There is a guide
to the distribution of locations
within the area with a very high
or high capability for each use.

3. Specific areas of land can be
located on the accompanying
maps. The land units which
occur on that land may be iden-
tified and the appendices used
to obtain information on the
relevant units and their capabili-
ties.

Appendix 1 lists brief descrip-
tions of the land units.

Each land unit has been as-
signed a code which appears on
the maps. The first letter of the
code refers to the land system to
which the land unit belongs. The
following letters refer to the
distinguishing features of the
unit.

The land system names are based
on localities within the systems.
The symbols for the land systems
are:
A—Abba Plains
B—Blackwood Alluvial Plain
C—Cowaramup Upland
D—D’Entrecasteaux Dunes
G—Gracetown Ridge
H—Glenarty Hills
K—Kilcarnup Dunes
L—Ludlow Plains
M—Metricup Scarp
N—Nillup Plain
Q—Quindalup Scarp
S—Scott River Plain
T—Treeton Hills
W—Wilyabrup Valleys
Y—Yelverton Shelf.

The symbols for the distinguishing
features are:
b—beaches
d—deep bleached sandy soils
e—moderate exposure to salt spray
E—high exposure to salt spray
f—higher soil fertility in compari-
son with other units in the land
system
F—fertile soils
i—shallow soils, usually over iron-
stone
k—karst topography
m—mobile sand dunes
r—rocky soils
R—rock outcrop
v—vales or drainage depressions
w—winter wet (poorly drained)
areas
y—areas saline or with potential to
become saline.

In addition, the following numeric
symbols denote land units in which
the dominant slope gradient is
> 2%:
2—gentle slopes (2-5% gradient)
3—low slopes (5-10% gradient)
4—moderate slopes (10-15% gradi-
ent)
5—steep slopes (> 15% gradient).
Appendix 2 gives a land capability rating for each land unit for grazing, market gardening, vineyards, orchards and forestry.

A five class system is used by the Department of Agriculture to assess land capability (Table 2). It ranges from Class I, which has a very high capability for the proposed land use, to Class V which has a very low capability for the proposed land use. The land qualities which are limiting for the land use are shown as letter notations (Table 3). No notation is shown for units rated as Class I because there are no significant limiting factors.

Appendix 3 lists the severe, major, moderate and minor physical limitations for housing on small rural lots for each land unit. These examine problems which are likely to be encountered in the construction of houses and secondary roads and the installation of septic tanks. These limitations are only guidelines. Because of the small area occupied by housing on rural blocks, it is not possible to accurately identify the limitations in each area at this scale of mapping.

Figure 4 gives an example of how to use land unit maps. This is done with the aid of a hypothetical land unit map on which a block of land has been shaded. Should there be a proposal to subdivide a block of land into lots for grazing and vineyards, the map indicates that two land units occur, with the eastern portion being W3 and the western portion W13.

![Figure 4. Portion of a hypothetical land unit map.](image)

<table>
<thead>
<tr>
<th>Capability class</th>
<th>General description</th>
<th>Degree of limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Very high capability for the proposed activity or use. Very few physical limitations present which are easily overcome. Risk of land degradation is negligible.</td>
<td>None to very slight</td>
</tr>
<tr>
<td>II</td>
<td>High capability. Some physical limitations affecting either productive land use or risk of land degradation. Limitations overcome by careful planning.</td>
<td>Slight</td>
</tr>
<tr>
<td>III</td>
<td>Fair capability. Moderate physical limitations significantly affecting productive land use or risk of land degradation. Careful planning and conservation measures required.</td>
<td>Moderate</td>
</tr>
<tr>
<td>IV</td>
<td>Low capability. High degree of physical limitations not easily overcome by standard development techniques and/or resulting in a high risk of land degradation. Extensive conservation requirements.</td>
<td>High</td>
</tr>
<tr>
<td>V</td>
<td>Very low capability. Severity of physical limitations is such that its use is usually prohibitive in terms of either development costs or the associated risk of land degradation.</td>
<td>Severe</td>
</tr>
</tbody>
</table>

Table 3. Subscript notations used for land qualities in this study

- b—wave erosion hazard
- c—climatic zone
- d—soil moisture availability
- e—exposure to salt spray
- f—soil fertility
- h—water erosion hazard
- j—flood hazard
- m—slope stability—relates to areas susceptible to landslides and slumps as well as unstable and mobile sand dunes.
- p—water supply—relates to the potential availability of good quality water from bores, rivers, farm dams and soaks.
- r—rooting conditions—relates to factors such as soil depth and rockiness which affect plant growth (as well as the ease of cultivation).
- t—wind exposure—the exposure to winds which can damage crops, vines and trees.
- u—wind erosion hazard
- w—waterlogging
- y—salinity
- z—trafficability—relates to factors such as slope and bogginess which affect vehicular access

Appendix 1 shows that W3 is one of the Wilyabrup Low Slopes with gradients between 5-10% and having gravelly soils. Appendix 2 shows that it is rated Class I for grazing and Class IIhpw for vineyards. This means that the eastern portion of the block has a very high capability for grazing and a high capability for vineyards. However, if the land is to be used for vineyards there are some physical limitations and a degradation risk. These are water erosion hazard (h), water supply (p) and waterlogging (notation w). The water erosion risk can be overcome through careful design of the vineyards’ layout. The availability of water supplies and subsoil waterlogging should not prove major obstacles, although they should be investigated before deciding to establish vineyards.
Wi3 is one of the Wilyabrup Ironstone Slopes, i.e. low slopes with shallow gravelly sands over laterite. Appendix 2 shows that it is Class IVdr for grazing and Class Vr for vineyards. This means that the rooting conditions (r) is the factor making the western area prohibitive for vineyards. It has a low capability for grazing because of poor moisture availability (d) and rooting conditions (r).

Appendix 3 shows that soil absorption and ease of excavation of septic waste are likely to be major problems if a house were built on the western portion (Wi3) of the block. On the eastern portion (W3) ease of excavation and soil absorption are likely to be moderate problems.

The eastern portion of the block may be suitable for the proposed subdivision, but the western portion would only be capable of supporting naturally vegetated blocks and suitable house sites would be difficult to find.

No attempt has been made to supply definitive information for land use planning at a detailed scale. The previous example shows how the maps and report can be used in the initial stages of planning or assessing a subdivision proposal by providing a quick, easily accessible description of the land in question and its capabilities. On-site investigations would be necessary to plan or assess the proposal. In such cases it would be advisable to prepare a map of the land at a scale of 1:5,000 or 1:10,000.

The information in this report could be used as a framework for this remapping, though it does not need to be rigidly adhered to. Remapping will reveal a more complex pattern of land units and any inaccuracies in the original mapping. It may show, for example, that there is a smaller area of shallow soil over ironstone than shown in Figure 4, and that small patches of deep sandy soil are present. Under no circumstances should the maps accompanying this report be enlarged. Our aim is to assist proper land use planning, not to provide a means of avoiding such planning.

The land capability assessments were based on available information, but as knowledge of the effects of land qualities upon land use improves, capability assessments can be further refined.

Information on climate; surface and groundwater supplies; soils; existing land uses of the Leeuwin-Naturaliste area; descriptions of land units mapped and the processes of land capability assessment used in our work are published in Technical Report No. 109, Division of Resource Management.

Much of the data is stored in the Department of Agriculture's Geographical Information System (GIS). This information may be used for detailed studies in the area or research into specific aspects of our work.

New information can be entered into the GIS to produce up-to-date capability assessments or produce assessments for other land uses. Examples could include capability assessments for Tasmanian blue gums (Eucalyptus globulus) or proteas (Protea spp.). Interpretive maps can be produced through the GIS from existing information. Examples are maps showing the land capability classification for a certain land use, or maps of wind erosion hazard or waterlogging risk.

The final step in land use planning is the assessment of land suitability. In addition to the physical environment, land suitability takes into account economic, social and political factors in evaluating the optimum use of a particular area of land. For example, areas proposed for special rural zoning must be considered for their potential plus the benefits derived from alternative uses such as intensive horticulture.

It is for society to make the final decisions on land suitability and the Leeuwin-Naturaliste Regional Plan and Shire planning schemes provide the forum for this to be done. The assessment of land suitability is beyond the scope of the Busselton-Margaret River-Augusta land capability study.

Method

Land systems and land units were identified and mapped on 1:25,000 scale colour aerial photographs. A land system is defined as an area, or group of areas, throughout which there is a recurring pattern of topography, soil and vegetation (Christian and Stewart 1953). Each land system can be subdivided into a number of land units, which are defined as areas of common land form, frequently with common geology, soils and vegetation types, occurring repeatedly at similar points in a landscape over a defined region (Houghton and Charman 1986). In this survey, 15 land systems were identified. These were subdivided into 130 land units.

Field verification consisted of reconnaissance traverses and descriptions of 1290 sites.

Small scale maps were prepared showing climatic zones and the availability of surface and groundwater supplies.

A list of attributes, or land qualities, which influence the capability of the land to sustain specified land uses was compiled (Table 3). Each of the land units were then assessed for these qualities. Ratings tables were then prepared for each of the land uses to be assessed. These show how each land quality affects the land use and define the physical requirements for that particular land use.

By comparing the land qualities of a land unit with the requirements of a particular land use, a land capability rating is derived for that use on that unit and the limiting factors identified. This process was done with the use of the LANDCAP model and a capability class was assigned to each unit for each use, with a subclass showing the limiting land quality or qualities. A similar process was used to derive the list of limitations for housing on small rural lots. A detailed description of the methodology employed in this survey is provided by Tille and Lantzke (1990).
The land systems identified in the Leeuwin-Naturaliste area are described, and their capabilities for various land uses discussed. Figure 5 shows the distribution of these land systems.

Figure 5. Land systems of the Leeuwin-Naturaliste area.
Land systems of the Swan Coastal Plain

Quindalup (Vasse) Coast land system

The Quindalup Coast covers an area of 75 km² and is located on the edge of the Swan Coastal Plain (see Figure 5). It forms a narrow strip, some 1-2 km wide, fringing Geographe Bay. To the south it adjoins the Ludlow Plain land system.

![Image of Quindalup Coast land system]

1. The beach and foredunes (Qb) of the Quindalup Coast land system. This unit is prone to wave erosion. The trees in the background are on the gently inclined beach ridges and flats (Q).

Figure 6. Block diagram of the Quindalup Coast land system.
Land resources

The Quindalup Coast has formed on Recent or Holocene aeolian, marine and estuarine deposits, and is commonly less than a few metres above sea level.

A continuous beach, backed by a very low foredune system (Qb)* of calcareous sand, extends along the coastline (Figure 6 and Photograph 1). Behind this is a series of low, very gently inclined beach ridges and flats (Q). These consist of calcareous sands with some accumulation of organic matter in the surface and support a peppermint (Agonis flexuosa) woodland which has been partly cleared for agriculture and urban development. At Peppermint Grove, on the eastern edge of the study area, there are dunes (Q5) of calcareous sand up to 30 metres high.

Behind the beach ridges and flats is a long narrow depression. The main channel (Qwy, Photograph 2), which includes the Vasse, Wonnerup and Broadwater estuaries, is under water for much of the year. It is flanked on either side by slightly raised terraces (Qw) which are poorly drained in winter. Dark calcareous sands and estuarine deposits are found on the terraces and in the channels. Vegetation ranges from samphire flats to paperbark (Melaleuca spp.) and tea-tree (Leptospermum spp.) scrub.

Land capability

Urban and semi-urban developments stretch along the Geographe Bay coastline. As a result, many of the beach ridges (Q) have been levelled and cleared. Some areas of the coast are eroding while others are accreting. Groynes have been built to try to stabilize the coastline. Any development in these areas (Qb) is not recommended.

Areas of the beach ridges and flats (Q) further inland are used for grazing. They do not support good pasture because of low fertility and poor moisture availability. These areas are unsuitable for horticulture and forestry because of their exposure to salt spray, low groundwater quality, low fertility and poor moisture availability.

The slightly raised terraces (Qw) which surround the estuaries are used for grazing. Some areas however, become severely water-logged, suffer occasional flooding and some are saline. For these reasons they are unsuitable for horticulture, forestry and housing. The main channel (Qwy) is an important waterfowl breeding area and has a high environmental value.

On this land system, there are few areas suitable for soaks. Stock and domestic water is obtained from bores, although some are saline because of salt water intrusion from the ocean. This problem may be increasing because of over use of groundwater supplies.

* These symbols in parentheses refer to the symbols used on the land unit maps.
Ludlow Plain land system

The Ludlow Plain covers an area of 105 km² and occurs as a narrow strip, 1-4 km wide running parallel to, and about 2 km inland from the coast of Geographe Bay (see Figure 3).

3. The Ludlow Plain land system with the poorly drained clayey soils (Lwg) in the foreground and tuart forest on the well drained Spearwood sands (L) in the background.

Figure 7. Block diagram of the Ludlow Plain land system.
Land resources

The Ludlow Plain is a level to gently undulating plain formed on aeolianite and calcarenite of the Tamala Limestone. Its elevation is between 5 and 15 m above sea level.

To the east of Marybrook, the northern portion of the plain has deep brownish yellow sands (Spearwood sands). East of the Sabina River these sands are mainly well drained throughout the year (L)* and support tuart (Eucalyptus gomphocephala) forest (see Figure 7). West of the river there are areas where some subsoil waterlogging occurs in winter (Lw) and the natural vegetation is a flooded gum (E. rudis) and peppermint woodland with patches of jarrah-marri (E. marginata, E. calophylla) forest.

On the northern edge of the plain, east of Busselton, there is a narrow strip of land which is poorly drained in winter, with shallow brownish yellow sands overlying limestone (Lwr).

The southern portion of the plain consists of a low lying depression (Lwg) with clayey (Cokelup) soils (see Photograph 3). This depression is poorly drained in winter and some areas are saline. It supported a paperbark (Melaleuca spp.) woodland which has been largely cleared.

Much of the better drained Ludlow Plain (L) is covered by State Forest and National Park, comprising both tuarts and pine plantations, mainly radiata pine (Pinus radiata). Sands on the Ludlow Plain are also mined for minerals.

Land capability

Areas of the Spearwood sands (L) and Lw provide less than average quality grazing country because the soils have a low moisture availability. Stock water is obtained from shallow bores. The potential for soaks is limited because of the deep sands and porous limestone.

These areas have a high capability for market gardening as they are well drained. However, as a result of heavy chemical and fertilizer use on these porous soils there is potential for pollution of groundwater and the adjacent wetlands. North of the study area, these sands are widely used for vegetables and lucerne. These units (L and Lw) are also suitable for orchards, vineyards and forestry.

Sufficient groundwater for the irrigation of horticultural crops is usually available at shallow depths (10-20 m). For large horticultural concerns, bores may have to reach up to 100 m to obtain sufficient water.

A number of areas on these Spearwood sand flats have been subdivided into Special Rural Zones and their close proximity to Busselton suggests that further subdivision is likely. With land subdivision and the area reserved as State Forest or National Park, only a limited area will be available for horticulture.

The low lying clayey flats (Lwg) are marginal for grazing and unsuited to horticulture, forestry or housing because of waterlogging. The occurrence of soil salinity suggests that some areas of this unit should not have been cleared.

* These symbols in parentheses refer to the symbols used on the land unit maps.
Abba Plain land system

The Abba Plain covers an area of 460 km² occupying the major portion of the Swan Coastal Plain within the study area (see Figure 5). It extends about 10 km inland from the southern edge of the Ludlow Plain land system to the edge of the Blackwood Plateau.

4. The Abba Plain land system is largely flat and much of it becomes waterlogged in the winter months. This photograph shows both the slight rises (A) and slight depressions (Aw), although the two are often barely distinguishable from ground level.

Figure 8. Block diagrams of the Abba Plains land system.
Land resources

The Abba Plain is a level to gently undulating plain formed on Quaternary alluvium, lying between 10-40 m above sea level, containing extensive areas of poor drainage.

The dominant landform pattern of the Abba Plain is an intricate patchwork of slight depressions (Aw)* and slight rises (A) (see Figure 8 and Photographs 4 and 22). There is little height difference between these. The depressions tend to become waterlogged in winter while the rises tend to suffer subsoil waterlogging. The soils on these depressions and rises are generally similar with sandy grey-brown gradational (Busselton) and duplex (Abba) soils occurring on both (see Photographs 21 and 23).

Superimposed on this general pattern are a variety of areas including the following—

- depressions and flats which experience even greater winter waterlogging than the remainder of the plain. Some have clayey soils displaying patches of salinity in summer (Awy) and some have shallow soils overlying sheet laterite (Awi)
- low rises and dunes of deep bleached (Bassendean) sands (Ad2), which are especially common on the northern edge of the plain where they form a discontinuous band from Carbanup eastwards
- well drained flats with sandy grey-brown gradational (Busselton) soils (Af) and red-brown sandy and loamy (Marybrook) soils (AF) (see Photograph 26).

The dominant vegetation of the Abba Plain was marri and marri/jarrah (Eucalyptus calophylla, E. marginata) forest and woodland. However, these have been extensively cleared for agriculture. Banksia (Banksia spp.) woodlands occur on the low rises with deep bleached sands.

Land capability

The Abba Plain is predominantly good grazing country with the depression (Aw) being slightly less suitable than the better drained areas (A). The smaller areas of the deep bleached sands (Ad2), shallow soils over sheet laterite (Awi) and winter wet, clayey saline flats (Awy), are poor grazing country. There are some indications that salinity may be spreading in low lying areas and the area which is marginal for grazing may increase.

Soaks capable of watering stock can be built in many locations on the Abba Plains land system. Elsewhere, bore water is usually available at shallow depths.

Areas of well drained Busselton sands (Af) and Marybrook soils (AF) at Marybrook, Jindong and Acton Park, are used extensively for market gardening (see Photograph 24). Crops grown include potatoes, tomatoes, cauliflowers, pumpkins, onions and melons. They are sold locally, in the Perth metropolitan market and overseas. Within the study area, this location is by far the largest for market gardening. On a State-wide scale, this area is small for vegetable production. These soils are also suitable for viticulture, orchards and forestry.

A concern of the Department of Agriculture is that this area remain available for horticultural use rather than be subdivided into lot sizes which may be uneconomic for commercial horticulture.

The deep bleached sands (Ad2) are traditionally considered to have a very low agricultural potential. However, they are often underlain by good groundwater and it has been demonstrated in the Perth area that, with suitable management, similar soils are capable of producing good vegetable crops. The risk of groundwater pollution from these rapidly leached soils should be investigated before they are used for horticultural purposes.

Poor drainage is the major limitation to horticulture on most of the remainder of the Abba Plain. Although the slight rises (A) have a good capability for growing radiata pine (Pinus radiata) the depressions (Aw) become too waterlogged for this species. Loblolly pine (P. taeda) is one species that may grow well here.

Although the shallow groundwater under the Swan Coastal Plain is often sufficient for irrigation, on the AF and Af units bores may have to penetrate to depths of around 100 m to obtain greater yields. Groundwater is not an unlimited resource.

* These symbols in parentheses refer to the symbols used on the land unit maps.
Land systems of the Blackwood Plateau

Yelverton Shelf land system

The Yelverton Shelf is located on the northern edge of the Blackwood Plateau and covers an area of 130 km². It occurs as a band, 5-6 km wide in the west, tapering to 1 km wide in the east (see Figure 5). It lies between the Swan Coastal Plain and the Treeton Hills land system.

Figure 9. Block diagram of the Yelverton Shelf land system.
Land resources

The Yelverton Shelf appears to be the remnant of an ancient plain or plateau. Gently inclined slopes (Y3)* rise from the Swan Coastal Plain at an elevation of about 40 m above sea level, leading to a gently undulating plain (Y), sitting at a height of between 60-80 m (see Figure 9 and Photograph 5). The dominant soil types on this plain and the slopes are yellow-brown, gravelly duplex (Forest Grove) soils (see Photograph 20) and pale grey, mottled (Mungite) soils (see Photograph 18). Also present on the plain and slopes are patches of deep bleached sands (Yd and Yd3) and shallow gravel over ironstone (Yi and Yi3). On the plain there are also poorly drained depressions (Yw), some of which have ironstone close to the surface (Ywi). The plain has been dissected by a number of small valleys (Yv), some of which have broad swampy floors (Yvw). In some places this dissection has resulted in a landform of undulating rises. Fertile alluvial flats (Yf) occur along some drainage lines.

The natural vegetation of jarrah-marri forest has been extensively cleared.

Land capability

Much of this land system is good for grazing. The deep bleached sands (Yd and Yd3) and shallow gravel over ironstone (Yi, Yi3 and Ywi) are less suitable.

Some of the better drained soils on slopes are suitable for vineyards (Yv and Y3). Some of the flatter areas, mainly located east of the Carbanup River, are good for market gardening or vineyards (Y, Yf), though drainage is a problem in many locations.

Over most of the study area, stock water is readily available from soaks. These soaks rarely yield enough water to irrigate a market garden or vineyard. A few good dam sites exist. It is also unlikely that large enough supplies of groundwater for a horticultural block could be obtained from the shallow groundwater table. Deeper bores may provide higher yields, but at a very high cost.

* These symbols in parentheses refer to the symbols used on the land unit maps.
Treeton Hills land system

The Treeton Hills occupy a large portion of Blackwood Plateau and cover an area of 330 km². They extend eastwards from the edge of the Margaret River Plateau into the State Forest, which forms the eastern boundary of the study area.

They adjoin the Yelverton Shelf land system to the north and the Nillup Plain land system to the south.

Figure 10. Block diagram of the Treeton Hills land system.
Land resources

The Treeton Hills are undulating rises to rolling low hills on lateritized sedimentary rocks of the Perth Basin. This landscape has formed through the dissection of the Blackwood Plateau by the Margaret and Carbanup Rivers and Chapman Brook. The elevation ranges from 80-120 m above sea level in the north, to 20-80 m in the south (commonly between 60 and 100 m).

The dominant landform pattern is of gently inclined ridges and hill crests (T2)* with gently to moderately inclined sideslopes (T3 and T4) down to valley floors (see Figure 10). These may be narrow and v-shaped (Tv), but are more commonly broad and poorly drained (Tvω) with alluvial soils.

On the crests and sideslopes, yellow-brown, gravelly duplex (Forest Grove) soils and pale, grey mottled (Mungite) soils occur. Areas of deep bleached sands (Td3) and ironstone outcrop (Ti3) may also be present in these areas. The ironstone often exists on the crests.

Along the Margaret River and Upper Chapman Brook are some alluvial flats (Tf) with well drained red-brown and grey loamy (Marybrook) soils.

Outside of the State Forest much of this land system has been cleared, but remnants of jarrah/marri forest are still present.

Land capability

Most of this land system is used for grazing. The majority of the units are good grazing country. The main exceptions are the deep, bleached sands (Td3) and ironstone outcrops (Ti3).

Ample stock water can be obtained from dragline soaks.

Market gardening is largely restricted to fertile alluvial flats (Tf) along the Margaret River, the water erosion risk being too great on the hillslopes. Many of the sideslopes (T3 and T4) are likely to be suitable for orchards and vineyards (see Photograph 6). Some problems may be encountered with drainage, especially on the pale, grey mottled (Mungite) soils. The water erosion hazard on the steeper slopes (T4) makes them unsuitable for market gardening. Drainage is likely to be a major problem for horticultural activities on the gentle slopes and ridge crest (T2).

The frost risk, with an average of 4-5 frost days per year throughout the Treeton Hills land system, may be a limitation to viticulture. These conditions may however, benefit certain grape varieties.

At present, water supplies for horticulture are drawn mainly from the Margaret River and the Upper Chapman Brook, however these supplies are limited. There are good sites and suitable clays for the construction of dams and soaks in many areas of the Treeton Hills, but these will only provide enough water to irrigate a limited area. On many properties, no suitable sites occur or water yields are too low. Sufficient quantities of groundwater are available, but very costly to obtain.

The better drained gravelly soils have good potential for pine and Eucalyptus plantations.

* These symbols in parentheses refer to the symbols used on the land unit map.
Nillup Plain land system

The Nillup Plain covers an area of 105 km², on the southern edge of the Blackwood Plateau. It lies between the Blackwood River and the Scott River Plain land systems and extends into the State Forest beyond the study area.

7. The Nillup Plain land system has been extensively cleared and is used for grazing. This photograph shows the flats (N).

Figure 11. Block diagram of the Nillup Plain land system.
Land resources

The Nillup Plain is a level to gently undulating plain lying at an elevation of between 20-40 m above sea level. It has formed on lateritized sedimentary rocks of the Perth Basin.

The Plain consists mainly of flats (N)* with pale grey, mottled (Mungite) soils (see Figure 11). There are poorly drained depressions, which are either closed (Nw) or shallow, open drainage depressions (Nvw). There are also some areas of deep bleached sands (Nd).

Most of the area has been cleared for agriculture, but there are some remnants of jarrah/marri forest. Paperbark woodland is found in poorly drained locations.

Land capability

Most of the Nillup Plain is used for grazing (see Photograph 7), with the exception of the deep sandy areas (Nd). Stock water is available from soaks.

Poor drainage is the major limitation to the horticultural development of this land system, with subsoil waterlogging on the flats in winter. Strong winds from the south and the difficulty of obtaining sufficient water supplies are further problems.

Most of the area is suitable for timber production, although few landholders have planted trees for commercial purposes.

* These symbols in parentheses refer to the symbols used on the land unit maps.
Land systems of the Margaret River Plateau

Cowaramup Upland land system

The Cowaramup Upland, on the Margaret River Plateau, extends from Cape Naturaliste southwards to Augusta and covers an area of 475 km². The Upland is 5-15 km wide, but is not continuous as it is dissected in a number of places by the Wilyabrup Valleys land system and the Glenarty Hills land system.

8. The Cowaramup Upland land system with the Gracetown Ridge land system in the background. A flat (C) is visible in the foreground while a slight poorly drained depression (Cw) lies behind.

Figure 12. Block diagram of the Cowaramup Upland land system.
Land resources

The Cowaramup Upland is a gently undulating to undulating plain (see Photograph 8), with an elevation ranging from 80-140 m above sea level in the north to 20-80 m in the south. It has formed on the lateritized granitic basement of the Leeuwin Block.

The major portion of the Cowaramup Upland consists of flats and gentle slopes (C and C2)* with yellow-brown, gravelly duplex (Forest Grove) and pale grey mottled (Mungite) soils (see Figure 12). There is an extensive network of shallowly incised drainage depressions, commonly having broad, poorly drained floors (Cvw), but sometimes being narrow and v-shaped (Cv). There are also poorly drained slight depressions (Cw), flats and low rises of deep bleached sands (Cd2), areas with a lateritic cap at or near the surface (Ci), and shallow rocky soils (Cr2).

The natural vegetation of jarrah/marri forest and woodland has been extensively cleared for agriculture, although some patches still remain. There are remnants of the banksia woodland on the deep bleached sand and tea-tree scrub in poorly drained depressions.

Land capability

This land system is used primarily for grazing sheep as well as beef and dairy cattle. Pasture growth is good except on areas of deep bleached sands (Cd2) or those with lateritic caprock at or near the surface (Ci). Ample stock water can be supplied from dragline soaks.

This land system is generally unsuitable for horticulture because of the lack of irrigation water. Groundwater is almost nonexistent and dams or soaks able to supply sufficient quantities of water are not common. Much of the area is poorly drained, with subsoil waterlogging during winter and early spring. Areas with some slope (C2 and Cv) are better drained and suitable for grapevines.

Strong winds which can damage crops, trees and vines are a problem over much of this land system.

Most of the area is suitable for forestry. The exceptions are the deep sands (Cd2), areas with lateritic cap at or near the surface (Ci), shallow rocky soils (Cr2) and poorly drained depressions (Cw and Cvw).

* These symbols in parentheses refer to the symbols used on the land unit maps.
**Metricup Scarp land system**

The Metricup Scarp forms the eastern edge of the Margaret River Plateau between Yelverton and Dunsborough, an area of 22 km². It is 1-2 km wide and lies between the Yelverton Shelf land system and the Cowaramup Upland land system.

*Land resources*

The Metricup Scarp has developed on the edge of the lateritized granitic basement of the Leeuwin Block. It forms rolling low hills as it rises from an elevation of between 40-140 m above sea level.

The Scarp has a relatively even slope which is moderately inclined (M*). This has been heavily dissected by small, but deep valleys, (Mv) (Figure 13). The valley floors have relatively steep gradients (up to 5%).

The dominant soils on the slopes of the Scarp and the valley sideslopes are yellow-brown gravelly duplex (Forest Grove) soils.

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Figure 13. Block diagram of the Metricup Scarp land system.
In the northern portion of the Scarp, granitic and lateritic outcrop is sometimes present on the slopes (Mr) and the soils tend to be shallow and gravelly, while sideslopes of the valleys often have gradients steeper than 15% (Mvr).

The Metricup Scarp has been partially cleared for grazing although jarrah/marri forest remains on most of the rocky slopes and valleys. Some of these areas are now special rural zones.

*Land capability*

While much of the Scarp is good grazing country (see Photograph 9), the rocky slopes and valleys (Mr and Mvr) are marginal for grazing (see Photograph 10). These areas also have a low capability for horticulture because of the shallow stony soils and erosion hazard. The slopes and valleys in the southern portion of the Scarp (M and Mv) have a good capability for vineyards and orchards. Obtaining sufficient water supplies may be a problem. Little groundwater is available and the gravelly or rocky soils are often unsuitable for dam construction, especially in the north.

* These symbols in parentheses refer to the symbols used on the land unit maps.
Wilyabrup Valleys land system

The Wilyabrup Valleys are, in a number of separate locations, scattered throughout the Margaret River Plateau and cover an area of 138 km². The most notable occurrences are where the Margaret River and Gunyulgup, Wilyabrup and Boodjidup Brooks have incised into the plateau. They also occur along the eastern edge of the plateau south of Margaret River and in the Cape Naturaliste area. The Wilyabrup Valleys form undulating to rolling low hills lying below the surrounding Cowaramup Upland land system. Generally they have incised from an elevation of between 80-100 m above sea level down to a level between 20-40 m.

Land resources

The sideslopes of the valleys commonly have yellow-brown, gravelly duplex (Forest Grove) and red-brown, gravelly gradational (Keenan) soils. These slopes are usually either gently inclined (W3) or moderately inclined (W4) (see Figure 14 and Photograph 11).
Some patches of deep bleached sands (Wd3), shallow gravels over ironstone (Wi3) or rocky soils (Wr3) also occur on these slopes. In the Cape Naturaliste and Augusta areas there are slopes exposed to strong winds coming directly off the ocean (WE3, WrE3). Along some of the valley floors, especially along the Margaret River, alluvial flats (Wf) with well drained red-brown and grey loamy (Marybrook) soils occur.

Marri/jarrah forests grew over much of the Wilyabrup Valleys, but these have been largely cleared for agriculture. Patches of karri (Eucalyptus diversicolor) forest can be found in some locations.

Land capability

The Wilyabrup Valleys have traditionally been used for grazing. Most of the area, with the exception of the deep sands (Wd3), shallow rocky soils (Wi3) and exposed positions on the coast (WE3, WrE3), are highly suitable for this land use. Sufficient water for stock can usually be provided from dams.

Since 1967, the viticultural industry has developed and is producing fine quality table wines. The slope gradient and the usually high gravel content ensure good drainage. The gentle slopes (W3) are preferred for viticulture, because, on the steeper slopes (W4), there is a greater risk of water erosion. Cut-off banks may need to be located above the vineyards to prevent run-on and sod culture practised to maintain ground cover. Viticulturalists prefer east and north facing slopes, as damage to vines from the prevailing south to westerly winds is reduced. These slopes are also suitable for orchard crops and forestry.

The availability of water for irrigation is a limitation, with groundwater virtually unobtainable. The gravelly or rocky soils with variable clay quality limit the potential for dams. On some properties, dams suitable for irrigating vineyards can be constructed. In some places there are problems with saline seepage into dams. Water erosion hazard is usually unacceptable for market gardening, except on the alluvial flats (Wf).

Areas of deep sand (Wd3), shallow or rocky soils (Wi3, Wr3) or exposed to the coastal wind and salt spray (WrE3, WE3) are not suited to horticulture and forestry.

* These symbols in parentheses refer to the symbols used on the land unit maps.
Glenarty Hills land system

The Glenarty Hills cover an area of 105 km² on the southern section of the Margaret River Plateau and overlap onto the Blackwood Plateau. They are bordered on the north and south by the Cowaramup Upland land system, the Gracetown Ridge land system in the west, and the Blackwood Alluvial Plain land system in the east. There is a small occurrence of Glenarty Hills on the western edge of the Blackwood Alluvial Plain.

Figure 15. Block diagram of the Glenarty Hills land system.

12. Sheep grazing on valley sideslope (H3) of the Glenarty Hills. The broad swampy valley floor (Hvw) has been left uncleared.
Land resources

The landform pattern of the Glenarty Hills is undulating rises to rolling low hills, formed by the dissection of the Margaret River and Blackwood Plateau by the McLeod and Glenarty Creeks. Although Leeuwin Block gneiss and granite is the dominant underlying parent material, sedimentary rocks of the Perth Basin form the basement in the east. Both may be lateritized.

Most of the Glenarty Hills consist of gently inclined valley sideslopes and ridge crests (H3)* leading into broad swampy valley floors (Hvw) (see Figure 15 and Photograph 12). A variety of soils are found on these slopes, including yellow-brown, gravelly duplex (Forest Grove) soils, pale grey, mottled (Mungite) soils and gritty duplex soils. Patches of deep bleached sands and quartz grits (Hd3) and shallow sands over ironstone (Hi3) are also present. The western edge of the land system is generally a gently undulating plain with a pattern of deep yellow and bleached sands on low rises (Hd) and poorly drained depressions with sandy soils (Hdw).

Natural vegetation is mainly jarrah/marri forest with some patches of karri forest.

Land capability

Cleared areas of this land system are used for grazing. The valley sideslopes and ridge crests (H3) and poorly drained areas (Hdw and Hvw) are generally good for grazing, although patches of highly erodible soils with poor fertility do occur. The rocky areas (Hi3) and deep sandy areas (Hd and Hd3) are not suitable for grazing.

Groundwater is generally unobtainable and there is limited potential for the construction of dams and development of soaks. Although sufficient stock water can be provided, it is often difficult to obtain enough water to irrigate horticultural crops. Deep sandy soils (Hd3), shallow rocky areas (Hi3), waterlogging (Hvw) and the water erosion hazard on the slopes (H3, Hd3, Hi3) are other limitations to horticulture in the Glenarty Hills. Some of the slopes (H3) north of Karridale have proved to be suitable for vineyards.

The valley sideslopes and ridge crests (H3) are suitable for forestry.

* These symbols in parentheses refer to the symbols used on the land unit maps
Land systems of the Leeuwin-Naturaliste Coast

Gracetown Ridge land system

The Gracetown Ridge is the dominant feature of the Leeuwin-Naturaliste coast. It forms a discontinuous strip, 1-4 km wide, running from Cape Naturaliste to Cape Leeuwin and covers an area of 168 km².

13. The ridge crest (Ge) and western facing slope (GE) of the Gracetown Ridge land system can be seen in the background of this photograph. The Kilcarnup Dunes land system occupies the foreground, adjacent to the granite outcrop.
Land resources

The Gracetown Ridge consists of sand dunes which have lithified to form Tamala Limestone. It occurs in a number of sections 5-10 km long lying parallel to the coast, rising from sea level to a height of between 140-210 m above sea level.

The Ridge has a gently undulating crest (Ge)* and moderately inclined sideslopes (see Figure 16). The western facing slopes of the Ridge (GE) are exposed to strong winds originating from the Indian Ocean (see Photograph 13). The east facing slopes (G3) are sheltered from the prevailing winds. Soils on the ridge are deep, brownish yellow, siliceous sands (Spearwood sands). In some places, these sands are shallow with outcropping limestone.

Along the southern half of the Ridge, especially around Boranup, gently inclined footslopes (G2) are often found on the eastern edge of the ridge. These can be up to 4 km wide and the soils are similar to those on the rest of the Ridge, but are redder. Areas of karst topography (Gk) are scattered throughout the ridge.

Although the Ridge rises directly from the ocean or granitic coastline, much of the western slopes are overlain by the more recent Kilcarnup Dunes land system.

Almost all of the Ridge remains uncleared. Acacia and peppermint scrub and low woodland cover the exposed western slopes and ridge crest while peppermint and jarrah/marri woodland grow on the sheltered eastern slopes with areas of karri forest on the footslopes.

Land capability

The Leeuwin-Naturaliste National Park and Boranup State Forest cover a large portion of the Gracetown Ridge, although much of the area is privately owned. Most of this area is uncleared because of its poor grazing potential. The Spearwood sands found on the Ridge have poor moisture availability, low fertility and support only average pasture growth. Water supplies are very limited.

The west facing slopes and the ridge crest (GE, Ge) have a very high wind erosion hazard and should not be cleared.

The lack of adequate water supplies prohibits horticultural development despite some areas of suitable soils and landform (e.g. G2).

Small to moderate yields of groundwater can be obtained from the limestone. Availability is very patchy and the water may be brackish in places. Water supplies that are available are in demand for urban use (Yallingup, Gracetown and Augusta all rely on this source for town water). Further pumping of groundwater from the limestone may have a detrimental effect on the cave formations. These caves are significant as a resource for tourism.

The east facing slopes and footslope (G3, G2) are suitable for forestry.

There are demands for areas of this coastal land system to be subdivided. Areas of highly erodible land should not be developed. The west facing and flat top of the ridge (GE, Ge), which are exposed to strong winds, are most susceptible.

Subsidence or cave collapse is another factor which should be considered. Geotechnical advice should be sought before any development is attempted on the ridge.

* These symbols in parentheses refer to the symbols used on the land unit maps
Kilcarnup Dunes land system

The Kilcarnup Dunes are distributed along the western edge of the Leeuwin-Naturaliste Coast from Cape Naturaliste to Cape Leeuwin. They occur mainly as a series of discontinuous areas of land, 0.2-3 km wide, overlying the western slopes of the Gracetown Ridge land system and cover a total area of 90 km². Small patches of Kilcarnup Dunes are distributed along the eastern slopes of the Gracetown Ridge.

14. The Kilcarnup Dune land system remains almost entirely under natural vegetation. These dunes are highly susceptible to wind erosion if this vegetation is disturbed.

Figure 17. Block diagram of the Kilcarnup Dunes land system.
Land resources

The Kilcarnup Dunes are parabolic dunes (see Photograph 13 and 14), often steeply inclined. They are formed from calcareous sands deposited in the late Pleistocene or Holocene. They usually rise from sea level to a height of 100 m, but can be as high as 200 m above sea level. They are usually exposed to strong winds off the ocean.

The most recently formed dunes (KE)* consist of pale calcareous sands and are sparsely vegetated (Figure 17 and Photograph 27). The older dunes tend to be more densely vegetated and have an accumulation of organic matter in the top soil (KEf). Blowouts are sometimes present (KEm). In the oldest dunes (KrE), aeolianite has begun to form and this combined with the build-up of organic matter has resulted in dark calcareous sands containing limestone rubble.

Small dunes occur in sheltered east facing locations (Kf and Kr).

The Kilcarnup Dunes remain largely uncleared. The vegetation consists primarily of acacia (Acacia spp.) and peppermint scrub.

Land capability

This land system is not suitable for any form of agriculture or forestry. The soil is poor, slopes are often steep, most units are exposed to strong, salt laden winds and even small amounts of fresh water are hard to obtain.

Any disturbance of the vegetation is likely to result in wind erosion. Regeneration of degraded areas is difficult.

National Park or coastal reserves are the most suitable use for these dunes.

* These symbols in parentheses refer to the symbols used on the land unit maps
Land systems of the Southern Coastal Plain

Scott River Plain land system

The Scott River Plain is the dominant land system of the Southern Coastal Plain, occupying 307 km².

15. Most of the Scott River Plain land system consists largely of drained flats (Sd). These flats are good grazing country.

Figure 18. Block diagram of the Scott River Plain land system.
Land resources

The Scott River Plain is a broad, poorly drained, level to gently undulating plain. It ranges in elevation from 0-10 m above sea level in the west up to 40 m in the north and east and has formed on Quaternary sediments.

Most of the plain consists of poorly drained flats with deep bleached sands (Sd)* (see Figure 18). There are some areas of extremely poor drainage with either organic stained sands (Swd) or shallow sands over ironstone (Swi). Numerous low, sandy rises and dunes (Sd2) occur.

The Scott River Plain has been extensively cleared for agriculture although large areas of the natural vegetation, sedgeland and paperbark scrub remain. Banksia woodland is found on well drained sandy rises.

Land capability

The Scott River Plain is used for grazing. It was cleared more recently than the remainder of the study area and property sizes are larger. The poorly drained flats with deep bleached sands (Sd) and the extremely poorly drained areas (Swd) provide good grazing country (see Photograph 15). The poor water-holding capacity of these sands is partly compensated by the higher rainfall and longer growing season compared with the rest of the study area. The sandy rises and dunes (Sd2) and ironstone flats (Swi) provide poor grazing.

Recently (1980s), some farmers have planted cereal crops in spring and harvested in late summer. Of these, barley has proved the most successful. The mild summer and perched water tables make this possible.

Horticulture is limited on the Scott River Plain because of waterlogging. Much of the area (Sd, Swd) is too waterlogged for horticultural crops although in some of these it may be possible to produce a summer crop. The low sandy rises and dunes (Sd2) are generally unsuitable because of their poor water holding capacity and wind erosion hazard. A further limitation to horticulture is exposure to the strong damaging winds from the south-west to south-east.

Stock water can be obtained from dragline soaks. Little is known about the groundwater supplies in the area. The superficial formations appear to contain an abundance of good quality water while further water is available from the aquifers of the Perth Basin sediments.

Poor drainage is also a limiting factor for most forest species. Loblolly pine may do well here although strong winds may be a problem.

There have been some indications of salinity in a few areas on the Scott River Plain. It is too early to tell whether these are isolated incidences or if salinity may become a widespread problem.

* These symbols in parentheses refer to the symbols used on the land unit maps
D'Entrecasteaux Dunes land system

The D'Entrecasteaux Dunes form a strip of land, 1-4 km wide, located on the southern edge of the Southern Coastal Plain. They lie between the Scott River Plain land system and the Southern Ocean, extending east from the mouth of the Blackwood River and occupy 102 km².

16. The D'Entrecasteaux Dunes land system faces the Southern Ocean and remains largely uncleared, although they contain a number of blowouts (DEn5) which can be seen in the foreground of this picture.

Figure 19. Block diagram of the D'Entrecasteaux Dunes land system.
Land resources

The D’Entrecasteaux Dunes consist of a beach (Db)* backed by a series of steeply sloping parabolic dunes ranging from 20-80 m high and consisting mainly of pale calcareous sands (see Figure 19 and Photograph 16). The southern slopes of these dunes (DE5) are exposed to strong winds coming directly off the ocean and they contain numerous blowouts (DEm5). The northern slopes (D5) are relatively sheltered from the prevailing winds.

Behind these dunes are a series of lower (generally 10-40 m high) dunes consisting of siliceous sand, which is commonly bleached and sometimes contains limestone (Dd2 and Dd5). Areas of sand flats lie between the dunes (Dd).

The D’Entrecasteaux Dunes remain largely uncleared and support a scrub of acacia and peppermint in exposed locations. In more sheltered locations this has developed into a woodland with occasional marri and jarrah.

Land capability

This land system is generally not suitable for agriculture or forestry. The south facing dunes (DE5 and DEm5) have a severe to extreme wind erosion hazard and should not be cleared. All units are covered with deep sands with low water-holding capacities. Steep slopes are a limitation in many areas. Some of the sand flats lying between the dunes (Dd and D) have been cleared, and provide small pockets of low quality grazing land. Some areas have been grazed, which, together with bushfires, has resulted in blowouts.

Horticultural crops would be affected by the high salt content in the wind, even in sheltered locations. Water supply is limited to bores, and availability and quality of groundwater is not well documented.

* These symbols in parentheses refer to the symbols used on the land unit maps
The Blackwood Alluvial Plain lies on both sides of the lower reaches of the Blackwood River from Warner Glen Bridge to Hardy Inlet. It covers an area of 94 km² on the western edge of the Southern Coastal Plain. It is 2-5 km wide and

17. The Blackwood Alluvial Plain system lies on either side of the Blackwood River. The slopes of the Glenarty Hills land system can be seen in the foreground; poorly drained flats (Bw) lie behind.

Figure 20. Block diagram of the Blackwood Alluvial Plain land system.
Land resources

The Blackwood Alluvial Plain is a level to gently undulating plain (see Photograph 17). It has formed on the Quaternary alluvial floodplains and terraces of the Blackwood River and rises from sea level to a height of 20 m.

A variety of soil types occur on the Blackwood Alluvial Plain and most are sandy. While much of the Plain is well drained flats or low rises (B), there are also extensive areas of poor drainage (Bw), especially to the south (see Figure 20). There are also patches of well drained yellow loamy soils (Bf) and low rises with deep bleached sands (Bd).

The natural vegetation is marri/jarrah forest and woodland, with paperbark woodland and sedge-land in poorly drained areas. About half the area has been cleared for agriculture.

Land capability

The Blackwood Alluvial Plain land system is mostly good grazing country with the exception of the deep sandy areas (Bd) and the wet saline flats along the lower Blackwood (Bwy). Adequate stock water can be obtained from dragline soaks.

The well drained yellow, loamy soils (Bf) are good for horticulture. One problem is exposure to winds from the south. Windbreaks may need to be erected. The cold, wet climate limits winter vegetable growth, although this cooler climate is an advantage in summer for certain crops. Other units on this land system are generally not suitable for horticulture because they are waterlogged during winter and spring. The well drained deep sands (Bd) may have some horticultural potential.

The availability of water may limit the development of horticultural blocks. Irrigation water can be obtained in some cases from high yielding soaks or deep bores.

The well drained flats and low rises (B, Bf) are suitable for forestry.

* These symbols in parentheses refer to the symbols used on the land unit maps.
19. Good pasture growth and grazing conditions occur on the Mungite (Photograph 18) and Forest Grove (Photograph 20) soils. These are the dominant soil types of land systems of the Blackwood and Margaret River Plateaux.

20. Forest Grove Soil, Wilyabrup (map unit W3). Forest Grove soils consist of yellowish brown sandy topsoil with a high gravel content overlying a brownish yellow clay subsoil. They are better drained than the Mungite soils. Most of the area's vineyards have been planted on this soil type.

Mungite soil, Cowaramup Upland (map unit C). Mungite soils are characterized by a gleyed mottled impermeable clay subsoil. The topsoil is a greyish brown sandy loam. These soils are poorly drained in winter and often retain moisture into the summer, sometimes supporting perennial pastures.
21. Abba soil, Abba Plain (map unit Aw). Abba soils have duplex profiles characterized by a sandy topsoil with a bleached A2 horizon. There is a clear boundary to the mottled clay subsoil.

22. Abba Plain from the air (map units A, Aw, and Ad2). The dominant landform pattern of the Abba Plain is an intricate patchwork of slight rises (A) and depressions (Aw). The two main soil types are the Abba (Photograph 21) and Busselton (Photograph 23) soils. In this photograph taken in June, waterlogging can be seen in the depressions. A patch of deep bleached sand (Ad2) can also be seen in this photo. This sand is very similar to the one shown in Photograph 25.

23. Busselton soil, Abba Plain (map unit A). Busselton soils are similar to Abba soils (Photograph 21). However the sandy topsoil has slightly more clay and colour and grades into the mottled clay subsoil. Both soil types support good pasture growth but poor drainage limits horticultural development.
24. Marybrook soils from the air, Jingdong (map unit AF). Some areas of well drained flats with reddish coloured Marybrook soils (Photograph 26) occur on the Abba Plain. As well as being good grazing country these flats are often used for market gardening.

25. Deep bleached sand, Scott River Plain (map unit Sd2). The deep bleached sands are siliceous sands over one metre deep. The sand is a very pale to whitish colour although the topsoil has a grey organic stain. These sands occur in most of the land systems. Poor moisture and nutrient availability limit their agricultural value, while the rapid leaching of applied fertilizers and risk of wind erosion are environmental constraints to the use of these soils.

26. Marybrook Soil, Marybrook (map unit AF). The Marybrook soils are deep red-brown sandy and loamy soils. They are generally well drained with good moisture and nutrient availability. This photograph shows a red sandy loam being used for potato growing.
27. Calcareous sand, Cape Naturaliste (map unit KEm). Calcareous sands occur all around the coast of the study area. They have little agricultural value and are highly susceptible to wind erosion, especially where they have formed dunes. The colour of these sands varies according to the amount of organic matter they contain. The sands in this photograph contain almost no organic matter. In the background, aeolianite (limestone) which formed in the sand has been exposed by wind erosion.

28. Map unit W3, Wilyabrup. Most of the existing vineyards are in the Wilyabrup Valleys on Forest Grove soils. These vineyards play an important role in tourism in the area as well as providing a significant proportion of agricultural earnings.

29. Spearwood sand, Ludlow Forest (map unit L). The Spearwood sands are iron stained siliceous sands which overlie limestone in the Ludlow Plain and Gracetown Ridge land systems. Their colour ranges from yellow to red. This photograph shows a deep brownish yellow sand under tuart woodland.
Six land uses are described and discussed: grazing, market gardens, vineyards, orchards, forestry and housing on small rural lots. Current land uses (1989) and their future potential are reviewed, as are their requirements and the capability of different parts of the study area to sustain each land use. In Appendix 2, capability ratings for each of the agricultural land uses are given for each of the land units. Appendix 3 lists the physical limitations for housing on small rural lots for each unit.

Tables 4 and 5 are based on information obtained from the Australian Bureau of Statistics. Table 4 shows the areas used for various agricultural activities as well as the gross value of production of each activity for the shires of Busselton and Augusta-

<table>
<thead>
<tr>
<th>Item</th>
<th>Area (ha) (no. of holdings)</th>
<th>Gross value $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of agricultural establishments (a)</td>
<td>137,738 (500)</td>
<td></td>
</tr>
<tr>
<td>Livestock slaughtered and other disposals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle and calves</td>
<td>13,974,000</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1,205,000</td>
<td></td>
</tr>
<tr>
<td>Livestock products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole milk</td>
<td>16,893,000</td>
<td></td>
</tr>
<tr>
<td>Wool</td>
<td>5,228,000</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>80,000</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37,480,000</td>
<td></td>
</tr>
<tr>
<td>Total—Pastures and grasses</td>
<td>96,011 (409)</td>
<td>($390/ha)</td>
</tr>
<tr>
<td>Potatoes</td>
<td>354 (27)</td>
<td></td>
</tr>
<tr>
<td>Other vegetables</td>
<td>177</td>
<td></td>
</tr>
<tr>
<td>Total—vegetables</td>
<td>531 (36)</td>
<td>6,841,000 ($12,883/ha)</td>
</tr>
<tr>
<td>Total—fruit</td>
<td>18 (7)</td>
<td>157,000 ($8,722/ha)</td>
</tr>
<tr>
<td>Total grapevines (bearing and not yet bearing)</td>
<td>509 (34)</td>
<td></td>
</tr>
<tr>
<td>Production of grapes for winemaking or distillation</td>
<td>1,773 tonnes</td>
<td>2,172,000 ($4,267/ha)</td>
</tr>
<tr>
<td>Wine made (b)—unfortified</td>
<td>777 KL</td>
<td></td>
</tr>
<tr>
<td>—fortified</td>
<td>20 KL</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>797 KL</td>
<td>8,000,000(c)</td>
</tr>
<tr>
<td>Total—nurseries</td>
<td>72 (18)</td>
<td>409,000 ($5,681/ha)</td>
</tr>
<tr>
<td>Total—horticulture (including wine and nurseries)</td>
<td>1,130</td>
<td>15,500,000</td>
</tr>
<tr>
<td>Total—all agricultural commodities</td>
<td>137,738</td>
<td>*53,133,000 ($386/ha)</td>
</tr>
</tbody>
</table>

(a) Excludes establishments with an estimated value of agricultural operations <$20,000.
(b) Represents wine made in the area regardless of the area in which the grapes were grown.
(c) The value of wine produced was not collected by the Australian Bureau of Statistics. This value was estimated by the authors and is based on the wholesale value of the wine.

Source: This table has been adapted from data provided by the Australian Bureau of Statistics.

Note: After 1985/86 the method of assessment by the Australian Bureau of Statistics changed, making direct comparisons of later statistics difficult.
Margaret River in the 1987/88 season. Table 5 shows the growth in the areas under various uses since 1970.

Grazing

Current status (late 1980s)

Grazing continues to be the predominant agricultural use in the area. More than 95% of the cleared agricultural land is used for grazing. In 1987/88, grazing returned $37 million in the Shires of Busselton and Augusta-Margaret River (Table 4). This was almost three-quarters of the gross value of agricultural production. The land is among the best for grazing in the State, partly because of the high, reliable rainfall. Many properties support areas with perennial pasture.

The main animals grazed are dairy cattle, beef cattle and sheep. While stocking levels have remained fairly constant since the 1970s there have been fluctuations in sheep and beef cattle numbers in response to market conditions (Table 5). During this time the number of dairy cattle has remained at about 33,000. Dairying is the most profitable form of grazing. Although there are greater numbers of both sheep and beef cattle in the area, dairying contributes almost half of the grazing income (Table 4).

Although there is unlikely to be any overall expansion of grazing, it is predicted that dairying will increase. The area may eventually produce between a third and a half of the State’s total dairy production if there is a re-location in the industry from the irrigated land north of Bunbury to higher rainfall areas (ACIL 1987).

Small numbers of goats, horses and deer are grazed. However, for our purposes, the land use grazing is defined as the grazing of sheep and beef and dairy cattle on non-irrigated volunteer and improved pastures.

Land use requirements

The minimum area required for a viable grazing enterprise property is between 100-200 ha, with a stocking rate of 10 dry sheep equivalents per hectare. Because of historical factors, most of the lots in the area are too small to be viable grazing units. To overcome this problem most of the farmers own more than one lot and, although these lots are adjoining in some cases, many properties are fragmented. The amalgamation of adjoining lots in good grazing country would help ensure the long term viability of grazing properties. However, there will always be a need for a supply of smaller lots for farm build-up.

Many of the criteria that need to be considered in assessing the capability of land to support grazing actually determine pasture growth. On sandy soils with poor moisture availability, pasture is likely to experience moisture stress. This is likely to result in a shortage of feed in late summer and autumn unless stocking rates are lowered.

Soil fertility also needs to be considered. Although all the soils in the district require fertilizer to produce good quality pasture, the costs of fertilizing the deep highly leached sands can be excessive. Added nutrients leached from these sands may pollute surface and groundwater.

Soils should be at least 50 cm deep to provide adequate rooting depth. Salinity will adversely affect pasture growth. Waterlogging restricts growth if the water table comes within 20 cm of the surface. Winter waterlogging may be compensated for by extra growth in spring and early summer.

The risk of wind and water erosion must be considered. Slope gradients should be < 8% to ensure that water erosion does not occur. However, slopes with gradients up to 33% can be used provided careful management of stocking rates is exercised. Areas with a high wind erosion hazard, mainly sandy soils in exposed positions, are generally unsuitable and should remain uncleared.

The provision of good quality water for stock is essential. This is only a problem in a few areas.

Table 5. Change in agricultural activities since 1970

<table>
<thead>
<tr>
<th></th>
<th>1970/71</th>
<th>1975/76</th>
<th>1985/86</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. agricultural holdings</td>
<td>850</td>
<td>761</td>
<td>745</td>
</tr>
<tr>
<td>Area of agric. holdings</td>
<td>174,000 ha</td>
<td>174,000 ha</td>
<td>160,000 ha</td>
</tr>
<tr>
<td>Area cleared</td>
<td>124,750 ha</td>
<td>N.A.</td>
<td>128,300 ha</td>
</tr>
<tr>
<td>Area of pasture</td>
<td>115,000 ha</td>
<td>122,000 ha</td>
<td>117,700 ha</td>
</tr>
<tr>
<td>Area of oats</td>
<td>N.A.</td>
<td>N.A.</td>
<td>1,400 ha</td>
</tr>
<tr>
<td>Area cut for hay</td>
<td>12,500 ha</td>
<td>N.A.</td>
<td>20,000 ha</td>
</tr>
<tr>
<td>Area of vegetables</td>
<td>309 ha</td>
<td>266 ha</td>
<td>440 ha</td>
</tr>
<tr>
<td>Area of potatoes</td>
<td>301 ha</td>
<td>249 ha</td>
<td>290 ha</td>
</tr>
<tr>
<td>Area of other vegetables</td>
<td>8 ha</td>
<td>17 ha</td>
<td>150 ha</td>
</tr>
<tr>
<td>Area of orchards</td>
<td>4 ha</td>
<td>5 ha</td>
<td>27 ha</td>
</tr>
<tr>
<td>Area apple/citrus</td>
<td>4 ha</td>
<td>5 ha</td>
<td>5 ha</td>
</tr>
<tr>
<td>Area nuts</td>
<td>Nil</td>
<td>Nil</td>
<td>11 ha</td>
</tr>
<tr>
<td>Area kiwi fruit</td>
<td>Nil</td>
<td>Nil</td>
<td>6 ha</td>
</tr>
<tr>
<td>Area avocados</td>
<td>Nil</td>
<td>Nil</td>
<td>5 ha</td>
</tr>
<tr>
<td>Area of vineyards</td>
<td>&lt; 10 ha</td>
<td>131 ha</td>
<td>470 ha</td>
</tr>
<tr>
<td>No. of beef cattle</td>
<td>109,310</td>
<td>140,000</td>
<td>79,500</td>
</tr>
<tr>
<td>No. of dairy cattle</td>
<td>33,736</td>
<td>34,500</td>
<td>32,100</td>
</tr>
<tr>
<td>No. of sheep</td>
<td>121,800</td>
<td>100,000</td>
<td>206,000</td>
</tr>
<tr>
<td>d.s.e.¹</td>
<td>1,653,468</td>
<td>1,948,500</td>
<td>1,418,300</td>
</tr>
</tbody>
</table>

¹ This figure was calculated assuming that on average sheep equal 1 d.s.e., dairy cattle equal 13 d.s.e. and beef cattle equal 10 d.s.e.


LAND RESOURCES SERIES No. 5
Another requirement is for the land to be relatively free of pesticide residues. Unacceptable levels of organochlorine pesticides have been found in cattle grazed in paddocks previously used for potato growing. Pasture growing on areas where these pesticides have been used in the past, in 1989 were still considered unsuitable for the grazing of beef and dairy cattle and a number of paddocks have been temporarily placed under quarantine.

Land capability

Most of the area can be considered good quality grazing country (Figure 21 and Photograph 19). The main exceptions are the sandy coastal land systems, i.e. the D’En- trecasteaux Dunes, the Kilcarnup Dunes, the Gracetown Ridge and the Quindalup Coast. The Ludlow Plains and parts of the Metricup Scarp are also of lesser value, while within the remainder of the area there are patches of deep bleached sands, shallow stony soils and severely waterlogged areas which have limited potential.

About 1900 km² of land is classified as Class I or II for grazing. This is about 70% of the study area.

Market gardening

Current status

A horticultural industry based on potato production has operated for many years. In 1985/86 the area produced about 15% of the State’s potato crop. Potatoes remain the dominant crop, occupying about two-thirds of the area used for market gardening (Table 5).

Since the mid 1970s, the area has started to become an important producer of other vegetable crops (Table 5), although still small in comparison with some other areas in the State. These crops include tomatoes, cauliflowers, celery, pumpkins, onions, beans, peas, capsicums and melons. The suitable climate, later season and availability of large areas for rotation have resulted in high quality produce which can compete on the local and overseas market.

In 1987/88, over $6 million was earned from vegetable production in the area (Table 4).

The future is likely to see a growth in the production of both potatoes and other vegetables. There is now a trend for existing potato growers to move their operations from the Donnybrook area to Marybrook and Jindong on the Abba Plain. It is predicted that the production of vegetables in the area will increase by 5% per annum for the next 20 years (ACIL, 1987).

We define market gardening as the production of vegetable and fruit species with annual life cycles. It has been assumed crops are irrigated, rotation is practised and that cultivation is mechanized.

Land use requirements

On average, about 5 ha needs to be cropped per year for a market gardening enterprise to be economically viable. A minimum area of 20 ha is required to allow for rotation and infrastructure.

Sufficient supplies of irrigation water are essential. The amount of water required will vary according to the type of crop grown and method of irrigation and ranges between 5,000-15,000 m³/ha/a. Most of this water will be needed during the summer months. The water should contain < 300 mS/m total soluble salts, with a preferred concentration of < 100 mS/m.

A capacity for continuous year round cropping is preferable. The climate in the north of the area allows for this, while in the south...
the cooler, wetter winters tend to restrict production in the winter months. The climate in the south is better suited to certain crops produced in summer (e.g. lettuce).

Soils should be sufficiently deep (preferably > 100 cm) and free of stones (preferably < 20% volume) to allow for cultivation and root growth. Lighter textured soils provide for better rooting conditions and ease of cultivation.

Waterlogging has an adverse effect on crop growth, and the top 50 cm of soil should drain freely during cropping. Many areas which are waterlogged in winter are capable of producing summer crops. However, these areas are considered to have a low capability for market gardens as they cannot produce all year round. Waterlogging can also occur on the heavier soils during irrigation. Even on loamy soils, waterlogging from overwatering has been a problem in some cases. Bogginess resulting from waterlogging restricts machinery access. For summer cropping, it is preferable to have machinery access between September and May. It is possible to produce a crop from an area which is only accessible between November and April.

Deep sandy soils have poor moisture retention so plants suffer water stress unless the timing of irrigation is carefully managed.

On all soil types, fertilizers will need to be added to ensure good production. When considering the probable returns this is not a restrictive cost, even on the deep leached sands. The risk of surface and groundwater pollution on these sands is high. By applying fertilizer and water in small and regular doses this risk may be reduced.

Requests to the Western Australian Water Authority for groundwater allocations are referred to the Environmental Protection Authority. If the Authority believes there is a serious risk of pollution arising from a horticultural development, specific management practices, which must be adhered to, will be imposed or there will be no development.

Salinity in the soil has an adverse effect on plant growth, as does exposure to salt spray. High velocity winds and wind driven rain can cause crop damage.

The frequent cultivation practised on market gardens leaves the soil vulnerable to water and wind erosion. To minimize the risk of water erosion, cultivation of sloping land should be avoided. Areas with gradients of < 2% are considered to be of least risk. On slopes of 5-10%, cultivation should be across the slope and it may be necessary to install graded furrows. Slopes > 10% are usually unsuitable for market gardening. Land with a very high wind erosion hazard should be avoided. In other areas, care should be taken to minimize the time that recently cultivated areas are left bare when the soil is dry and susceptible to wind erosion.

**Land capability**

There are limited areas which are suitable for market gardens. These are largely restricted to the Swan Coastal Plain where good quality water supplies are often available (Figure 22). Two main areas of suitable country exist. An area of Marybrook soils and well drained Busselton sands extends from Marybrook through Carbanup and onto Jindong, while a strip of Spearwood sands extends from Capel westward, inland of Busselton and the Broadwater. Smaller patches of alluvial soils are also

![Figure 22. Land capability for market gardens.](image-url)
found on the Swan Coastal Plain. Further south, restricted areas of suitable alluvial soils occur e.g. along the Margaret River upstream from the township. Over most of the area factors such as the availability of water supply, waterlogging and the erosion hazard limit the potential for market gardening.

About 140 km², or 5% of the area, has been classified as being predominantly Class I or II for market gardens. Not all of this land will be available for the expansion of market gardening. Water supplies are not sufficient to crop the entire area of suitable soils. Areas of unsuitable soils occur within this 140 km².

Land requirements for crop rotation need to be considered. A significant proportion of this land identified as having a high capability is currently assigned to conflicting uses e.g. State Forest or special rural zones. There is a possibility that future restrictions may be placed on horticultural development in the Margaret River catchment and around the edges of the Vasse and Wonerup estuaries because of fears of water pollution. Careful planning is needed to allow the market gardening industry to expand to its full potential.

The deep bleached sands on the Swan Coastal Plain may prove to be capable of supporting market gardens where good supplies of groundwater are available. Although these soils have poor moisture and nutrient retention, they are well drained and provide for good rooting conditions and ease of cultivation. Similar soils around Perth are productive under suitable management techniques.

Some areas of sandy soils on the Scott River Plain may also prove to be capable of producing summer crops if the water table drops rapidly enough at the end of winter. Further investigations are necessary to determine the suitability of this area.

Vineyards

Current status

Viticulture is a relatively new and rapidly expanding industry in the area (see Photograph 28). In 1988, there were over 750 ha of vines. The vineyards are now a major source of income, returning between $6 and $7 million in 1986. The vineyards play a very important role in the tourist industry. The cool, mild climate allows for the production of high quality table wines which have gained acclaim throughout Australia and overseas. Varieties of grapes grown include Rhine Riesling, Semillion, Chardonnay, Verdelho, Traminer, Sauvignon Blanc and Cabernet Sauvignon.

The land use ‘vineyards’ we define as the commercial growing of grapes for the production of high quality table wines. It has been assumed that drip irrigation is used during critical periods and herbicides, rather than cultivation, are used to control weeds.

Land use requirements

A minimum area of between 10-20 ha of suitable land is required to establish a commercial vineyard. Originally, few vineyards in the area were irrigated, however, irrigation is now recognized as an important aspect of vine management. Between 2,000 and 4,000 m³/ha/a of water is used to irrigate vines. This is required in the summer and early autumn.

The climate of the area is suitable for growing high quality wine grapes. There is a risk of frost damage in inland areas (i.e. east of the Bussell Highway and south of Cowaramup). High velocity winds and wind driven rain can damage shoots, leaves and fruit. This is of concern especially in unprotected areas near the west coast. Northeast facing slopes are the most sheltered and as a result are preferred areas for planting vines. Vines have a low tolerance to salt spray.

The rooting depth requirement of vines is 40-60 cm. Soils about one metre deep are preferred. Soils with large amounts of stone (>150 mm) in the top 50 cm are considered unsuitable, although gravelly soils present few problems.

Waterlogging is a major limitation. The water table should be more than 50 cm below the surface by the time bud burst occurs in mid-spring or growth will be adversely affected. Gravelly soils in sloping areas usually provide suitable drainage conditions. Machinery access is important between November and April. Areas with soil salinity problems or which are subject to flooding should be avoided.

Vines will suffer water stress in summer on deep, light textured soils. This problem can be overcome with irrigation. Similarly, the addition of fertilizers can overcome nutrient deficiencies even on the highly leached sands. On the Marybrook soils, vegetative growth can become too vigorous and these areas may be more suited for producing table grapes than wine grapes.

The moderate to highly erodible soils, on which most vineyards are planted, have a significant water erosion risk on slopes with gradients >10%. There is little risk of erosion on slopes with gradients <5%. On the steeper slopes, vines should be planted along the contour and cultivation to control weeds should not be practised. Banks and furrows may be necessary to reduce the risk of water erosion. Slopes with gradients >15% should be avoided. Areas subject to wind erosion should be avoided.

Land capability

There are a variety of locations in the area which are capable of sustaining viticulture (Figure 23). The Spearwood sands, Marybrook soils and well drained Busselton sands of the Swan Coastal Plain, which have a high capability for market gardening, are well suited to vineyards. So too are alluvial soils in other areas, except where the flood risk is high. The Wilyabrup Valleys, and the sloping margins of the Cowaramup Uplands, also have a high capability. It is here that most of the vineyard development has taken place.

Problems in existing vineyard areas include difficulties in obtaining sufficient water for irrigation. Wind damage to vines occurs in the more exposed locations.
The areas described above are mostly classified as Class I or II for vineyards and total about 300 km², or 11% of the study area.

The Treeton Hills are capable of supporting vineyards, particularly on the Forest Grove soils. The main limitations in the hills are likely to be waterlogging on the Mungite soils and the risk of water erosion on the steeper slopes. The risk of frost is also greater, though this may suit some varieties. The hills area is 330 km², although probably only half of this area may have good potential. Water supply availability is usually better than in the Wilyabrup Valleys, while wind exposure is less likely to be a problem.

We have defined orchards as the annual production of fruit and nut crops that grow on perennial species. It has been assumed that orchards are irrigated and that cultivation is only required at the initial planting.

**Land use requirements**

A minimum area of 5-10 ha of suitable land is required for a commercial orchard. Irrigation is considered essential to produce good crop yields. Different crops have different water requirements. Most of the crops now grown in the area require between 7,000-10,000 m³/ha/a of water. Proteas require irrigation during their first year and probably benefit from continued irrigation in following years.

Fruit and nut trees are highly susceptible to wind damage so that areas exposed to strong winds should be avoided. Wind-breaks or protective fences may be necessary in some locations. Areas subject to salt spray should be avoided.

A minimum depth of 100 cm of soil is required for root growth. The top 50 cm should be relatively free of stones (> 150 mm).

Different species also have different tolerances to waterlogging, and areas prone to flooding should be avoided. As a rule, the water table should be at least 100 cm below the surface throughout the year. Deciduous species can stand a slightly greater winter waterlogging. Saline soils are unsuitable.

Problems of summer water stress on sandy soils can be overcome by careful management of irrigation. Nutrient deficiencies of these soils can be overcome by the application of fertilizers, but risk of surface and groundwater pollution should be considered.

In orchards, if pasture is grown between rows, water erosion is unlikely to occur on slopes with gradients < 10%. With careful management, slopes with gradients up to 15% can be used safely. Areas with a severe wind erosion hazard should be avoided.
Land capability

Most of the areas capable of supporting vineyards are well suited for orchards (Figure 24). These include the Spearwood sands, Marybrook soils and well drained Busselton sands on the Swan Coastal Plain as well as the Wilyabrup Valleys. In the Wilyabrup Valleys, difficulties may be encountered in obtaining sufficient irrigation water.

Some areas within the Treeton Hills will also have a high capability. Waterlogging is more likely to be a constraint here for some orchard crops than for grapevines.

Forestry

Current status

The hardwood timber industry, based on natural forests, has been important in the area since the mid to late 1800s. Softwood plantations have gained significance since the 1950s.

Most forestry occurs in the State Forests adjacent to the study area. In 1984/85, the gross value of production in the Augusta-Margaret River and Busselton Shires was $6 million (Table 1). Forestry on farmland, including softwood share-farming and agroforestry, is likely to become more important in the future. In softwood share-farming, pines are grown by landholders in conjunction with the Department of Conservation and Land Management. Agroforestry is a combination of grazing and producing timber with mutual benefits to stock and trees, and the timber can be used on the farm or sold commercially. There is also a scheme whereby farmers can cooperate with timber companies to produce hardwood timber for woodchips.

There are a number of tree species which can be planted on farms for timber production which have differing land requirements. The most popular species are radiata pine (*Pinus radiata*) and Tasmanian blue gum (*Eucalyptus globulus*). In this study, it is the capability of the land for growing *P. radiata* that has been assessed. Areas suitable for *P. radiata* are likely to be suitable for other species including maritime pine (*P. pinaster*), loblolly pine (*P. taeda*) and Tasmanian blue gum. Some of these species will also grow in areas with a poor capability for *Pinus radiata*.

Land use requirements

A minimum area of 2-5 ha is necessary for the commercial production of timber. Trees will grow best where land is best for agriculture. Areas unsuited to timber production include those exposed to high velocity winds or salt spray, those with shallow stony soils or subject to severe waterlogging and those with soil salinity problems.

Soil moisture and nutrient availability are other important factors. Good timber yields will not be obtained from *P. radiata* on the deep bleached sands, where the trees will suffer nutrient deficiencies and summer water stress. The cost of fertilizing this species on these sands is not justified. *P. pinaster* will, however, produce good quality timber on these sands. The production of timber from *P. pinaster* may prove to be the most appropriate use for many of these areas.

*P. radiata* and *P. pinaster* both have a low tolerance to waterlogging, and areas where the water table rises above 50 cm are considered unsuitable for these species. P.
*P. teada* will grow quite well in areas with the water table near the surface in winter. Establishing *P. teada* as agroforestry may eventually lead to a lowering of water tables and improved pasture growth.

**Land capability**

There are about 1,550 km² in the study area which are classified as Class I or II for the commercial production of *P. radiata* (Figure 25). This is 55% of the total area.

The coastal areas exposed to strong winds and salt spray are unsuited to timber production, as are areas of shallow stony soils and areas of severe waterlogging and salinity on the Swan Coastal Plain. Most of the Swan Coastal Plain consists of a mosaic pattern of relatively well drained soils and winter waterlogged areas. Although only the former has a good capability for *P. radiata*, the latter may produce good timber from *P. teada*. A similar situation exists on the Nillup Plain and the Blackwood Alluvial Plain. A large area of the Scott River Plain may also have good potential for *P. teada*, although wind exposure may be a problem there.

Throughout the area there are expanses of deep bleached sands on which *P. radiata* will not produce good timber, but may be quite suitable for *P. pinaster*.

**Small rural lots**

Since the 1970s, there has been an increasing demand within the area for small rural lots. These are blocks of variable size in rural areas. They are larger than an urban block, but smaller than most farming blocks. Commonly they are between 2-5 ha, but can be up to 100 ha.

Small rural lots are often used for rural residences or weekend and holiday retreats and usually have some form of dwelling built on them. The land use varies on the remainder of the block. Many are bush blocks where natural vegetation has been retained or vegetation is being re-established. Other blocks are cleared and grazed or left unstocked. There are small commercial market gardens or orchards on some lots. Many have domestic gardens or poultry and, quite often, there is a mixture of these uses.

Management of small rural lots is variable and may cause concern. Problems can include overgrazing, poor control of weeds and vermin and a lack of bushfire prevention. The temporary occupancy of some blocks can contribute to these problems.

Assuming there are suitable house sites, almost all of the land is capable of supporting some form of small rural lots. The main exceptions are the fragile coastal and severely waterlogged areas.

The capability ratings for the other land uses will give a good indication of what sort of activities may be suitable on these lots for a particular area. Areas with a low capability for grazing or horticultural uses are usually capable of supporting bush blocks with only the house site being cleared.

As well as the availability of sites suitable for house construction, access (usually in the form of an unsealed road without kerbs) and sewerage disposal (usually by means of septic tanks), are two factors which need to be considered when assessing whether land is capable of supporting small rural lots. All three are covered in the assessment of the physical limitations for housing on small rural lots in Appendix 3.
One of the first requirements of housing is stability of the land surface. Areas prone to wave erosion or mass movement in the form of landslips or slumping should be avoided. Problems are likely to be encountered if nearby sand dunes have the potential to become mobile, or if the area is underlain by caves or subject to flooding. Geotechnical advice should be obtained before any construction in these areas takes place.

The risk of erosion on the land, especially during construction when the ground surface is bare and disturbed, can damage house and access roads. On erosion prone land, care and professional advice are necessary during house design and construction. Soil erosion on firebreaks cleared around houses and lot boundaries may be a problem.

Steep slopes and shallow stony soils present problems. They increase the care which needs to be put into house design and site preparation and the cost of construction. Slopes with gradients of < 5% present few problems while major problems can be encountered on slopes > 15%, especially with shallow stony soils where excavation is difficult. Surface rock can present an obstacle to machinery. There is also the risk of batters cut on steep slopes eroding or collapsing.

Problems will be encountered in boggy, waterlogged areas. Although houses and roads can be built on raised pads, they will be surrounded by swampy ground during winter. Access difficulties for machinery will be experienced during construction.

Factors to be considered regarding the disposal of sewerage effluent through septic systems include the depth of soil available to install the septic tanks and leach drains (Wells 1987). Ideally, there should be at least 2 m of soil. Where soil depth is < 80 cm, raised sand pads may need to be constructed. Excavation will be difficult in stony soils.

The ability of soil to absorb effluent is also very important. Poor soil absorption can result in the overflow of septic systems creating a health risk. Soil absorption problems will be encountered on heavy textured soils with poor permeability or in areas where subsoil waterlogging occurs, especially where the water table rises above a depth of 50 cm. High stone or gravel content decreases the soil's absorption ability. Seepage from septic systems can also occur in steep slopes.

Equally important is the ability of the soil to purify the effluent. Sandy soils which leach readily allow the effluent to pass through rapidly with risk of groundwater pollution or contamination of surface waters nearby.

A house, road and septic system occupy a very small area, so even in places having major limitations for housing, suitable sites can often be located. With the exception of land stability, most limitations can be overcome. It is largely a matter of how much the land owner or developer is prepared to spend to overcome these problems.

There are four categories of land where there are severe limitations for housing on small rural lots. These are:

- sandy coastlines subject to wave erosion
- steep slopes of the D'Entrecasteaux Dunes and the Kilcarnup Dunes and western-facing slopes of the Gracetown Ridge where slope, wind erosion hazard and potential instability are all problems
- areas of bare rock outcrop and steep cliffs, mainly on the coast
- areas subject to severe waterlogging, most notably the Vasse and Wonerup estuaries and the Broadwater

None of these areas should be considered for subdivision into small rural lots.

Areas experiencing major limitations for housing on small rural lots are more widespread. These include areas subject to winter waterlogging which cover most of the Scott River Plain and a large portion of the Abba Plain, the Ludlow Plain and the Quindalup Coast. Similar areas exist in scattered patches on the Nillup Plain, Yelverton Shelf, Cowaramup Uplands, Blackwood Alluvial Plain and along drainage lines in the Treeton Hills and Glenarty Hills. Flooding is also a major limitation along drainage lines throughout the area.

Other areas with major limitations include those with shallow stony soils scattered throughout the area, the restricted areas underlain by caves on the Gracetown Ridge as well as some steep slopes on the Metricup Scarp and in the Treeton Hills which have a very high water erosion hazard and the potential for slope instability problems. Wind erosion hazard is a major limitation on the crest of the Gracetown Ridge and much of the Kilcarnup Dunes. On these dunes, slope and water erosion hazard are also often major limitations.

Minor or moderate limitations are experienced over the remainder of the area, but in many cases these are easily overcome.
Acknowledgements

We thank the staff of the Busselton office of the Department of Agriculture for their assistance and advice throughout the project, especially John Wise, Ken Haywood, Doug Home, Warren Slade and Peter Gherardi. Harry Gratte, Geoff Godley, John Middlemass, Kevin Whitely, Tony Devitt and Robert (Rob) Floyd (Department of Agriculture); all provided advice on horticultural land uses. Jock Gilchrist assisted with information concerning the requirements of forestry. Klaus Hirschberg (Geological Survey) provided information concerning groundwater resources, and Peter Driscoll (Shire of Augusta-Margaret River) helped with rural zoning information. Howard Garner of the Australian Bureau of Statistics assisted with agricultural statistics. We also thank the staff of the Margaret River office of the Department of Conservation and Land Management for logistical assistance, William (Bill) McArthur for help with mapping soil types on the Swan Coastal Plain and S.S. Mahendrian for assistance with field work. There were numerous staff members within the Division of Resource Management who were very helpful at various stages of the project. Members of the Division’s Geographical Information Systems Group assisted with map preparation and land capability analysis, especially Greg Mlodawski who developed the LANDCAP program. Simon Eyres of the Department of Agriculture’s Information Branch took most of the photographs appearing in this publication. The Department’s Word Processing Centre staff prepared various manuscripts.
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These appendices are for use in conjunction with the 1:50,000 scale land unit maps. Appendix 1 lists brief descriptions of each land unit in alphabetical order. Appendix 2 gives land capability ratings for each of the land units. Appendix 3 lists the limitations for housing on small rural lots for each of the land units.

Appendix 1

Land unit descriptions

Abba Plains land system
A—Abba Flats: Flats and low rises with sandy grey-brown duplex (Abba) and gradational (Busselton) soils. Also included in areas mapped as A are minor areas of; A2—Abba gentle slopes; gentle slopes (2-5% gradients) with gravelly sands and grey-brown gradational and duplex soils.
Ad2—Abba Deep Sandy Dunes: Gently sloping low dunes and rises (0-5% gradients) with deep bleached sands.
Af—Abba Fertile Flats: Well drained flats with sandy gradational grey-brown (Busselton) soils, some red-brown sands and loams (Marybrook Soils).
AF—Abba Very Fertile Flats: Well drained flats with deep red-brown sands, loams and light clays (i.e. Marybrook soils).
Afw—Abba Fertile Wet Flats: Slight depressions, which are poorly drained in winter, with deep red-brown sands, loams and light clays (i.e. Marybrook soils).
Av—Abba Vales: Small narrow depressions along drainage lines. Alluvial soils.
Avw—Abba Wet Vales: Small narrow swampy depressions along drainage lines. Alluvial soils.
Aw—Abba Wet Flats: Winter wet flats and slight depressions with sandy grey brown duplex (Abba) and gradational (Busselton) soils.
Awi—Abba Wet Ironstone Flats: Winter wet flats and slight depressions with shallow red-brown sands and loams over ironstone (i.e. Bog iron ore soils).
Awy—Abba Very Wet Saline Flats: Poorly drained depressions with some areas which become saline in summer. Shallow sands over clay subsoils (i.e. Abba clays).

Blackwood Alluvial Plain land system
B—Blackwood Flats: Flats with a variety of deep (mainly sandy) soils
Bd—Blackwood Deep Sandy Flats: Flats and low dunes with deep bleached sands.
Bf—Blackwood Fertile Flats: Flats, mainly with deep yellow loamy soils (i.e. Marybrook yellow sandy loam).
Bvw—Blackwood Wet Vales: Drainage depressions with broad swampy floors. Mixed alluvial and sandy soils.
Bw—Blackwood Wet Flats: Flats and slight depressions which are winter wet. Mixed alluvial and sandy soils.
Bwy—Blackwood Estuarine Flats: Estuarine flats fringing the Blackwood River near its mouth.
Cowaramup Uplands land system

C—Cowaramup Flats and Gentle Slopes: Flats (0-2% gradient) and with gravelly duplex (Forest Grove) and pale grey mottled (Mungite) soils. Also included in areas mapped as C are areas of C2—Cowaramup Gentle Slopes: Gentle slopes (2-5% gradient) with gravelly duplex (Forest Grove) soils. The flats (C) are the dominant unit, the gentle slopes (C2) occur on the margins of the land system, usually adjacent to the Wilyabrup slopes.

Cd2—Cowaramup Deep Sandy Rises: Flats and gently sloping rises (gradients 0-5%), with deep bleached sands. Some areas of low and moderate slopes (gradients 5-15%).

CdW—Cowaramup Deep Sandy Wet Flats: Poorly drained flats and depressions with deep organic stained sands.

Ci—Cowaramup Ironstone Flats: Flats and gentle slopes (0-5% gradient) with some laterite outcrop and shallow gravelly sands over laterite.

Cr2—Cowaramup Rocky Gentle Slopes: Flats and gentle slopes (0-5% gradient) with shallow rocky soils and some granitic outcrop.

CR—Cowaramup Rock Outcrop: Areas dominated by granitic outcrop.

Cv—Cowaramup Vales: Small, narrow V-shaped drainage depressions with gravelly duplex (Forest Grove) soils.

Cvw—Cowaramup Wet Vales: Small, broad U-shaped drainage depressions with swampy floors. Gravelly duplex (Forest Grove) soils on sideslopes and poorly drained alluvial soils on valley floor. This unit can be subdivided into the (side) slopes and the (valley) floor.

Cw—Cowaramup Wet Flats: Poorly drained flats and slight depressions with pale grey mottled (Mungite) soils.

D’Entrecasteaux Dunes land systems

D—D’Entrecasteaux Flats: Interdune flats with deep calcareous sands with organic stained topsoils.

D5—D’Entrecasteaux Steep Dunes: Steep dunes, sheltered from the prevailing winds, with deep calcareous sands.

Db—D’Entrecasteaux Beaches: Beach and foredunes stretching along the south coast, with deep calcareous sands.

Dd—D’Entrecasteaux Deep Sandy Flats: Flats with deep bleached siliceous sands.

Dd2—D’Entrecasteaux Deep Sandy Gentle Dunes: Gently sloping (2-5% gradient) dunes, sheltered from the prevailing winds, with bleached and yellow-brown siliceous sands, sometimes overlying limestone.

Dd5—D’Entrecasteaux Deep Sandy Steep Dunes: Steep dunes (gradient in excess of 15%) with bleached and yellow-brown siliceous sands, sometimes overlying limestone.

DE5—D’Entrecasteaux Exposed Steep Dunes: Steep dunes with deep, calcareous sands, exposed to prevailing winds which come off the ocean.

DEm5—D’Entrecasteaux Blowouts: Steep bare dunes of mobile pale calcareous sands.

Dr—D’Entrecasteaux Rocky Dunes: Dunes with dark calcareous sands containing limestone rubble.

Gracetown Ridge land system

G2—Gracetown Gentle Slopes: Gentle slopes (gradients 2-5%) with deep reddish and yellow-brown siliceous sands over limestone (Spearwood Sands). Not exposed to prevailing winds.

G3—Gracetown Low Slopes: Low slopes (gradients 5-10%) with deep yellow-brown siliceous sands over limestone (i.e. Spearwood Sands). Not exposed to prevailing winds.

Ge—Gracetown Exposed Flats: Ridge crest, exposed to prevailing winds, with deep and shallow yellow-brown siliceous sands over limestone (i.e. Spearwood sands).

GE—Gracetown Exposed Slopes: Moderate slopes (gradients 10-15%) on the west coast exposed to prevailing wind directly off the ocean, with deep and shallow yellow-brown siliceous sands over limestone (i.e. Spearwood Sands).

GEm—Gracetown Blowouts: Small blowouts with deep yellow siliceous sands.

Gk—Gracetown Karst Areas: Small areas with sinkholes, dolines, limestone scarps and cave entrances.

Gv—Gracetown Valleys: Deepish narrow valleys incised into the Gracetown Ridge.

Glenarty Hills land system

H3—Glenarty Low Slopes: Slopes (gradients mainly 5-10%) with a variety of soil types.

Hd—Glenarty Deep Sandy Flats: Flats with deep bleached sands

Hd3—Glenarty Deep Sandy Slopes: Slopes (gradients mainly 5-10%) with deep bleached sands and quartz grits.

Hdw—Glenarty Sandy Wet Flats: Poorly drained flats and depressions with deep organic stained sands.

Hf—Glenarty Fertile Flats: Well drained valley flats and floodplains with deep (often red-brown loamy) alluvial soils.

Hi3—Glenarty Ironstone Slopes: Slopes (gradients mainly 5-10%) with shallow gravelly sands over laterite.

HR—Glenarty Rock Outcrop: Areas dominated by granitic outcrop.

Hv—Glenarty Valleys: Narrow V-shaped open depressions along drainage lines.

Hyw—Glenarty Wet Valleys: Broad U-shaped drainage depressions with swampy floors.

Hw3—Glenarty Wet Slopes: Slopes (gradients mainly 5-10%) with high winter water tables and pale grey mottled (Mungite) soils.
Kilcarnup Dunes land system

**Kb**—Kilcarnup Beaches: Beaches and foredunes of calcareous sand, along the west coast.

**KE**—Kilcarnup Exposed Dunes: Steep dunes (gradients usually in excess of 20%) on the west coast, exposed to prevailing winds which come directly off the ocean, with deep pale calcareous sands. Poorly vegetated.

**KEf**—Kilcarnup Exposed Dunes (with organic matter build up): Steep dunes (gradients usually over 20%) on the west coast, exposed to prevailing winds which come directly off the ocean. Deep pale calcareous sands with brown topsoil. Well vegetated.

**KEm**—Kilcarnup Exposed Blowouts: Steep bare dunes of mobile pale calcareous sands, on the west coast exposed to prevailing winds directly off the ocean.

**Kf**—Kilcarnup Dunes (with organic matter build up): Steep dunes, (gradients usually over 20%) not exposed to prevailing winds. Deep pale calcareous sands with brown topsoil.

**Km**—Kilcarnup Blowouts: Steep bare dunes of mobile calcareous sand, not exposed to prevailing winds.

**Kr**—Kilcarnup Rocky Dunes: Low to steep dunes (gradients 5-10%), not exposed to prevailing winds. Dark calcareous sands containing limestone rubble.

**KrE**—Kilcarnup Exposed Rocky Dunes: Steep dunes (gradients usually in excess of 20%) with dark calcareous sands containing limestone rubble, on the west coast exposed to prevailing winds directly off the ocean.

**KRE**—Kilcarnup Exposed Rock Outcrop: Dominantly highly eroded areas where bare limestone has been exposed.

Ludlow Plain land system

**L**—Ludlow Flats: Flats and very low dunes. Deep yellow-brown siliceous sands over limestone (i.e. Spearwood sands).

**Lv**—Ludlow Vales: Narrow floodplains in small depressions along creeks and rivers. Sandy alluvial soils.

**Lvg**—Ludlow Wet Clayey Vales: Narrow floodplains in small depressions along creeks and rivers. Clayey alluvial soils.

**Lvw**—Ludlow Wet Vales: Narrow swampy small depressions. Sandy soils.

**Lw**—Ludlow Wet Flats: Flats with poor subsoil drainage in winter. Deep yellow-brown siliceous sands over limestone (i.e. Spearwood Sands).

**Lwg**—Ludlow Wet Clayey Flats: Poorly drained flats with heavy clayey (Cokelup) soils. Some areas saline in summer.

**Lwr**—Ludlow Wet Rocky Flats: Flats with high winter water tables and shallow brown and yellow sands over limestone (i.e. Shallow Spearwood sand). Limestone often present on surface.

Metricup Scarp land system

**M**—Metricup Slopes: Moderate slopes (gradients mainly 10-15%) with gravelly duplex (Forest Grove) soils.

**Mr**—Metricup Rocky Slopes: Moderate slopes (gradients mainly 10-15%) with shallow gravelly soils and occasional lateritic and granitic outcrop.

**Mv**—Metricup Valleys: Valleys with moderately inclined sideslopes and valley floors with relatively steep gradients. Gravelly duplex (Forest Grove) soils.

**Mvr**—Metricup Rocky Valleys: Deeply incised valleys with steep sideslopes and valley floors with relatively steep gradients. Shallow gravelly soils and occasional lateritic and granitic outcrop.
Nillup Plain land system
N—Nillup Flats: Flats mainly with pale grey mottled (Mungite) soils.
Nf—Nillup Fertile Flats: Well drained valley flats with deep (often reddish and brown loamy) alluvial soils.
Ni—Nillup Ironstone Rises: Low rises with shallow gravelly sands over laterite.
Nv—Nillup Vales: Small narrow V-shaped drainage depressions.
Nvw—Nillup Wet Vales: Small broad U-shaped drainage depressions with swampy floors.
Nw—Nilup Wet Flats: Poorly drained flats with mottled pale grey (Mungite) soils.

Quindalup Coast land system
Q—Quindalup Flats: Flats and low rises with deep pale calcareous sand. This unit also includes a narrow strip of: Qb—Quindalup Beach; beach and foredunes of calcareous sand, along the Geographe Bay coastline.
Q5—Quindalup Dunes: Steep dunes (with gradient mainly around 20%) of calcareous sands.
Qw—Quindalup Wet Flats: Poorly drained flats around the edge of the Vasse Estuary. Dark calcareous sands and mixed estuarine deposits.
Qwy—Quindalup Very Wet Saline Flats: Vasse, Wonnerup and Broadwater Estuaries. Low lying depressions which are often underwater in winter and saline in summer.

Scott River Plain land system
Sd—Scott Deep Sandy Flats: Flats with high winter water tables and deep bleached siliceous sands.
Sd2—Scott Deep Sandy Gentle Rises: Low dunes and rises with deep bleached siliceous sands.
Si—Scott Ironstone Rises: Low rises with shallow sands over laterite.
Swd—Scott Deep Sandy Wet Flats: Poorly drained flats with deep organic stained siliceous sands.
Swi—Scott Wet Ironstone Flats: Poorly drained flats with shallow sands over laterite (bog iron ore).
Treeton Hills land system

T—Treeton Slopes: Slopes with gradients generally ranging from 2-15% and gravelly duplex (Forest Grove) and pale grey mottled (Mungite) soils. This unit can be subdivided into: T2—Treeton Gentle Slopes; slopes 2-5%, T3—Treeton Low Slopes; slopes 5-10%, T4—Treeton Moderate Slopes; slopes 10-15%, and T5—Treeton Steep Slopes; slopes > 15%. In most cases T3 is the dominant unit present.

Td3—Treeton Deep Sandy Slopes: Slopes (with gradients generally 5-10% but ranging from 2-15%) with deep bleached sands.

Tf—Treeton Fertile Flats: Well drained valley flats and floodplains with deep alluvial soils, often red-brown loams (i.e. Marybrook soils).

Tfw—Treeton Wet Fertile Flats: Poorly drained valley flats and floodplains with deep alluvial soils (usually Marybrook soils).

Ti3—Treeton Ironstone Slopes: Low slopes (gradients ranging from 2-10%) with shallow gravelly sands over laterite.

Tv—Treeton Valleys: Narrow V-shaped drainage depressions.

TvW—Treeton Wet Valleys: Broad U-shaped drainage depressions with swampy floors.

Tw2—Treeton Wet Slopes: Gentle slopes (gradients 2-5%) with high winter water tables and mottled pale grey mottled (Mungite) soils.

Wilyabrup Valleys land system

W—Wilyabrup Slopes: Slopes with gradients generally 5-15%, but ranging from 2-30% and gravelly soils (i.e. Forest Grove and Keenan Soils). This unit can be divided into: W3—Wilyabrup Low Slopes; gradients 5-10% and W4—Wilyabrup Steep Slopes; gradients 10-15%. In most cases W3 is the dominant unit present.

Wd3—Wilyabrup Deep Sandy Slopes: Low slopes (gradients generally 5-10%) with deep bleached sands.

We3—Wilyabrup Exposed Slopes: Low slopes (gradients generally 5-10%) exposed to strong winds off ocean.

WeW—Wilyabrup Exposed Swamps: Swamp on granitic headland at Cape Leeuwin.

Wf—Wilyabrup Fertile Flats: Well drained valley flats and floodplains with deep alluvial soils, often red-brown loams (i.e. Marybrook soils).

Wfw—Wilyabrup Wet Fertile Flats: Poorly drained valley flats and floodplains with deep alluvial soils.

Wi3—Wilyabrup Ironstone Slopes: Low slopes (gradients generally 5-10%) with shallow gravelly sands over laterite.

Wr3—Wilyabrup Rocky Slopes: Low slopes (gradients generally 5-10%) with shallow rocky soils and some granitic outcrop.

WR—Wilyabrup Rock Slopes: Slopes dominated by granitic outcrop.

WrE3—Wilyabrup Exposed Rocky Slopes: Low slopes (gradients mainly 5-10%) with shallow rocky soils and some granitic outcrop, exposed to strong winds off the ocean.

WRE—Wilyabrup Granitic Headlands: Areas on the west coast dominated by granitic outcrop.

Wv—Wilyabrup Valleys: Narrow V-shaped drainage depressions.

Wvw—Wilyabrup Wet Valleys: Broad U-shaped drainage depressions with swampy floors.

Ww3—Wilyabrup Wet Slopes: Low slopes (gradients 5-10%) with high winter water tables.
Yelverton Shelf land system

Y—Yelverton Flats and Slopes: Flats and low slopes with mottled pale grey gradational (Mungite) and gravelly duplex (Forest Grove) soils. This unit can be divided into: Y—Yelverton Flats; flats (gradients 0-2%) with gravelly duplex (Forest Grove), mottled pale grey (Mungite) and yellow sandy soils, and Y3—Yelverton Low Slopes; low slopes (gradients 5-10%) with gravelly duplex (Forest Grove) and mottled pale grey (Mungite) soils. Y3 usually occurs along the northern margin of the land system.

Yd—Yelverton Deep Sandy Flats and Low Slopes: Flats and low slopes with deep bleached sand. This unit can be divided into: Yd—Yelverton Deep Sandy Flats; gradients 0-2%, and Yd3—Yelverton Deep Sandy Low Slopes; gradients generally 5-10%. Yd3 usually occurs along the northern margin of the land system.

Yf—Yelverton Fertile Flats: Valley flats and floodplains with deep alluvial soils, often red-brown loams (i.e. Marybrook Soils)

Yi—Yelverton Ironstone Flats; Flats with shallow gravelly sands over sheet laterite. Laterite outcrop sometimes present.

This unit can be divided into: Yi—Yelverton Ironstone Flats; gradients 0-2%, and Yi3—Yelverton Low Ironstone Slopes; gradients 5-10%. Yi3 usually occurs along the northern margin of the land system.

Yv—Yelverton Valleys: Narrow V-shaped drainage depressions and small valleys.

Yvw—Yelverton Wet Valleys: Broad U-shaped drainage depressions with swampy floors.

Yw—Yelverton Wet Flats: Poorly drained flats with mottled pale grey (Mungite) soils.

Ywi—Yelverton Wet Ironstone Flats: Winter wet flats with shallow red-brown sandy and loamy soils over sheet laterite (bog iron ore).

XX—Disturbed Terrain: Areas where the natural land surface has been greatly altered. i.e. areas of landfill, sand mining activity.
Appendix 2.

The Department of Agriculture's five class land capability rating system

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The Department of Agriculture’s five class land capability rating system

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Appendix 3

Physical limitations for housing on small rural lots

* Trafficability—the ease and safety of vehicle access

- A — Moderate limitations: soil absorption
  Minor limitations: trafficability

- A2 — Moderate limitations: soil absorption
  Minor limitations: trafficability

- Ad2 — Moderate limitations: groundwater pollution risk

- Adw — Major limitations: soil absorption, waterlogging, trafficability
  Minor limitations: groundwater pollution risk

- Af — Moderate limitations: soil absorption

- AF — Minor limitations: soil absorption

- Afw — Moderate limitations: soil absorption
  Minor limitations: trafficability

- Av — Major limitations: flood hazard
  Moderate limitations: soil absorption
  Minor limitations: trafficability, water erosion hazard

- Avw — Major limitations: waterlogging, trafficability, flood hazard, soil absorption
  Minor limitations: water erosion hazard

- Aw — Major limitations: waterlogging, soil absorption
  Minor limitations: trafficability

- Awl — Major limitations: waterlogging, ease of excavation, soil absorption
  Minor limitations: trafficability

- B — Moderate limitations: soil absorption
  Minor limitations: trafficability

- Bd — Moderate limitations: groundwater pollution risk

- Bf — Minor limitations: soil absorption

- Bvw — Major limitations: waterlogging, flood hazard, trafficability, soil absorption
  Minor limitations: slope

- Bw — Major limitations: waterlogging, soil absorption
  Minor limitations: trafficability

- Bwy — Severe limitations: waterlogging, flood hazard
  Major limitations: trafficability, soil absorption
  Minor limitations: salinity

- C — Moderate limitations: soil absorption
  Minor limitations: trafficability

- C2 — Moderate limitations: soil absorption
  Minor limitations: trafficability

- Cd2 — Moderate limitations: groundwater pollution risk
  Minor limitations: wind erosion hazard

- Cdw — Major limitations: waterlogging, trafficability, soil absorption
  Moderate limitations: groundwater pollution risk

- Ci — Major limitations: ease of excavation, soil absorption

- Cr2 — Moderate limitations: ease of excavation, soil absorption
  Minor limitations: trafficability

- CR — Severe limitations: ease of excavation
  Major limitations: soil absorption, water erosion hazard

- Cv — Moderate limitations: soil absorption, ease of excavation
  Minor limitations: trafficability, water erosion hazard, slope
Cvw — Major limitations: waterlogging, trafficability, flood hazard
    Moderate limitations: soil absorption
    Minor limitations: water erosion hazard, slope

Cw — Major limitations: waterlogging, trafficability, soil absorption

D — Moderate limitations: groundwater pollution risk
    Minor limitations: soil absorption

D5 — Severe limitations: slope
    Major limitations: land instability hazard
    Moderate limitations: water erosion hazard, wind erosion hazard

Db — Severe limitations: land instability hazard
    Major limitations: wind erosion hazard
    Minor limitations: wind exposure, salt spray exposure

Dd — Moderate limitations: groundwater pollution risk

Dd2 — Moderate limitations: groundwater pollution risk

Dd5 — Severe limitations: slope
    Major limitations: land instability hazard
    Moderate limitations: water erosion hazard, wind erosion hazard
    Groundwater pollution risk

DE5 — Severe limitations: slope
    Major limitations: wind erosion hazard, land instability hazard
    Moderate limitations: water erosion hazard, groundwater pollution risk
    Minor limitations: wind exposure, salt spray exposure

DEm5 — Severe limitations: land instability hazard, slope
    Major limitations: wind erosion hazard
    Moderate limitations: water erosion hazard, groundwater pollution risk
    Minor limitations: wind exposure, salt spray exposure

Dr — Moderate limitations: ease of excavation, soil absorption, groundwater pollution risk
    Minor limitations: wind erosion hazard, slope

Drd — Moderate limitations: ease of excavation, groundwater pollution risk
    Minor limitations: wind erosion hazard, slope, soil absorption

G2 — Moderate limitations: groundwater pollution risk
    Minor limitations: land instability hazard

G3 — Moderate limitations: water erosion hazard, slope, groundwater pollution risk
    Minor limitations: land instability hazard

Ge — Moderate limitations: groundwater pollution risk
    Minor limitations: ease of excavation, land instability hazard, wind erosion hazard

GE — Severe limitations: wind erosion hazard
    Moderate limitations: water erosion hazard, slope, groundwater pollution risk
    Minor limitations: ease of excavation, wind exposure, salt spray exposure

GEm — Severe limitations: land instability hazard
    Moderate limitations: water erosion hazard, slope, wind erosion hazard, groundwater pollution risk
    Minor limitations: wind exposure, salt spray exposure

Gk — Major limitations: land instability hazard, trafficability
    Moderate limitations: ease of excavation, water erosion hazard, groundwater pollution risk, soil absorption

Gv — Major limitations: water erosion hazard, slope, trafficability
    Moderate limitations: ease of excavation, groundwater pollution risk
    Minor limitations: land instability hazard, soil absorption
H3 — Moderate limitations: water erosion hazard, ease of excavation, soil absorption
     Minor limitations: slope, trafficability

Hd — Moderate limitations: groundwater pollution risk

Hd3 — Moderate limitations: water erosion hazard, groundwater pollution risk
     Minor limitations: slope

Hdw — Major limitations: waterlogging, soil absorption
     Moderate limitations: groundwater pollution risk
     Minor limitations: trafficability

Hf — Major limitations: flood hazard
     Minor limitations: soil absorption, trafficability

Hi3 — Major limitations: ease of excavation, water erosion hazard, soil absorption
     Minor limitations: slope

HR — Severe limitations: ease of excavation
     Major limitations: soil absorption

Hv — Major limitations: flood hazard
     Moderate limitations: ease of excavation, soil absorption
     Minor limitations: slope, water erosion hazard, trafficability,

Hvw — Major limitations: flood hazard, waterlogging, trafficability
     Moderate limitations: soil absorption
     Minor limitations: water erosion hazard, slope, ease of excavation

Hw3 — Major limitations: waterlogging, trafficability
     Moderate limitations: soil absorption, water erosion hazard
     Minor limitations: slope

Kb — Severe limitations: wave erosion hazard
     Major limitations: wind erosion hazard
     Moderate limitations: land instability hazard, groundwater pollution risk
     Minor limitations: wind exposure, salt spray exposure

KE — Major limitations: wind erosion hazard, slope, land instability hazard, trafficability
     Moderate limitations: water erosion hazard, groundwater pollution risk
     Minor limitations: wind exposure, salt exposure

KEf — Major limitations: wind erosion hazard, slope, land instability hazard, trafficability
     Moderate limitations: water erosion hazard, groundwater pollution risk
     Minor limitations: wind exposure, salt spray exposure

KEm — Severe limitations: land instability hazard, slope
     Major limitations: wind erosion hazard
     Moderate limitations: water erosion hazard, groundwater pollution risk
     Minor limitations: salt spray exposure, wind exposure

Kf — Major limitations: slope, land instability hazard, trafficability
     Moderate limitations: water erosion hazard, groundwater pollution risk

Km — Severe limitations: land instability hazard, slope
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Kr — Major limitations: water erosion hazard, slope, trafficability, land instability hazard
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<td>Qb</td>
<td>Wave erosion hazard</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

89 LAND RESOURCES SERIES No. 5
Q5 — Major limitations: wind erosion hazard, slope, trafficability, land instability hazard
     Moderate limitations: water erosion hazard, groundwater pollution risk
Qw — Major limitations: waterlogging, flood hazard, trafficability
     Moderate limitations: groundwater pollution risk
Qwy — Severe limitations: waterlogging, flood hazard
     Major limitations: trafficability
     Moderate limitations: soil absorption
     Minor limitations: salinity
Sd — Major limitations: waterlogging, soil absorption
     Moderate limitations: groundwater pollution risk
     Minor limitations: trafficability
Sd2 — Moderate limitations: groundwater pollution risk
     Minor limitations: wind erosion hazard
Si — Major limitations: ease of excavation, soil absorption
Swd — Major limitations: waterlogging, trafficability, soil absorption
     Moderate limitations: groundwater pollution risk
Swi — Major limitations: waterlogging, ease of excavation, soil absorption
     Moderate limitations: trafficability
T2— Moderate limitations: soil absorption
     Minor limitations: ease of excavation, trafficability
T3— Moderate limitations: soil absorption
     Minor limitations: water erosion hazard, ease of excavation, trafficability, slope
T —
   T4— Moderate limitations: soil absorption, water erosion hazard, slope
     Minor limitations: ease of excavation, trafficability
   T5— Major limitations: land instability hazard, slope, water erosion hazard, trafficability
     Moderate limitations: soil absorption
     Minor limitations: ease of excavation
Td3 — Moderate limitations: groundwater pollution risk
     Minor limitations: water erosion hazard, ease of excavation, slope
Tf — Minor limitations: soil absorption
Tfw — Major limitations: waterlogging, trafficability, flood hazard, soil absorption
     Minor limitations: water erosion hazard
Ti3 — Major limitations: ease of excavation, soil absorption
     Moderate limitations: water erosion hazard
     Minor limitations: slope
Tv — Major limitations: flood hazard
     Moderate limitations: soil absorption
     Minor limitations: water erosion hazard, ease of excavation
Tvww — Major limitations: waterlogging, trafficability, flood hazard, soil absorption
     Minor limitations: water erosion hazard, ease of excavation
Tw2 — Major limitations: waterlogging, trafficability, soil absorption
     Minor limitations: water erosion hazard
W3 — Moderate limitations: soil absorption, ease of excavation
     Minor limitations: water erosion hazard
W —
   W4 — Moderate limitations: soil absorption, water erosion hazard, ease of excavation, slope
     Minor limitations: trafficability
Wd3 — Moderate limitations: groundwater pollution risk
     Minor limitations: water erosion hazard, ease of excavation, slope
We3 — Moderate limitations: ease of excavation, soil absorption
   Minor limitations: water erosion hazard, slope, trafficability

WEw — Major limitations: waterlogging, trafficability, soil absorption
   Moderate limitations: ease of excavation
   Minor limitations: wind exposure, salt spray exposure

Wf — Minor limitations: soil absorption

Wfw — Major limitations: waterlogging, trafficability, flood hazard, soil absorption

Wi3 — Major limitations: ease of excavation, soil absorption
   Moderate limitations: water erosion hazard
   Minor limitations: slope

Wr3 — Moderate limitations: water erosion hazard, ease of excavation, soil absorption
   Minor limitations: trafficability, slope

WR — Severe limitations: ease of excavation
   Major limitations: soil absorption, water erosion hazard
   Moderate limitations: slope

WrE3 — Major limitations: ease of excavation, slope, soil absorption
   Moderate limitations: water erosion hazard
   Minor limitations: wind exposure, salt spray exposure, wind erosion hazard

WRE — Severe limitations: ease of excavation
   Major limitations: slope, soil absorption
   Minor limitations: wind exposure, salt spray exposure

Wv — Major limitations: slope, flood hazard, trafficability
   Moderate limitations: water erosion hazard, ease of excavation, soil absorption

Wvw — Major limitations: waterlogging, trafficability, flood hazard, soil absorption
   Minor limitations: water erosion hazard, ease of excavation, slope

Ww3 — Major limitations: waterlogging, trafficability, soil absorption
   Moderate limitations: water erosion hazard
   Minor limitations: slope

Y — Moderate limitations: soil absorption
   Minor limitations: trafficability

Y3 — Moderate limitations: soil absorption
   Minor limitations: water erosion hazard, slope, trafficability

Yd — Moderate limitations: groundwater pollution risk

Yd3 — Moderate limitations: groundwater pollution risk
   Minor limitations: water erosion hazard, slope

Yf — Major limitations: flood hazard
   Minor limitations: soil absorption

Yi — Major limitations: ease of excavation, soil absorption

Yi3 — Major limitations: ease of excavation, soil absorption
   Moderate limitations: water erosion hazard
   Minor limitations: slope

Yv — Moderate limitations: soil absorption
   Minor limitations: water erosion hazard, ease of excavation, slope, trafficability

Yvw — Major limitations: waterlogging, trafficability, flood hazard, soil absorption
   Minor limitations: water erosion hazard, slope

Yw — Major limitations: waterlogging, trafficability, soil absorption

Ywi — Major limitations: waterlogging, ease of excavation, soil absorption, trafficability
Appendix 4

Land unit maps (4 sheets)

Accompany this report.