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Horticultural capability study of soils adjacent to plantations at Carnarvon, Western Australia

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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

Summary And Recommendations

A detailed soil survey and horticultural capability assessment was undertaken over 1,804 ha of land adjacent to existing plantations on levees of the Gascoyne River near Carnarvon. The purpose of the study was to provide mapped land resource data and advice in relation to land management and the possibility of further land release for horticulture. Approximately 27% or 480 ha of the survey area was uncropped land with the zone identified for irrigated horticulture in the Shire's planning scheme.

Mapping is presented at 1:15,000 scale with map units being components of three soil associations, Gascoyne, Coburn and Brown. A group of map units with soils having transitional properties between Gascoyne and Coburn are also delineated.

In the assessment of horticultural capability primary consideration has been given to the risk of erosion during flood events, to salinity, and to soil drainage conditions.

The following recommendations are made:

1. Any expansion of horticulture within the study area, as a result of either new allocations of water or more efficient use of existing allocations, should be primarily directed to those areas of Gascoyne soil association which have the highest capability for the major crops currently produced (map units G1, G1c, G1+, Gm, Gmc Gm+).

2. No land with a very high risk of erosion during flooding should be used for horticulture. These areas should be maintained clear of rubbish and debris to permit passage of flood waters (map units Gsc, Gg2, Csc, Gtd).

3. Land with a high risk of erosion during flooding should be used only for bananas or perennial tree crops which require minimal cultivation and therefore are least susceptible to erosion (map units Gtl, Gtm, Gdz, Ggl, Cdz).

4. Minimum cultivation and mulching should be encouraged for all areas where annual vegetable crops are grown because of the general risk of erosion from flooding of the Gascoyne River.

5. A 100 m wide buffer strip adjacent to the Gascoyne River in front of McGlade Road should be appropriately zoned to guard against river bank erosion and to prevent clearing of existing vegetation.

6. Land which is strongly susceptible to salinity should not be used for horticulture (map units C, Cel, Ce2, Cdz, Cdp).

7. Expansion of horticulture onto areas where soils have transitional properties between those of the non-saline Gascoyne association and the saline Coburn association (map units GC1, GC2, GC3) is generally not recommended. If permitted however, expansion should only occur using a current water allocation and tomatoes or mangoes would be the better crop choices.

Acknowledgements

Land capability studies require contribution of expertise from a variety of sources. Significant contributions in relation to determining the land use requirements and rating tables for horticultural crops, were made by Messrs Terry Hill, Alec Holm, John Burt and Terry Muller from the Carnarvon office of the Department of Agriculture. In Perth, assistance was also received from Dr Ian McPharlain and Mr Greg Luke.

The field work for this study was conducted with the assistance of Ms Roni Oma, Ms Cobma Keating and Mr Jim Broun. Ms Liz Sommervibbe prepared the preliminary 1;10,000 scale map sheets, and digitized the linework presented on the map accompanying this report. Editing and final production of the map and its associated database, was conducted by Mr Greg Mbodawski. Mr David Clayton prepared figures 1 and 2 herein and the laboratory analyses were conducted by Messrs Brian Wren and Gary Scrase. The report was reviewed by Messrs Jim Dixon, Terry Hill and, most comprehensively, by Geoff Moore.

The contribution of all those mentioned is gratefully acknowledged.

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1. Introduction

This work was conducted at the request of the Carnarvon district office of the Western Australian Department of Agriculture and the Carnarvon Land Conservation District Committee. The objective was to provide a framework for a horticultural land release policy which could address erosion and salinity considerations for approximately 1,800 ha of land adjacent to the current plantations. These are located between 5 and 18 km from the mouth of the Gascoyne River (Figure 1). The results herein form part of a land resource study of the entire Carnarvon Land Conservation District. This LCD study was initiated in 1987 to provide mapped information on soils, landforms and land degradation problems to generally assist land use planning (Wells et al. in press). Figure 1 shows the relationship of the horticultural study area to the land conservation district.

The study area contains approximately 480 ha of vacant or undeveloped land within the zone designated for intensive horticulture under the Shire of Carnarvon's planning scheme (Drake and Smith, 1987). It also includes 1,324 ha beyond the intensive horticulture zone, but within the boundary of the Shire's planning scheme area. Most of this land occurs on the northern side of the river and is either vacant Crown land or Crown land leased on a short term basis for grazing purposes. A small portion, to the north of the McGlade Road plantations, is part of a pastoral lease to Brickhouse Station and, to the west of Bibbawarra Bore Road, there is an Aboriginal mission property.

The development of land for horticulture is controlled principally by the availability of water suitable for irrigation. Around Carnarvon water is obtained from aquifers beneath the bed of the Gascoyne River. Most irrigation water currently used by Carnarvon growers is supplied through a pipeline system from Water Authority bore fields 19 to 51 km upstream from the town. The remainder is pumped from growers' river frontage aquifers. The Gascoyne River normally flows sometime between February and August each year recharging these aquifers.

Water for irrigation is rationed by the Water Authority with individual blocks receiving an allocation of up to 10,000 kL of water each month. This amount may be decreased after significant periods without a river flow to conserve fresh water and to prevent intrusion of saline water from surrounding aquifers. For any horticultural block the maximum annual allocation at the time of survey was 72,000 kL. However, when the river is flowing, growers are permitted to pump freely from their own river frontage bores.

The release of areas of Crown land for irrigated horticulture is controlled by the Department of Land Administration after receipt of technical advice from various government bodies including the Water Authority and the Department of Agriculture. The amount of land released to form individual horticultural blocks is determined therefore by considering the amount of water available, and the watering and land management requirements of likely crops. At the time of survey the desirable minimum lot size was considered to be 6 ha.

An increasingly important factor in determining suitable horticultural block sizes is the technique used for irrigation. Low volume trickle, drip or tree sprinkler systems are now commonly used and these allow for more efficient water usage compared to the flood irrigation systems which were once more prevalent.

Under more efficient irrigation techniques further land can be utilized on existing water allocations. This suggests that at least some of the smaller blocks within the Carnarvon irrigation area (blocks range from 1.7 to 40.5 ha, average 10.7 ha*) are inappropriate and the minimum desirable size could be increased. From a soil conservation/ management perspective, smaller horticultural blocks are also undesirable since economic conditions are more likely to drive growers into a system of continuous cropping compared to a more conservative approach involving rotational spelling of land. These factors have resulted in the following policy objective for the Department of Agriculture in relation to land release.

“Where possible to provide sufficient land to existing land holders within the intensive horticultural zone to enable them to maximize the efficiency of use of their water allocation.” (A. Holm, personal communication. Carnarvon Regional Office, Department of Agriculture)

There are two main factors, in addition to water supply and usage, which affect further horticultural development. These are flooding and the associated risk of erosion and salinity. During major flood events, such as that of the 1961 or 1980, losses are incurred by both crops and soils. It can be argued that soil losses are most significant as the crops are a relatively easily renewable resource. With respect to salinity the unfavourable physical and chemical properties of saline-alkaline soils are a serious limitation for horticulture. The risk of salinization of groundwater aquifers resulting from irrigation of these soils and of salt intrusion into freshwater aquifer, also needs to be considered.

The assessment of horticultural capability herein is based on semi-detailed mapping of soil and land types and a consideration of the requirements and tolerances of six major crops currently grown in the area. These are tomatoes, beans, capsicums, cucumbers, bananas and mangoes. The effect of temperature or humidity factors on these corps was not considered because they are already successfully grown in the area. The soils mapping and capability assessment was limited to the study area shown in Figure 1 following Water Authority advice (1988) that further groundwater supplies for irrigation were not available.

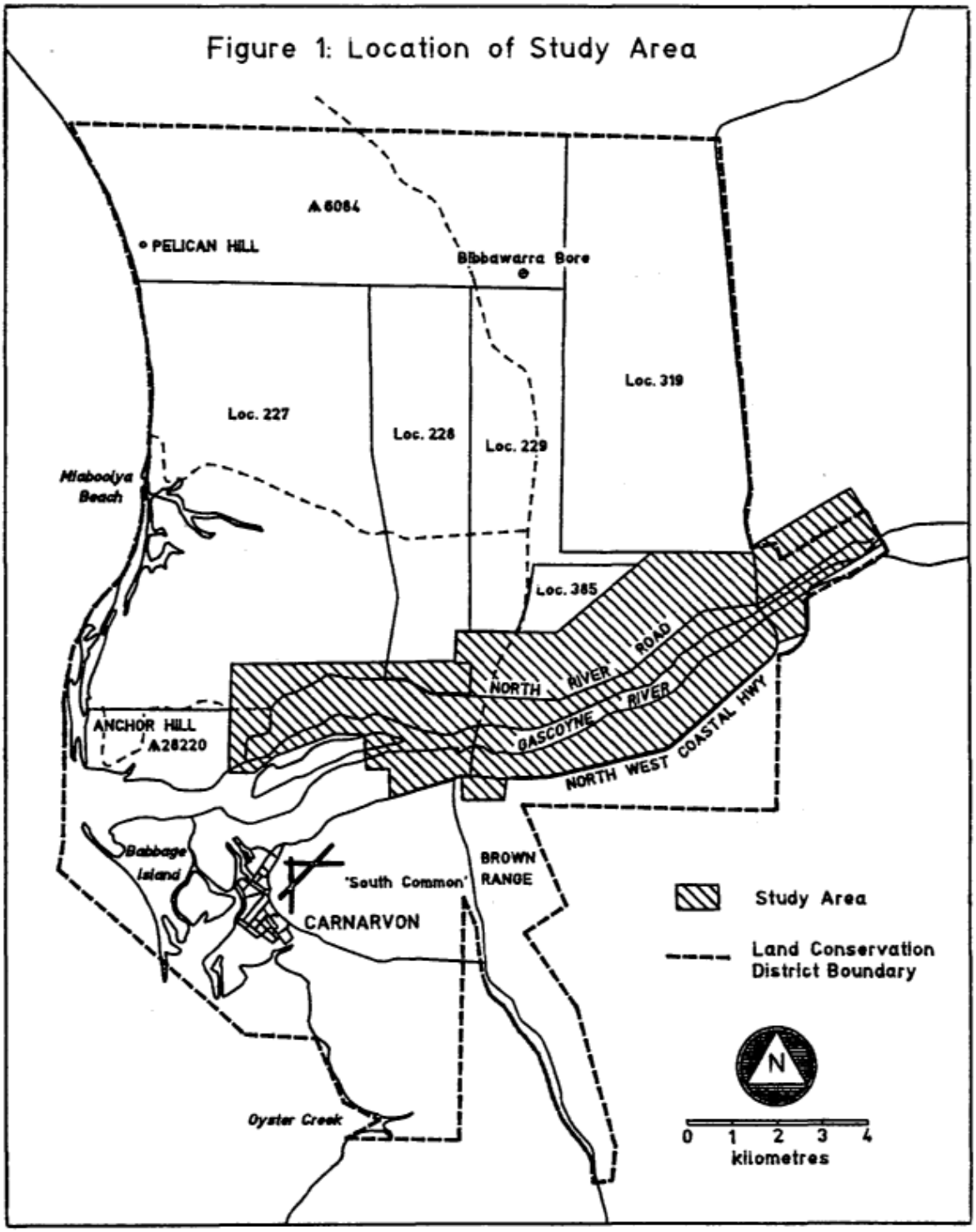

Figure 1. Location of Study Area

2. Soil Resources

2.1 Previous Studies

The soils of areas adjoining the Gascoyne River near Carnarvon, between the coast and Rocky Pool some 56 km upstream have been described and mapped by Bettenay et al. (1971). Within this area, the Department of Agriculture has conducted a soil survey of the Gascoyne Research Station (Clarke, 1971a) and reported on soil conditions encountered during two traverse sampling exercises (Clarke, 1971b). Salinity and boron data are also available from soils sampled at various spot locations within the existing plantation areas (Burt, 1979, 1983).

The soil association mapping by Bettenay et al. (1971) was presented at a scale of 1:126,000 and is based mainly on soil morphology. Four soil associations were mapped and these occurred within two independent systems of alluvium, referred to as the Gascoyne and Doorawarrah layers. The following paragraphs summarize the descriptions by Bettenay et al. of the alluvial layers and two of the soil associations, Gascoyne and Coburn.

The Gascoyne alluvium layer is the parent material for soils of the Gascoyne and Coburn associations. The parent material is dominantly dark brown to brown in colour and characterized by high sand and moderate silt and clay contents (Bettenay, 1966). The sands are generally fine and mitch of the soil contains fine plates of mica and exhibits an effervescence with N HC1 indicating the presence of finely divided lime.

The Doorawarrah layer is characteristically redder in colour and has a coarse sand component. The Doorawarrah layer is the parent material for the Moyamber and Doorawarrah soil associations which do not occur on the surface within the current study area. Nevertheless the Doorawarrah alluvial layer is present as buried soils beneath the Gascoyne layer. The relationship between the Gascoyne and Doorawarrah layers and spatial changes in their properties are represented diagrammatically in Figure 2.

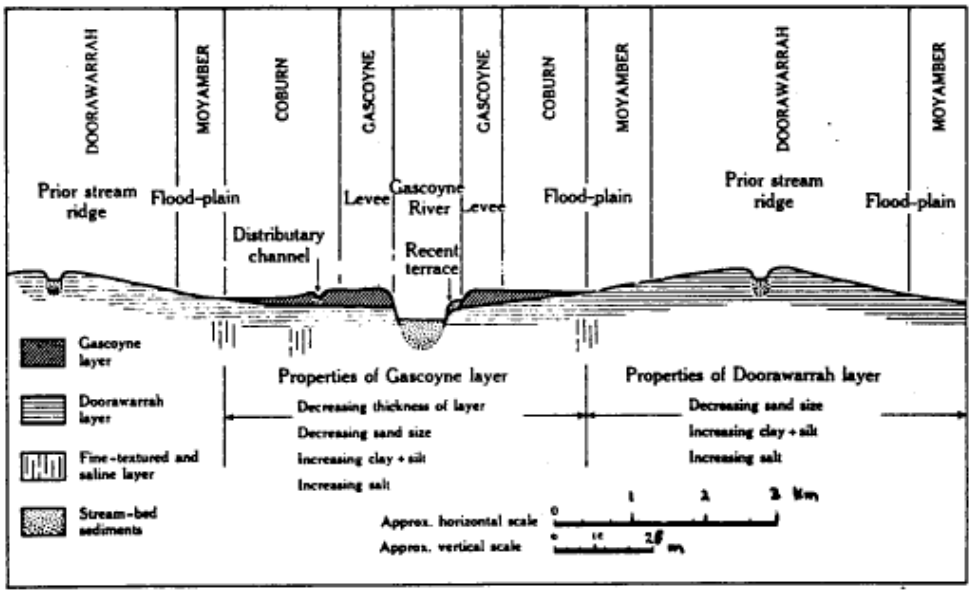

Figure 2. Generalized section of the Gascoyne delta showing major topographical features and general layer relationships. Source Bettenay et al. (1971).

Gascoyne Association

Soils of the Gascoyne association occur close to the Gascoyne River on slightly elevated levees. They are brown (reddish brown to yellowish red) in colour, freely drained and have uniform profile texture trends. Textures vary from loamy fine sands (Uc 5.32) to silty loams (Um 5.2) and silty clay barns (Um 5.12). Total soluble salts are present in only small quantities and the soils are neutral or alkaline in the surface becoming strongly alkaline at depth.

Coburn Association

Soils of the Coburn association occur adjacent to the Gascoyne association but further from the river. They are of similar colour to those of Gascoyne association but include soils with some profile texture development (gradational and duplex, Gn 2.13, Dr 4.13, Dr 2.33) as well as some uniform clays (Uf 1.3). Drainage conditions are generally less favourable to irrigation. In the absence of surface sealing, as on some duplex soils (Dr 2.33) and clays (Uf 1.3) internal drainage is moderately good. Under natural rainfall conditions Coburn soils are seldom leached to any depth and there are high levels of soluble salts particularly in the subsoils. The soils are strongly alkaline.

2.2 Survey Method

The survey involved the following stages:

- Compilation of existing land resource data and base maps;
- Definition of the desired mapping unit framework;
- Stereoscopic examination of 1983, 1:10,000 scale colour aerial photographs to delineate tentative map unit boundaries and identify sites for field examination;
- Field survey work to record soil and landform data according to the standards and terminology of the “Australian Soil and Land Survey Field Handbook” (McDonald et al. 1984);
- Laboratory analysis of soils sampled from representative sites;
- Correlation of survey data with aerial photograph interpretations and previous mapping to check and adjust map unit boundaries and descriptions;
- Production of preliminary maps on a cadastral base by conventional cartographic techniques, followed by computer digitizing to allow for subsequent production of interpretive or thematic maps from the survey’s database;
- Preparation of project report and digital database.

Field survey work was undertaken during the months of July to September in 1987 and August to September 1988. Soils were hand augered at 138 sites to a depth of 1.5 m and, where possible, classified according to the Factual Key Notation of Northcote (1979). Samples were taken from most soil horizons for laboratory determinations of salinity and boron. Site data were recorded in the field using a portable laptop NEC computer and subsequently downloaded to the Department’s PDP-1l computer in Perth. To characterize internal drainage properties of the major soil types, saturated hydraulic conductivity measurements were made in the field at a limited number of sites using the method of Talsma and Hallam (1980) (refer Appendix 1).

Electrical conductivity of the soil saturation extract (ECe) was determined by the methods described by Piper (1950). The criteria used to determine a salinity class are adapted from Northcote and Skene (1972) (Table A2.2, Appendix 2).

Boron levels, in ppm, were determined from the saturation extract using the technique in USDA Agriculture Handbook No.60 (Richards, 1954). A level of 1 ppm or greater was considered indicative of possible toxicity problems for sensitive crops. This data was supplemented by previously unpublished information from soil investigations conducted by the Carnarvon office of the Department of Agriculture in 1979 and 1983.

All site data relevant to this survey are held on the Department's PDP-ll computer and may be accessed using the WARIS* data storage and retrieval system (Rosenthal ~t ~ 1986). The site database includes soil profile descriptions and classifications, landform and land surface characteristics and laboratory analytical data. A complete listing of the site attributes recorded during Department of Agriculture band resource surveys and the associated data codes and terminology is in King and Wells (1988). The WARIS programs were used to generate the descriptions for each map unit in the following section of the report.

A map unit database was established for the digital mapping from the survey to enable the production of interpretive or thematic maps from the basic soils data. The database comprises values for a range of land qualities, and capability ratings for six horticultural land uses. Land qualities are attributes of land such as 'waterlogging risk' or 'erosion risk' which directly influence its land use capability. Qualitative values, such as high, moderate or low, are used for each attribute. These values are derived from primary diagnostic soil or landform characteristics such as soil texture or slope gradient which are usually recorded at each site during a survey. Definition of the land qualities listed for each map unit, and the means by which their values have been assessed, are given in Appendix 2.

2.3 The Mapping Units

The mapping units are soil/landform units which are components of soil associations. Three soil associations are mapped, Gascoyne, Coburn and Brown. The first two have been previously mapped, at broader scale, by Bettenay et al. (1971). The latter is introduced here as a logical name for those soils which characterize the Quarternary dunes associated with deposits of the Brown delta, and mapped by Payne et al. (1987) as Brown land system. Within these associations, 30 soil/landform mapping units have been identified primarily on the basis of landform and soil texture attributes. An analysis or breakdown of the soil associations, including a group of transitional soils referred to as Gascoyne-Coburn intergrades, into their component soil/landform units is shown in Table 1.

Map units within Gascoyne association generally have well drained, non saline soils with small, if any, texture differences throughout the solum. They have been divided initially into four groups on the basis of landform, i.e. essentially flat areas on the major levee surface, isolated dune ridges, mid-level terraces and active drainage features. On the main levee, soils are divided into light, medium and heavy textured variants. The light soils Gb, have sands or sandy loams throughout the profile, the medium soils Gm, have predominantly loams, and the heavy soils Gh, have clay barns or light clays. Further differentiation occurs to distinguish units containing soils with highly calcareous subsoil, those where buried soils or unrelated alluvial material is encountered beneath the soil but within 1 in of the surface, and those soils occurring within minor depressions on the levee surface. These features are indicated by a postscript, i.e. 'c' for calcareous subsoils, '+' for buried soils and 'd' for depressions.

Hummocky dune ridges which occur parallel to the river, are likely to be remnant levee features and are mapped as Gr.

The mid-level terraces adjacent to the river, and bower than the main levee surface, are mapped as Gt. These are further divided into those with light or medium textured soils by appropriate postscripts, i.e. Gtl and Gtm.

Active drainage features which can occur on both the main levee or mid-level terraces are distinguished on landform criteria only, i.e. major stream channels Gsc, minor gullies Ggl, major gullies Gg2, broad flood scoured drainage zones on the levees Gdz, and on the terraces, Gtd.

It should be noted that landform descriptions reflect conditions at the time of survey. For example, a major gully created during the last major flood but subsequently filled in by earthworks is likely to be shown as Gb or Gm or, if it still acts as a drainage feature, will be shown as Ggl (minor gully) or Gdz (non incised drainage zone).

Map units within the Coburn association have soils which are generally less well drained. They are saline and show significant textural contrast between the surface (A) horizons and the subsurface (B) horizons. Within Coburn association, minor dune ridges (sandy banks) and some active drainage features are mapped. These are identified with the same postscripts used for Gascoyne association. The first letter will of course be ‘C’ for Coburn. Most of this association occurs on extensive alluvial backplains where further differentiation of units is made on erosion status or whether it occurs as a depression or relic drainage feature. Moderately eroded Coburn soils are shown as Cel, severely eroded as Ce2, and depressions as Cdp.

Map units containing soils which are transitional in character between Gascoyne and Coburn are shown as CC. These occur on the outer levee areas merging into the alluvial backplains and are further divided on the basis of surface texture and subsoil salinity. Areas with sand to sandy loam surface textures have either slightly saline subsoils, GC1, or moderately to strongly saline subsoils, GC2. Areas with loam to clay loam surface textures and slightly to moderately saline subsoils are mapped as GC3.

Brown soil association is distinguished by reddish brown siliceous sands and earthy sands. These are somewhat similar to the ‘light’ Gascoyne soils, but occur as mainly N-S orientated dune ridges Br, or as undulating sandplains or dune footslopes, Bsp.

Descriptions of representative soil profiles of the light, medium and heavy soils within Gascoyne association, and of Coburn and Brown soils, are given in Appendix 3. Variations are also discussed.

Table 1. Analysis of Mapping Units

LANDFORM	TEXTURE GROUP *	OTHER DISTINGUISHING CRITERIA	MAP UNIT
Gascoyne Soil Association			
Levees	Light (Groups 1&2)	With non or slight calcareous subsoil	G1
		With highly calcareous subsoil	G1c
		Overlying buried soil within 1m	G1+
	Medium (Group 3)	With non or slightly calcareous subsoil	Gm
		With highly calcareous subsoil	Gmc
		Overlying buried soil within 1m	Gm+
	Heavy (Groups 4&5)	With non or slight calcareous subsoil	Gh
		With highly calcareous subsoil	Ghc
		Overlying buried soil within 1m	Gh+
		Occurring in depressions	Ghd
Dune Ridges			Gr
Mid level Terraces	Light (Groups 1&2)		Gt1
	Medium (Group 3)		Gtm
Active Drainage Features		Stream channels – major	Gsc
		Gully – minor	Gg1
		Gully – major	Gg2
		Drainage Zones – on levees	Gdz
		Drainage Zones – on terraces	Gtd

Table 1. Continued

LANDFORM	TEXTURE GROUP *	OTHER DISTINGUISHING CRITERIA	MAP UNIT
Coburn Soil Association			
Backplains		Moderately eroded	C
		Severely eroded	Ce1
		Occurring in depressions	Ce2
Dune Ridges			Cr
Active Drainage Features		Stream channels – major	Csc
		Drainage zones	Cdz
Gascoyne-Coburn Intergrades			
Backplains/Outer Leeves	Light (Groups 1&2)	Slightly saline subsoils	GC1
		Moderate to strongly saline subsoil	GC2
	Medium-Heavy (Groups 3&4)	Slightly to moderately saline subsoils	GC3
Brown Association			
Dune Ridges			Br
Sandplain			Bsp

* Texture groups according to Northcote (1979).

Group 1 Sands, Group 2 Sandy Loams, Group 3 Loams, Group 4 Clay Loams, Group 5 Light Clays.

For Gascoyne soils, with mainly uniform profile texture trends, the texture groups refer to the whole soil profile. For Gascoyne-Coburn intergrades where gradational and duplex profiles occur, the texture groups refer to surface or A horizons only.

The remainder of this section presents a description of each landform/soil unit on a one per page basis to allow easy reference. The soils are described according to the terminology of Northcote et al. (1975); and the principal profile forms are classifications according to the factual key nomenclature of Northcote (1979).

The terms used to describe permeability, rebated to saturated hydraulic conductivity limits, and soil reaction are as follows:

very rapid	> 5.0 m/day
rapid	1-5 m/day
moderately rapid	0.5-1 m/day
moderate	0.05-0.5 m/day
moderately slow	0.01-0.05 m/day
slow	0.01 m/day
strongly acid	< 5.0
acid	5.0-5.9
neutral	6.0-7.4
alkaline	7.5-8.5
strongly alkaline	> 8.5

The band quality values, which are subsequently used to determine band capability ratings, represent the average or most common condition within a map unit.

MAP UNIT	**G1: Gascourne association – "light textured" soil type**
Area	220ha; 32has zoned but unused
Landform	Flat terrace plains and levee surfaces
Site Drainage	Well drained, less commonly moderatedly well or rapidly drained
Soils	Reddish brown sands and, less commonly, reddish brown siliceous sands or sandy gradational red earths. These sometimes overlie buried sands at depths greater than 1m
Main Principal Profile Forms	Uc 5.21, Uc 1.23, Gn 2.13
Surface Texture Group and Condition	Sands or sandy loams; firm or soft
Depth to Any Clay Layer	>2m
Profile Permeability	Moderately rapid or rapid
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Low
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderate
Moisture Availability (m)	Low
Soil Workability (k)	Good
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Moderate

MAP UNIT	**G1c: Gascoyne association – "light textured over calcareous" soil type**
Area	3ha; all zoned but unused
Landform	Flat terrace plains and levee surfaces
Site Drainage	Well drained
Soils	Reddish brown siliceous sands overlying calcareous loams usually at depths greater than 50cm
Main Principal Profile Forms	Uc 1.23
Surface Texture Group and Condition	Sands; soft
Depth to Any Clay Layer	>1.5m
Profile Permeability	Moderately rapid or rapid
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Possible (limited data only)
Flood Risk (f)	Low
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderate
Moisture Availability (m)	Low
Soil Workability (k)	Good
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Moderate

MAP UNIT	**G1+: Gascoyne association – "light testured over buried profile" soil type**
Area	141ha; 35ha zoned but unused
Landform	Flat terrace plains and levee surfaces
Site Drainage	Well to moderately well drained
Soils	Reddish brown earthy sands and, less commonly, reddish brown siliceous sands. These overlie buried red duplex soils at depths from 50 to 100 cm
Main Principal Profile Forms	Uc 5.21, Uc 1.23
Surface Texture Group and Condition	Sands or sandy loams; firm or soft
Depth to Any Clay Layer	>1m
Profile Permeability	Moderately rapid or moderate
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Low
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderate
Moisture Availability (m)	Low
Soil Workability (k)	Good
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Moderate

MAP UNIT	**Gm: Gascoyne assocation – "medium textured" soil type**
Area	155ha, 74ha zoned but unused
Landform	Flat terrace plains and levee surfaces
Site Drainage	Moderately well to well drained
Soils	Reddish brown earthy loams, non-calcareous loams and less commonly gradational red earths
Main Principal Profile Forms	Um 5.52, Um 5.22, Gn 2.13
Surface Texture Group and Condition	Sandy loams or loams; firm
Depth to Any Clay Layer	>1.5m
Profile Permeability	Moderate or moderately rapid
Soils Reaction (pH)	Topsoil – Alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Low
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	High
Soil Workability (k)	Good-fair
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Moderate

MAP UNIT	**Gmc: Gascoyne association – "medium textured over calcareous" soil type**
Area	5ha; 4ha zoned but unused
Landform	Flat terrace plains and levee surfaces
Site Drainage	Moderately well to well drained
Soils	Calcareous reddish brown earthy loams and gradational earths. These grade into or overlie calcareous loams or clays, usually at depths greater than 50cm
Main Principal Profile Forms	Gc 1.22, Um 5.52
Surface Texture Group and Condition	Sandy loams or loams; firm
Depth to Any Clay Layer	>50cm
Profile Permeability	Moderate or moderately rapid
Soils Reaction (pH)	Topsoil – Alkaline to strongly alkaline; Subsoil – Strongly Alkanline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Low
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	High
Soil Workability (k)	Good – fair
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Moderate

MAP UNIT	**Gm+: Gascoyne association – "medium textured over buried profile" soil type**
Area	66ha; 45ha zoned but unused
Landform	Flat terrace plains and levee surfaces
Site Drainage	Predominantly moderately well to well drained, less commonly imperfectly drained
Soils	Reddish brown earthy loams and less commonly, gradational red earths. These overlie buried red duplex soils at depths from 30 to 100cm
Main Principal Profile Forms	Um 5.52, Um 5.51, Gn 2.13
Surface Texture Group and Condition	Sandy loams, loams or clay loams; firm
Depth to Any Clay Layer	>1m
Profile Permeability	Moderately slow to moderately rapid
Soils Reaction (pH)	Topsoil – Alkaline; Subsoil – Alkaline to stongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low to moderate
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Low
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	High
Soil Workability (k)	Good – Fair
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Moderate

MAP UNIT	**Gh: Gascoyne association – "heavy textured" soil type**
Area	95ha; 46ha zoned but unused
Landform	Flat terrace plains, levee surfaces and backplains
Site Drainage	Variable, poorly to moderately well drained
Soils	Reddish brown friable clays with rough ped fabric
Main Principal Profile Forms	Uf 6.12
Surface Texture Group and Condition	Light clays or less commonly, clay loams; firm or surface crust
Depth to Any Clay Layer	0-10cm
Profile Permeability	Moderately slow or slow
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderate
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	High
Moisture Availability (m)	Moderately low
Soil Workability (k)	HighFiar – Poor
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Low

MAP UNIT	**Ghc: Gascoyne association – "heavy textured over calcareous" soil type**
Area	9ha; Nile zoned but unused
Landform	Flat terrace plains, levee surfaces and backplains
Site Drainage	Moderately well to imperfectly drained
Soils	Reddish brown, friable clays and red earthy clay loams. These underlie or grade into calcareous clay loams or clays, usually at depths greater than 50cm
Main Principal Profile Forms	Uf 6.12, Um 5.52
Surface Texture Group and Condition	Loams or clay loams;firms
Depth to Any Clay Layer	Variable, 25 to >100cm
Profile Permeability	Moderate
Soils Reaction (pH)	Topsoil – Alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderate
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	High
Moisture Availability (m)	Moderate
Soil Workability (k)	Fair – Poor
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Low

MAP UNIT	**Gh+: Gascoyne association – "heavy textured over buried profile" soil type**
Area	46ha; 32hazoned but unused
Landform	Flat terrace plains, levee surfaces and backplains
Site Drainage	Variable, poorly to moderately well drained
Soils	Reddish brown clay loams overlying buried red duplex or gradational soils at depth from 30 to 100cm
Main Principal Profile Forms	Um 5.51, Um 5.52
Surface Texture Group and Condition	Clay loams; firm or surface crust
Depth to Any Clay Layer	Variable, 60 to > 100cm
Profile Permeability	Moderate or moderately slow
Soils Reaction (pH)	Topsoil – Alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderate
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	High
Moisture Availability (m)	Moderately high
Soil Workability (k)	Fair
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Low

MAP UNIT	**Ghd: Gascoyne association "heavy soils, drainage depression"**
Area	2ha; 1ha zoned but unused
Landform	Very shallow, elongated, enclosed drainage depressions (possibly remnant stream channels)
Site Drainage	Poorly drained
Soils	Reddish brown friable clay with rough-red fabric
Main Principal Profile Forms	Uf 6.12
Surface Texture Group and Condition	Light clays; hard-set
Depth to Any Clay Layer	0
Profile Permeability	Slow
Soils Reaction (pH)	Topsoil – Neutral; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderately high
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	High
Moisture Availability (m)	Moderate
Soil Workability (k)	Fair
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Low

MAP UNIT	**Gr: Gascoyne association "dune ridge"**
Area	38ha; 1ha zoned but unused
Landform	Hummocky dune ridges, usually parallel to the river, less than 4m high, and with gently to moderately inclined (3-20%) sideslopes. These are likely to be remnant levee features, sometimes remobilized by wind
Site Drainage	Rapidly drained
Soils	Reddish brown siliceous sands
Main Principal Profile Forms	Uc 1.23
Surface Texture Group and Condition	Sands; loose
Depth to Any Clay Layer	>2m
Profile Permeability	Very rapid
Soils Reaction (pH)	Topsoil – Neutral; Subsoil – Neutral to alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Nil
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Very low
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderate
Moisture Availability (m)	Very low
Soil Workability (k)	Fair – Poor
Erosion Risk (e) (during floods)	Very low
Wind Damage Risk (w)	Very high

MAP UNIT	**Gt1: Gascoyne association – "light textured soil on mid-level terrace"**
Area	57ha; 1ha zoned but unused
Landform	Mid-level terraces or channel benches
Site Drainage	Well drained
Soils	Reddish brown earthy sands
Main Principal Profile Forms	Uc 5.21
Surface Texture Group and Condition	Sands; soft
Depth to Any Clay Layer	> 2m
Profile Permeability	Rapid
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Neutral to alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Moderate
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderate
Moisture Availability (m)	Low
Soil Workability (k)	Good
Erosion Risk (e) (during floods)	High
Wind Damage Risk (w)	Moderate

MAP UNIT	**Gtm: Gascoyne association – "medium textured soil in mid-level terrace"**
Area	84ha; Nile zoned but unused
Landform	Mid-level terraces or channel benches
Site Drainage	Moderately well drained
Soils	Reddish brown, non-calcareous loams and reddish brown earthy loams
Main Principal Profile Forms	Um 5.22, Um 5.52
Surface Texture Group and Condition	Sandy loams or loams; firm
Depth to Any Clay Layer	> 2m
Profile Permeability	Moderately rapid
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil - Alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Moderate
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	High
Soil Workability (k)	Good – Fair
Erosion Risk (e) (during floods)	High
Wind Damage Risk (w)	Moderate

MAP UNIT	**Gsc: Gascoyne association – stream channel**
Area	34ha; 1ha zoned but unused
Landform	Major prior stream channels and their associated minor levees, occurring within the surface or the floodplain. Sideslopes may be very gently to moderately inclined (3-20%) and channels are generally greater than 3m deep
Site Drainage	Well drained on banks, imperfectly drained in channels
Soils	Variable, recent alluvial soils, mainly sandy with thin loamy horizons of flood deposited material (limited data only)
Main Principal Profile Forms	-
Surface Texture Group and Condition	Sands; soft
Depth to Any Clay Layer	> 1.5m
Profile Permeability	Moderately rapid
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Neutral to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low to moderate
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f) Wind Damage Risk (w)	Moderate
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderate
Moisture Availability (m)	Moderate
Soil Workability (k)	Fair
Erosion Risk (e) (during floods)	Very High

MAP UNIT	**Gg1: Gascoyne association "minor gully"**
Area	32ha; 10ha zoned but unused
Landform	Narrow gullies emanating from the river channel and generally incised to less than 1.5m depth
Site Drainage	Imperfectly drained
Soils	Reddish brown earthy loams with mildly truncated profiles (limited data only)
Main Principal Profile Forms	Um 5.52
Surface Texture Group and Condition	Loams or clay loams; firm or hard-set
Depth to Any Clay Layer	> 2m
Profile Permeability	Moderately slow or moderate
Soils Reaction (pH)	Topsoil – Alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderate
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Moderate
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	High
Soil Workability (k)	Fair
Erosion Risk (e) (during floods)	High
Wind Damage Risk (w)	Low

MAP UNIT	**Gg2: Gascoyne association, "major gully"**
Area	41ha; 19ha zoned but unused
Landform	Narrow gullies emanating from the river channel and generally incised to greater than 1.5m depth
Site Drainage	Imperfectly drained
Soils	Not sampled but likely to be reddish brown earthy loams or earthy sands with moderately truncated profiles
Main Principal Profile Forms	-
Surface Texture Group and Condition	Loams or clay loams; firm or hard-set
Depth to Any Clay Layer	> 2m (assumed)
Profile Permeability	Moderately slow or moderate
Soils Reaction (pH)	Topsoil – Alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderate
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Moderate
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	High
Soil Workability (k)	Fair
Erosion Risk (e) (during floods)	Very high
Wind Damage Risk (w)	Low

MAP UNIT	**Gdz: Gascoyne association, drainage zone**
Area	94ha; 10ha zoned but unused
Landform	Broad, very gently inclined, flood scoured drainage zones within major levee surface
Site Drainage	Moderately well to well drained
Soils	Reddish brown, earthy sands, non-calcareous loams and earthy loams with mildly truncated profiles in scoured areas
Main Principal Profile Forms	Uc 5.21, Um 5.22, Um 5.52
Surface Texture Group and Condition	Sands, sandy loams or loams; firm or soft
Depth to Any Clay Layer	> 2m
Profile Permeability	Moderately rapid
Soils Reaction (pH)	Topsoil – Neutral; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Moderate
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	Moderately high
Soil Workability (k)	Good – Fair
Erosion Risk (e) (during floods)	High
Wind Damage Risk (w)	Moderate

MAP UNIT	**Gtd: Gascoyne association, terrace drainage zone**
Area	26ha; Nil zoned but unused
Landform	Broad, very gently inclined, flood scoured drainage zones within mid-level terraces or channel benches
Site Drainage	Moderately well to well drained
Soils	Reddish brown, earthy sands, non-calcareous loams and earthy loams with mildly truncated profiles in scoured areas
Main Principal Profile Forms	Uc 5.21, Um 5.22, Um 5.52
Surface Texture Group and Condition	Sands, sandy loams or loams; firm or soft
Depth to Any Clay Layer	> 2m
Profile Permeability	Moderately rapid
Soils Reaction (pH)	Topsoil – Neutral; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Moderate
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	Moderately high
Soil Workability (k)	Good – Fair
Erosion Risk (e) (during floods)	Very high
Wind Damage Risk (w)	moderate

MAP UNIT	**C; Coburn association**
Area	112ha; 37ha zoned but unused
Landform	Level alluvial backplains
Site Drainage	Predominantly imperfectly drained, less commonly poorly drained
Soils	Mainly hard-setting red duplex soils and less commonly reddish brown friable clays which may overlie lighter textured soils at depths greater than 50cm
Main Principal Profile Forms	Dr 2.53, Dr 2.13, Uf 6.12
Surface Texture Group and Condition	Variable, usually sands or sandy loams; less commonly clay loams or light clays; firm, hard-set or surface crust
Depth to Any Clay Layer	0-50cm
Profile Permeability	Moderately slow
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderate
Salinity Risk (y)	
0-50 cm (ys)	Variable, but generally not susceptible
50-100 cm (ym)	Moderate to strong
> 100cm (yd)	Strong
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	Moderately high
Soil Workability (k)	Good – Fair
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	High

MAP UNIT	**Cel: Coburn association – "erosion moderate"**
Area	87ha; 31ha zoned but unused
Landform	Level alluvial backplains with moderate erosion (ie with large, isolated scalds and hummocks)
Site Drainage	Poorly drained, sometimes imperfectly drained
Soils	Hard-setting red duplex soils and less commonly, reddish brown friable clays which may overlie lighter textured soils at depth greater than 50cm. Truncated profiles and surface wind blown deposits are common
Main Principal Profile Forms	Dr 2.53, Dr 2.13, Uf 6.12, Uf 1.43
Surface Texture Group and Condition	Variable, usually sands or sandy loams with clay loams or light clays in eroded areas; hard-set or surface crust
Depth to Any Clay Layer	0-80cm
Profile Permeability	Moderately slow
Soils Reaction (pH)	Topsoil – Alkaline; Subsoil – Alkaline to strongly alkanline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderately high
Salinity Risk (y)	
0-50 cm (ys)	Moderate to strong
50-100 cm (ym)	Strong to moderate
> 100cm (yd)	Strong
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	Moderately high
Soil Workability (k)	Fair
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	High

MAP UNIT	**Ce2: Coburn association – "erosion severe"**
Area	71ha; 7ha zoned but unused
Landform	Level alluvial backplains with severe erosion (with major deflation or the soil surface resulting in large continuous scalds & frequent large hummocks against obstacles)
Site Drainage	Poorly drained, sometimes imperfectly drained
Soils	Hard setting and friable red duplex soils and, in scald areas, reddish brown non-cracking clays. Truncated profiles and surface wind blown deposits are very common
Main Principal Profile Forms	Dr 2.13, Dr 2.53, Dr 4.53, Uf 1.43
Surface Texture Group and Condition	Variable, usually sands or sandy loams with light clays in eroded dares, surface crust or hard-set
Depth to Any Clay Layer	0-80cm
Profile Permeability	Moderately slow
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderately high
Salinity Risk (y)	
0-50 cm (ys)	Possible
50-100 cm(ym)	Moderate to strong
> 100cm (yd)	Strong
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate – difficult
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	Moderate
Soil Workability (k)	Fair – Poor
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	High

MAP UNIT	**Cdp: Coburn association – drainage depression**
Area	12ha; 6ha zoned but unused
Landform	Very shallow, elongated, enclosed drainage depressions (possibly remnant stream channels)
Site Drainage	Poorly drained
Soils	Reddish brown friable clays with rough-ped fabric
Main Principal Profile Forms	Uf 6.12
Surface Texture Group and Condition	Clay loams or light clays; hard-set or surface crust
Depth to Any Clay Layer	0-10cm
Profile Permeability	Slow
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderately high
Salinity Risk (y)	
0-50 cm (ys)	Strong
50-100 cm (ym)	Strong
> 100cm (yd)	No data
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	High
Moisture Availability (m)	Moderate
Soil Workability (k)	Fair – Poor
Erosion Risk (e) (during floods)	Low
Wind Damage Risk (w)	Moderate

MAP UNIT	**Cr: Coburn association – dune ridge**
Area	9ha; Nil zoned but unused
Landform	Sandy banks and very low dune ridges
Site Drainage	Well drained
Soils	Brownish sands or reddish brown, earthy sands
Main Principal Profile Forms	Uc 5.11, Uc 5.21
Surface Texture Group and Condition	Sands; soft
Depth to Any Clay Layer	> 1.5m
Profile Permeability	Very rapid
Soils Reaction (pH)	Topsoil – Neutral; Subsoil – Neutral to alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	No analytical date, but
50-100 cm (ym)	Vegetation observations indicate
> 100cm (yd)	Non-saline conditions
Flood Risk (f)	Low
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderate
Moisture Availability (m)	Low
Soil Workability (k)	Good
Erosion Risk (e) (during floods)	Low
Wind Damage Risk (w)	High

MAP UNIT	**Csc: Coburn association – stream channel**
Area	32ha; 7ha zoned but unused
Landform	Major prior stream channels and their associate minor levees, occurring within the surface or the floodplain. Sideslopes may be gently to moderately inclined (3-20%) and channels are generally > 3m deep
Site Drainage	Poorly drained
Soils	Not sampled but likely to be variable recent alluvial soils and truncated red duplex soils
Main Principal Profile Forms	-
Surface Texture Group and Condition	Mainly sands to sandy loams; firm (assumed)
Depth to Any Clay Layer	-
Profile Permeability	Moderate
Soils Reaction (pH)	Topsoil – Alkaline to strongly alkaline; Subsoil - Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderately high
Salinity Risk (y)	
0-50 cm (ys)	No analytical date, but
50-100 cm (ym)	Vegetation indicates some
> 100cm (yd)	Salinity
Flood Risk (f)	Moderate
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	Moderately high
Soil Workability (k)	Fair
Erosion Risk (e) (during floods)	Very high
Wind Damage Risk (w)	Moderate

MAP UNIT	**Cdz: Coburn association – drainage zone**
Area	22ha; Nil zoned but unused
Landform	Broad, very gently inclines, flood scoured drainage zones
Site Drainage	Imperfectly drained
Soils	Hard-setting red duplex soils (pedal or apedal) and less commonly, reddish brown friable clays
Main Principal Profile Forms	Dr 2.53, Dr 2.13, Uf 6.12
Surface Texture Group and Condition	Sands or sandy loams, less commonly light clays; firm or hard-set
Depth to Any Clay Layer	0-80cm
Profile Permeability	Moderately slow
Soils Reaction (pH)	Topsoil – Alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderate
Salinity Risk (y)	
0-50 cm (ys)	No analytical data, but
50-100 cm (ym)	Vegetation incicates some
> 100cm (yd)	Salinity
Flood Risk (f)	Moderate
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	Moderately high
Soil Workability (k)	Good – Fiar
Erosion Risk (e) (during floods)	High
Wind Damage Risk (w)	high

MAP UNIT	**GC1: Gascoyne-Coburn intergrade type 1**
Area	80ha; 6ha zoned but unused
Landform	Level terrace plains or alluvial backplains
Site Drainage	Very variable, predominantly poorly to imperfectly drained, though sometimes moderately well or well drained
Soils	Variable, mainly hard-setting red duplex soils and less commonly gradational red earths and reddish brown earthy loams. Subsoils are characteristically slightly to moderately saline
Main Principal Profile Forms	Dr 2.53, Dr 2.13, Gn 2.13, Um 5.52
Surface Texture Group and Condition	Sands or sandy loams; firm
Depth to Any Clay Layer	30 to > 100cm
Profile Permeability	Moderately slow or moderate
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderate (though variable)
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Possible
> 100cm (yd)	Moderate
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	Moderately high
Soil Workability (k)	Good
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Moderate

MAP UNIT	**GC2: Gascoyne – Coburn intergrade type 2**
Area	33ha; 3ha zoned but unused
Landform	Level terrace plains or alluvial backplains
Site Drainage	Moderately well drained
Soils	Gradational red earths (apedal or pedal). These may overlie buried sands at depths greater than 1m. Subsoils are characteristically moderately to strongly saline
Main Principal Profile Forms	Gn 2.13, Gn 4.13
Surface Texture Group and Condition	Sands or sandy loams; firm
Depth to Any Clay Layer	> 80cm
Profile Permeability	Moderately rapid or moderate
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Low
Salinity Risk (y)	
0-50 cm (ys)	Possible
50-100 cm (ym)	Moderate
> 100cm (yd)	Strong
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	High
Moisture Availability (m)	High
Soil Workability (k)	Good
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Moderate

MAP UNIT	**GC3: Gascoyne – Coburn intergrade type 3**
Area	138ha; 48ha zoned but unused
Landform	Level terrace plain or alluvial backplains
Site Drainage	Imperfectly to poorly drained
Soils	Mainly reddish brown earthy loams or friable clays and, less commonly, gradational red earths (apedal or pedal). Subsoils are commonly moderately to strongly saline
Main Principal Profile Forms	Um 5.5, Uf 6.12, Gn 4.13, Gn 2.13
Surface Texture Group and Condition	Loams, clay loams or light clays; firm or surface crust
Depth to Any Clay Layer	Usually 30-100cm
Profile Permeability	Moderately slow
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Neutral to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Moderate
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Possible to moderate
> 100cm (yd)	Moderate
Flood Risk (f)	Low
Rooting Conditions (r)	Moderate
Nutrient Retention Ability (n)	Moderately high
Moisture Availability (m)	Moderately high
Soil Workability (k)	Fair – Poor
Erosion Risk (e) (during floods)	Moderate
Wind Damage Risk (w)	Moderate

MAP UNIT	**Br: Brown association – dune ridge**
Area	36ha; 17ha zoned but unused
Landform	Longitudinal dune ridges, mainly orientated N-S and with relief up to 15m. Sideslopes are gently to moderately included (3-20%)
Site Drainage	Rapidly drained
Soils	Reddish brown siliceous sands and earthy sands
Main Principal Profile Forms	Uc 1.23, Uc 5.21
Surface Texture Group and Condition	Sands; soft
Depth to Any Clay Layer	> 2m
Profile Permeability	Very rapid
Soils Reaction (pH)	Topsoil – Neutral; Subsoil – Neutral to alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Nil
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Nil
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderate
Moisture Availability (m)	Low
Soil Workability (k)	Fair – Poor
Erosion Risk (e) (during floods)	Very low
Wind Damage Risk (w)	High

MAP UNIT	**Bsp: Brown association – sandplain**
Area	24ha; 4ha zoned but unused
Landform	Level to very gently inclined sandplain remnants or dune footslopes
Site Drainage	Rapidly drained
Soils	Reddish brown siliceous snds, brownish snds or earthy sands
Main Principal Profile Forms	Uc 1.23, Uc 5.11, Uc 5.21
Surface Texture Group and Condition	Sands; soft
Depth to Any Clay Layer	> 1.5m
Profile Permeability	Very rapid
Soils Reaction (pH)	Topsoil – Neutral to alkaline; Subsoil – Alkaline to strongly alkaline
LAND QUALITIES	
Waterlogging/inundation Risk (i)	Nil
Salinity Risk (y)	
0-50 cm (ys)	Not susceptible
50-100 cm (ym)	Not susceptible
> 100cm (yd)	Not susceptible
Flood Risk (f)	Very low
Rooting Conditions (r)	Easy
Nutrient Retention Ability (n)	Moderate
Moisture Availability (m)	Low
Soil Workability (k)	Good
Erosion Risk (e) (during floods)	Very low
Wind Damage Risk (w)	High

3. Land Capability For Horticulture

3.1 Assessment method

Land capability classification generally involves the assessment of soil, band and climatic attributes of a study area in terms of its ability to sustain a specified band use with minimal risk of land degradation.

The Department of Agriculture system of land capability classification is specific to defined band uses. An area of band does not possess a unique capability ranking for all uses. The area can have a high capability ranking for one form of land use, and a low ranking for another.

A five class system is used where the classes (I to V) indicate the severity of limitations to the subject land use and subclass notations indicate the nature of those limitations.

Table 2. Land Capability Classes

CAPABILITY CLASS	GENERAL DESCRIPTION
I	Very high capability for the proposed activity or use. Very few physical limitations present which are easily overcome. Risk of band degradation is negligible.
II	High capability. Some physical limitations affecting either productive land use or risk of land degradation. Limitations overcome by careful planning.
III	Fair capability. Moderate physical limitations significantly affecting productive land use or risk of band degradation. Careful planning and conservation measures required.
IV	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.
V	Very bow capability. Severity of physical limitations is such that its use is usually prohibitive in terms of either development costs or the associated risk of band degradation.

Table 3. Land Capability Subclasses

CAPABILITY SUBCLASS	LAND QUALITY LIMITING PROPOSED LAND USE	CAPABILITY SUBCLASS	LAND QUALITY LIMITING PROPOSED BAND USE
e	Erosion risk (during floods)	r	Rooting conditions
f	Flood risk	w	Wind damage risk
i	Waterlogging/inundation risk	ys	Salinity risk - shallow
k	Soil workability		(0-50 cm)
m	Moisture availability	ym	Salinity risk - mod deep
n	Nutrient retention ability		(50-100cm)
		yd	Salinity risk - deep
			(>100 cm)

The procedure for land capability classification involves a comparison of the biophysical requirements and tolerances of the subject band use with the existing qualities of the band as listed, for each map unit, in Section 2.3.

Table 4 summarizes the general requirements for horticultural land use and relates these to band qualities and to a range of diagnostic characteristics which might be used for their assessment. Definitions of the land qualities and the specific methods by which they were assessed for this study are given in Appendix 2. These generally follow the methods developed for band capability studies elsewhere in Western Australia (Wells and King, 1989).

Table 4. Land Qualities Assessed in Relation to Band use Requirements

LAND USE REQUIREMENTS	LAND QUALITY (LIMITING FACTOR)	POSSIBLE DIAGNOSTIC CHARACTERISTICS
Plant growth requirements		
Adequate soil aeration	Waterlogging/inundation risk (i)	Site drainage Depth to impermeable layer Degree of soil mottling[3]
Absence of salinity (affecting ability to obtain water and nutrients)	Salinity risk (y)	Electrical conductivity[1] Total soluble salts[1] pH Extent of existing salinity[2]
Absence of excessive flooding	Flood risk (f)	Landform/topographic position[4] Duration and extent of flooding[4]
Adequate conditions for root proliferation and support	Rooting conditions (r)	Depth to impermeable layer Broad soil type Gravel and stone within profile
Adequate nutrient supply	Nutrient retention ability (n)	Soil texture trend Coherence and fabric (for sandy soils) Soil depth Gravel content P adsorption or retention data[1]
Adequate moisture supply	Moisture availability (m)	Broad soil type (texture, profile trend) Position in landscape Proximity to seepage area or water table
Minimum damage by wind and sandblasting	Wind damage risk (w)	Proximity to coast Landform/topography Surface texture Site drainage Surface condition Surface stone or gravel

LAND USE REQUIREMENTS	LAND QUALITY (LIMITING FACTOR)	POSSIBLE DIAGNOSTIC CHARACTERISTICS
Requirements Affecting Machinery Usage		
Absence of constraints to cultivation	Soil Workability (k)	Topsoil texture Surface boulders Surface condition of soil Stone within profile Slope
Requirements Affecting Land Degradation		
Minimum soil erosion	Erosion risk (e) (during floods)	Surface texture Surface stone or gravel Surface condition Slope Site drainage Depth to impermeable layer Permeability above impermeable layer Subsoil dispersion[1] Extent of existing erosion

Notes

1. From laboratory analysis data where available.
2. Assessed by field observation of halophytic vegetation.
3. Indicated by Principle Profile Form (PPF) classification (Northcote, 1979).
4. Field observations correlated with flood study mapping (Sinclair Knight and Partners, 1981).

Each horticultural crop has a specific set of requirements for plant growth and production. Each crop is also limited by its tolerance range to adverse environmental conditions. The specific requirements and tolerances for six major crops of the Carnarvon area are summarized in Table 5.

Climatic and water supply requirements are not considered because the crops are already successfully produced in the locality and because it has been assumed that existing water allocations from the current plantations would be used. Nutrient requirements are also not listed since there are little differences between the assessed crops. Any increase in the total amount of irrigated land is likely to result from either more efficient watering techniques or by transferred water entitlements.

Table 5. Summary of Crop Requirements and Tolerances*

	ANNAUL VEGETATABLE			ANNUAL VINE	TREE CROP	
	Tomatoes	**Beans**	**Capsicums**	**Cucumbers**	**Bananas**	**Mangoes**
Waterlogging tolerance	Poor	Slight	Slight	Poor	Fair	Good
Salinity tolerance	Fair	Poor	Slight	Slight	Slight	Fair
Rooting depth requirement[1]	Deep (>120 cm)	Moderate (.<120 cm)	Moderate	Moderate	Moderate	Deep
Moisture requirement[2]	Moderately high but short term	As for tomatoes	As for tomatoes	As for tomatoes	High all year	Moderately high but short term
Cultivation requirements[3]	Moderate	Moderate	Moderate	Moderate	Very low (only at planting)	Very low (only at planting)
Flood damage tolerance[4]	Slight if short duration	Slight if short duration	Slight if short duration	Very slight, easily destroyed	Fairly tolerant	Moderately tolerant
Wind damage tolerance	Moderate	Slight	Moderate	Slight	Moderate	High

***** Based on published data by Hackett and Carolane (1982), Landon (1982), Capebin (1987), Wessebing (1974) and Maas (1984), modified to reflect local expert knowledge (Messrs T. Hill, J. Burt, I. McPharlain, A. Holrn and T. Muller; Western Australian Department of Agriculture).

Footnotes:

1. Probably of little significance as most roots will be concentrated within the upper 40 cm under irrigation.

2. Although water needs are met by irrigation greater amounts will be needed for soils with bow or very bow moisture availability (e.g. sands) which may be undesirable.

3. Based on frequency, i.e. annual compared with perennial.

4. Refer also to Table 6 for nature of damage.

Table 6. The Nature of Flood Damage to Horticultural Crops*

CROP	FLOOD TOLERANCE
Tomatoes	Highly susceptible to damage from swift or bong duration flows. Submerged fruit is rotted or develops black spot disease. Fruit borne above the bevel of flooding is satisfactory, providing adequate control of disease, and inundation is less than two days.
Beans	Highly susceptible to damage from swift or bong duration flows. Beans are a staked crop and when floodwaters are 0.30-0.60 metres deep, produce above flood level is undamaged, provided duration of flooding is short. Developing plants are destroyed.
Capsicums	Highly susceptible to damage from swift or bong duration flows. Capsicum is a long-lived low growing, erect crop. Submerged semi-mature to mature fruit is rotted, but developing fruit and subsequent flowerings are not affected, provided the duration of flooding is not prolonged.
Cucumbers	As an untrellised vine crop, cucumbers are easily destroyed. Small plants prior to flowering can withstand damage provided depths and velocities of flow are low.
Bananas	Fairly tolerant to flooding up to two weeks. Damage principally is destruction of irrigation bays, and deposition of trash. If bunches become submerged they are not marketable.
Mangoes	No data.

***** Source: Sinclair Knight and Partners (1981).

Specific band use capability rating tables (Appendix 4) are used to express the requirements and tolerances of each crop in terms of band quality values ranging from ‘the most favourable conditions’ to ‘those which are unacceptable’.

The rating tables also show the effect of crop choice on the land itself. For example, in relation to ‘erosion risk’ annual crops are considered to offer only slight protection from erosion during flooding, while deep rooting tree crops are likely to offer more protection. The use of polythene covered mulching beds for some crops may offer soil protection but this is likely to be counteracted by a gullying effect between crop rows during flooding.

The risk of erosion due to flooding is the primary consideration rather than the risk of damage to crops. This is because soil is essentially a non-renewable resource while crops can be replaced or at beast the damage they sustain is short term.

With respect to wind, all horticultural crops are likely to offer a fairly high degree of protection to the band surface (particularly as many vegetables are produced using a polythene mulching bed). Therefore in this study the effect of wind relates to the risk of damage to crops (e.g. by sandblasting) rather than to the risk of damage to land through erosion.

Land capability ratings are determined for each map unit by matching band quality values (listed in Section 2.3) with those in the rating tables (Appendix 4). Using these tables, the severity or degree of limitation, on a 1 to 5 scale, of the most limiting band quality determines the map unit’s capability class. This is expressed as the Roman numeral equivalent of the obtained rating. The quality or qualities responsible for the rating are indicated by a capability subclass notation (Table 3).

3.2 Results and Discussion

Land capability assessment results for this study are given in Table 7. It should be noted that where more than one value is shown for a band quality in section 2.3 e.g. fair-poor, the capability rating has been determined from the 'worst case' i.e. in this case 'poor'. The ratings obtained for additional land qualities are shown in Appendix 5.

From Appendix 5 it is possible to see how a capability rating will change if a limiting factor (band quality) is overcome. For example, the capability rating for map unit Ghd (Gascoyne 'heavy' soil in a depression) for tomatoes is IVi indicating it has bow capability and is limited by the risk of waterlogging. If measures such as mounding of crops, incorporation of gypsum and ensuring good surface drainage were undertaken, the risk of waterlogging is substantially reduced. The capability class for tomatoes then changes to II (high capability) as determined by the rating of 2 obtained by the remaining limiting factors.

Table 7. Land Capability Assessments* for Major Crops

MAP UNIT	TOTAL AREA (ha)	TOMATOES	BEANS	CAPSICURNS	CUCUMBERS	BANANAS	MANGOES
Gascoyne Association							
Levees							
G1	220	II	II	II	II	II	II
G1c	3	II	II	II	II	II	II
G1+	141	II	II	II	II	II	II
Gm	155	II	II	II	II	II	II
Gmc	5	II	II	II	II	II	II
Gm+	66	IIIi	IIIi	IIIi	IIIi	II	II
Gh	95	IIIi,k	IIIi,k	IIIi,k	IVi	IIIr	IIir
Ghc	9	IIIi,k	IIIi,k	IIIi,k	IVi	IIir	IIir
Gh+	46	IIIi	IIIi	iiii	IVi	IIIr	IIIr
Ghd	2	IVi	IVi	IVi	IVi	IIIr,i	IIIr
Dunes							
Gr	38	IIIw,k	IVw	IIIw,k	IVw	IIIw,m	IIIw,in

MAP UNIT	TOTAL AREA (ha)	TOMATOES	BEANS	CAPSICURNS	CUCUMBERS	BANANAS	MANGOES
Mid-level terraces							
Gtl	57	Ve	Ve	Ve	Ve	IVe	Ille
Gtm	84	Ve	Ve	Ve	Ve	IVe	Ille
Active drainage features							
Gsc	34	Ve	Ve	Ve	Ve	Ve	Ve
Ggl	32	Ve	Ve	Ve	Ve	IVe	Ille
Gg2	41	Ve	Ve	Ve	Ve	Ve	Ve
Gdz	94	Ve	Ve	Ve	Ve	lVe	Ille
Gtd	26	Ve	Ve	Ve	Ve	Ve	Ve

***** Class	I	Very high capability	Subclass	e	erosion risk from flooding
				i	waterlogging/inundation
	II	High capability (limiting factor)		k	soil workability
				m	moisture availability
	III	Fair capability		r	rooting conditions
	IV	Low capability		w	wind damage risk
				ys	salinity; shallow
	V	Very low capability		ym	salinity, moderately deep

Note: Subclasses not shown for Class II because limitations are only slight, and for salinity the limitation for only the uppermost relevant depth category is shown

Table 7. (continued)

MAP UNIT	TOTAL AREA (ha)	TOMATOES	BEANS	CAPSICURNS	CUCUMBERS	BANANAS	MANGOES
Coburn Association							
Backplains							
C	112	Ivym	Vym	IVym	IVym, i	IVym	IVym
Ce1	87	IVys, I	Vys	IVys,i	IVys,i	IVys	IVys
Ce2	71	IVym, I	Vysm	IVyrn,i	IVym,i	IVym,r	IVyrn,r
Cdp	12	IVys, i	Vys	IVys,i	IVys,i	IVys	IVys
Dunes							
Cr	9	II	111w	II	IIIw	II	II
Active drainage features							
Csc	32	Ve	Ve,ys	Ve	Ve	Ve	Ve
Cdz	22	Ve	Ve,ys	Ve	Ve	IV,e,ys	IVys
Gascoyne-Coburn Intergrades							
GC1	80	IIIi	IVym	IIIi,ym	IVi	IIIym,r	III,r
GC2	33	IIIym	IVys	IVym	IVym	IVyrn	IIIym,r
GC3	138	IIIi, ym, k	IVym	IVym	IVym,i	IVym	IIIyrn,r

MAP UNIT	TOTAL AREA (ha)	TOMATOES	BEANS	CAPSICURNS	CUCUMBERS	BANANAS	MANGOES
Brown Association							
Br	36	IIIk	IIIw,k	111k,	IIIw,k	II	II
Bsp	24	II	111w	II	111w	II	II
Total	1,804 ha						

***** Class I Very high capability

II High capability (limiting factor)

III Fair capability

IV Low capability

V Very bow capability

Subclass e erosion risk from flooding

i waterbogging/inundation

k soil workability

(m) moisture availability

r rooting conditions

w wind damage risk

ys salinity; shallow

ym salinity, moderately deep

Note: Subclasses not shown for Class II because limitations are only slight, and for salinity the limitation for only the uppermost relevant depth category is shown.

Table 7 shows that there is a total of 524 ha of unused bight or medium textured Gascoyne association soils which have a high capability for the assessed crops. Although not free from the risk of erosion during major flood events, this is a relatively minor limitation and is outweighed on most areas of Gascoyne soil association by highly favourable properties for irrigated horticulture. These are free drainage, an absence of salinity and generally good fertility. Soil compaction or hardpan development resulting from flood irrigation has been encountered in the existing Carnarvon irrigation area (Burt, 1985). Although this can affect plant rooting conditions and cause waterlogging, deep ripping, the application of gypsum, and increased use of more efficient watering systems can alleviate the problem.

On a further 216 ha of Gascoyne association with heavier surface or subsurface textures, drainage conditions are poorer, particularly for cucumbers. However these areas still have a fair capability for tomatoes, beans, capsicums, bananas and mangoes. Hummocky dune ridges (38 ha) generally also have a fair capability for horticulture even though areas with steeper slopes, or more variable relief, will require reshaping. The capability is bower for beans and cucumbers which are particularly susceptible to wind damage.

Within Gascoyne soil association the risk of erosion during major floods restricts horticultural land use on mid-level terraces adjacent to the river and within active drainage areas. Only bananas and mangoes which require minimum cultivation and present the least susceptibility to erosion should be considered, and not within stream channels, major gullies, or drainage areas on mid-bevel terraces. Of these two crops, mangoes are preferable in the more highly flood prone areas. Mangoes are more tolerant of flooding and waterlogging, are less susceptible to being knocked over. They are therefore more able to protect against soil boss during flooding.

The soils of Coburn association have both a high level of exchangeable sodium and a high content of soluble salts which renders them unsuitable for irrigation (Bettenay et al. 1971). This is reflected in table 7 by their low to very low capability rating for all crops. Even though some grower experience (Burt, J. personal communication) suggests that salt leaching can be achieved, the limitation should not be ignored because the effect of salt movement on underlying or nearby groundwater aquifers is not clear

(C. Malcolm, R. George, WADA personal communication).

Most soils within the Coburn association are duplex types with sandy topsoils overlying clay subsoibs. Within the sandy surface of duplex soils capillary rise of salts from any temporarily perched watertable will be rapid, causing an accumulation of salt on the surface which is likely to prevent seeding establishment. It is important therefore, that if such soils are used for irrigated horticulture, that the rate of water application does not exceed the saturated hydraulic conductivity of the subsoil (Appendix 1).

With the backplains containing Coburn soil association, there are 282 ha of band with a prohibitive (very bow) capability for salt sensitive crops such as beans. These areas are marginally better (low capability) for tomatoes, capsicums, cucumbers, bananas or mangoes but the risks of salinity and/or waterlogging are still severe limitations.

Overlying the backplains, low sandy rises or sandy banks within Coburn association have more favourable drainage and are less saline but are of very limited extent (9 ha). As with Gascoyne association, the risk of erosion during flooding restricts horticultural land use within active drainage areas. The major stream channels should not be used for any cropping and the broad non-incised drainage zones have only a low capability for just bananas and mangoes.

Although many soil samples were analysed for boron, the results were quite variable and could not be correlated to individual mapping units. Higher bevels of boron C> 1 ppm) were however, generally found within Coburn, rather than Gascoyne association soils. This is important to crops such as beans which are sensitive to high B bevels.

Within the 251 hectares of soils with transitional properties between Gascoyne and Coburn, there are serious limitations to growing beans or cucumbers due to the risks of salinity and/or waterlogging. Capsicums and bananas are similarly affected in map units GC2 and GC3, but are ranked as fair capability in areas of map unit GC1. The capability of land for tomatoes or mangoes is fair in all the transitional soil areas.

The 60 ha of Brown association have a high or fair capability for horticultural use. The ridges do contain slopes which might require reshaping to assist machinery operation however this is not a serious limitation. There is also a risk of wind damage to sensitive crops but this is not as serious as in the hummocky dune rises of Gascoyne association because most Brown association soils have a soft, rather than loose, surface condition.

Within the existing horticulture zone, the McGlade Road area has been subject to considerable pressure from growers for additional band release (Morrissey, 1985). This is largely the result of the small size of existing blocks. The capability of land on either side of these blocks can be determined by reference to the map and to Table 7. Regardless of the capability ratings however, it is considered appropriate that a “buffer zone” in which no development is allowed, be delineated next to the river to guard against river bank erosion during major floods. This bend in the Gascoyne River was identified as a major outbreak point for flooding during the 1980 flood and the McGbade Road plantations suffered extensive damage (Sinclair, Knight and Partners, 1981; Morrissey, 1985). Because it was not possible during this study to determine long term net erosion or accretion rates for the river bank, an arbitrary 100 **in** figure, erring on the side of caution, is suggested for the buffer zone.

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Appendix 1. Saturated Hydraulic Conductivity Results For Selected Soils

The following is a summary of the results of tests conducted to determine saturated hydraulic conductivity for various soils within the Carnarvon area. Hydraulic conductivity was determined 'in situ' using a modified well pemeameter test (Talsma and Habbarn, 1980). At each site the results represented the average of three to four, individual tests. These were conducted within the 30-70 cm depth interval, except for site 385 where additional measurements were made at 110-150 cm depth. Hydraulic conductivity is only roughly synonymous with permeability.

MAP UNIT OR EQUIVALENT*	SITE NO.	TEXTURE OF HORIZON TESTED	MEAN SATURATED HYDRAULIC CONDUCTIVITY m DAY^{-1}	PERMEABILITY CATEGORY
Gm (Gascoyne 'medium')	225	Sandy clay loam	0.27	Moderate
Gm (Gascoyne 'medium')	227	Light sandy clay loam	0.41	Moderate
Gm (Gascoyne 'medium')	424	Loam fine sandy	0.67	Moderately rapid
Gm (Gascoyne 'medium')	426	Loam fine sandy	0.29	Moderate
Gm (Gascoyne 'medium')	427	Silty loam	0.20	Moderate
Gh (Gascoyne 'heavy')	387	Clay loam	0.01	Moderately slow to slow
G1+ (Gascoyne 'light' over buried soil)	385	Sand	0.79	Moderately rapid
	385	Silty clay loam	0.01	Moderate to moderately slow
C (Coburn)	331	Light clay	0.05	Moderate to moderately slow
Cel (Coburn- moderately eroded	236	Light clay	0.13	Moderate

***** Most sites occur outside this study area and are part of the broader land resource study of the Carnarvon region (Wells et al. in press) but are readily correlated to a soils mapping unit from this study.

Appendix 2. Land Qualities And Their Assessment

Land qualities, used within the horticultural capability study for the Carnarvon plantation area are described as well as the means by which values have been assessed. These generally follow the methods developed for land capability studies elsewhere in Western Australia (Wells and King, 1989). At the end of each land quality heading, the letter in brackets refers to the capability subclass notation.

Waterlogging/inundation risk (i)

Waterlogging is the condition of a soil which is saturated with water and in which most or all of the soil air has been displaced (Houghton and Charman, 1986). Inundation occurs after flooding or under severe waterlogging conditions when the band surface is covered by water.

Waterlogging or inundation risk has been assessed by considering the depth to an impermeable layer, the degree of mottling within the soil profile and position in the landscape. Classes of risk are correlated with the site drainage classes of McDonald et al. (1984) as described in Table A2.1.

Table A2.1. Assessment of Waterlogging/Inundation risk

WATERLOGGING/ INUNDATION RISK	DESCRIPTION
Nil	Very rarely waterlogged. Water is removed from the soil rapidly in relation to supply. Soils are usually coarse textured. No horizon is normally waterlogged/wet for more than several hours after addition of water. (Rapidly drained soils)
Low	Rarely waterlogged. Water is generally readily removed from the soil. Soils are often medium textured. Some horizons may remain waterlogged for several days to a week after addition of water. (Well or moderately well drained)
Moderate	Commonly waterlogged for periods of several weeks. Water is removed only slowly in relation to supply. Some horizons may be mottled and/or have orange or rusty linings of root channels. (Imperfectly drained)
Moderately high	Commonly waterlogged for periods of several months. Water is removed very slowly in relation to supply. A perched water table may be present and soil horizons are commonly gleyed, mottled or possess orange or rusty linings of root channels. (Poorly drained)
High	Usually waterlogged for many months and water is removed from the soil so slowly that the water table remains at or near the surface for most of the year. (Very poorly drained)
Very high	Inundated for most or all of the year either because of tidal action or topography (for example, a swamp)

Salinity risk (y)

Soil salinity is a major factor limiting the expansion of areas used for irrigated horticulture. A soil is considered saline when it contains a high enough concentration of soluble salts to limit (or prevent) plant growth. This occurs by the creation of an osmotic potential so high that it prevents plants from obtaining water and nutrients from the soil solution.

Assessment of salinity risk for soils within the Carnarvon study area was made primarily from laboratory measurements of electrical conductivity (saturated soil extract) of representative samples of soils. Salinity risk assessments are given for three depth classes, shallow (0-50 cm), moderate (50-100 cm) and deep (> 100 cm) to cater for the range of rooting depths within the assessed crops. The corresponding band capability subclass notations are ys, ym and yd.

Table A2.2 Assessment of Soil Salinity Risk

	DESCRIPTION	ECe (dS/m)*
N	Not susceptible	0-4
P	Possibly or slightly susceptible	4-8
M	Moderately susceptible	8-15
S	Strongly susceptible	>15

***** 1 decisiemens per metre dS/m = 1 millisiemens per centimetre mS/cm = 1 millimho per centimetre (mmho/cm).

1 dS/m = approximately 640 mg/L salt.

In areas where analytical data were not available, morphological features such as a white salt encrustation on the soil surface, or vegetation indicator species such as saltbush (Atriplex spp.), were used to assess the susceptibility of land to salinity.

Flood risk (f)

Flooding is the temporary covering of band by water from overflowing rivers or streams. Flooding differs from inundation in that it involves more significant movement of water over the band surface usually resulting in damage to land and property. In general, annual horticultural crops are intolerant of flooding whilst tree fruits are more tolerant.

The problem of flooding may be overcome in some areas by the construction of levee banks. However in Carnarvon's plantation areas, flood study reports (Sinclair Knight and Partners, 1981, 1982) commissioned by the Water Authority of Western Australia have concluded that the costs of a high bevel of flood protection far outweigh the aggregate damages avoided. Hence few structural works have been undertaken which affect the 'natural' flood risk to band. An assessment of flood risk was based on aerial photograph interpretations of landform and topographic data which were correlated to maps delineating the extent of flooding, major floodways and breakout points from the 1980 flood event (Sinclair Knight and Partners, 1981).

Table A2.3. Assessment of Flood Risk

FLOOD RISK RATING	GEOMORPHIC DESCRIPTION
High	Immediate margins of Gascoyne River including very low terraces and sandy islets within river bed.
Moderate	Incised gullies, scoured drainage zones and prior stream channels within the terrace plain (levee surface) and also mid-level terraces.
Low	Higher terrace or major levee surface where flooding can be expected to occur somewhere between one in every 10 and one in every 100 years.
Very low	Dune ridges and sandplain landforms occurring above general bevel of terrace plain.

Note that although flood risk ratings were given for each map unit in Section 2.3 of the report, flood risk per se were not used in any of the land use capability rating tables (Appendix 4). The primary risk from flooding is rebated to water erosion damage to band. Damage to crops from flooding was not specifically considered because it is a relatively short term effect, the magnitude of which is greatly influenced by crop management practices. In the capability rating tables the effect of flooding was therefore considered in relation to ‘erosion risk’.

Rooting conditions (r)

The development of an effective root system is vital to plant growth. Roots hold plants in place and have the further function of extracting moisture and nutrients. Rooting conditions are controlled by the effective soil depth and ease of root penetration.

Effective depth is the depth to a limiting horizon such as rock, a cemented hardpan, or a particularly dense massive clay subsoil. A perched or permanent water table can also act as a barrier to root development but effective depth will usually equate to the depth to an impermeable layer within the profile.

For annual crops, the major requirement in terms of soil depth is to obtain an adequate supply of moisture and nutrients, while for perennial tree crops, long term plant survival depends in most cases on a deep well drained soil mass for root proliferation and support. Hence in general, annual crops require only relatively shallow soils while the batter require deeper soils. This is particularly the case under irrigation where most of the root mass is likely to be concentrated within the top 40 cm or so of the soil surface.

Ease of root penetration will be determined by a combination of soil physical characteristics including bulk density, texture, structure, consistence and the percentage of stones and gravel within the profile.

Table A2.4. Assessment of rooting conditions

CHARACTERISTICS	RATING*			
	EASY	**MODERATE**	**DIFFICULT**	**VERY DIFFICULT**
Depth to rock	Deep (> 100 cm)	Moderately deep (50-100 cm)	Shallow (25-50 cm)	Very shallow (<25 cm)
Soil type	Uniform sands, or loams	Gradational soils, Duplex soils Uniform clays with strong structure	Uniform clays lacking structure (plastic-sticky when wet, hard when dry)	-
Stones in profile	Nib-few (< 10%)	Common (10-20%)	Many or more (>20%)	-
Gravels in profile	Nib-many (< 50%)	Abundant or more (> 50%)	-	-

***** The rating is determined by that of the most limiting characteristic.

Nutrient retention ability (n)

Nutrient retention ability refers to the ability of the soil profile (nominally to 2 m depth) to retain added nutrients against bosses caused by leaching. For horticulture, the effectiveness of fertilizer applications and the resultant risk of nutrient loading of groundwater systems may be of concern.

In the Carnarvon area the risk of nutrient loading of groundwater is likely to be minimal given the limited area of band used for horticulture in relation to the size of the total Gascoyne River catchment, the net groundwater flow gradient (i.e. immediately towards the sea), and because water extraction for domestic purposes occurs well upstream. Hence only the effectiveness of fertilizer applications, particularly of the major nutrient element phosphorus, need be considered here.

Phosphorus retention in the soil depends on characteristics rebating to the adsorption process. The process is influenced largely by the type and quantity of clay, and the presence of organic material and hydrous oxides. The presence of a high water table can also reduce the soil's nutrient retention ability as it affects the distance over which the soil can react with the percolating nutrients.

To qualitatively rank mapping units in terms of their nutrient retention ability, the relative amounts of clay, organic matter and hydrous oxides in both the topsoil and subsoil layers of the dominant soil types should be considered. The relative depths of these layers will also be important. Soil texture adequately reflects clay content, and soil colour can reflect organic matter and the presence of hydrous oxides. For this study assessment of nutrient retention ability was made using the criteria in Table A2.5.

Table A2.5. Assessment of Nutrient Retention Ability

SOIL TYPE EXAMPLES*	RATING
Deep C> 1 m) grey leached siliceous sands where weak iron-organic pans or coloured subsoils, if present, occur at depths greater than 1m	Very low
Grey beached sands or sandy loams with an iron-organic hardpan within 1m of the soil surface Duplex soils with moderately deep (50-100 cm) sandy leached topsoils, or leached sands of similar depth overlying unrelated clays or a hardpan Shallow (< 50 cm) gravelly sands over rock	Low
Sands and earthy sands which are either whole coloured or have coloured subsoils within 1m of the soil surface Deep gravelly sands Calcareous sands Duplex soils with shallow sandy topsoils	Moderate
Uniform loamy soils Duplex soils with sandy loam topsoils Gravelly duplex soils Gradational earths with loamy topsoils	Moderately high
Uniform clay loams or clays Gradational earths with loamy topsoils Duplex soils with loamy topsoils	High

***** From report by Wells and King (1989) but includes soil types common to this study area.

Moisture availability (m)

All horticultural crops grown in the Carnarvon area require irrigation. The timing and volume of irrigation water supplied to crops are determined by crop type, crop stage and soil moisture storage characteristics.

Soil moisture storage is mainly determined by soil texture and soil depth but is also influenced by local topographic or site drainage factors. Within the study area no soils were encountered where soil depth was a limitation or where the topography resulted in any bong term seepage areas. Only a generalization can be made about actual water availability to plants as rooting depths vary between crop species and because not all water held within a soil will be available for plant growth.

Actual plant-available water capacity is considered to be the difference between the amount of water that can be held in a soil after any excess has drained away following saturation (field capacity), and the moisture content at which plant growth ceases (wilting point) (Houghton and Charman, 1986). Soils with higher plant available water capacity will require less irrigation and costs of production will generally be lower.

Table A2.6. Assessment of Moisture Availability

SOIL TYPE EXAMPLES	RATING*
Uniform sands (with coarse sandy fabric or with gravels	Very low
Uniform sands (with earthy fabric or minor clay content	Low
Uniform clays	Moderately low
Duplex soils (with shallow topsoils)	Moderate
Duplex soils (with moderately deep topsoils)	Moderately high
Uniform loams, clay loams or gradational soils	High

***** If the soil type occurs in an incised or non-incised stream channel or drainage area, the rating should be increased one bevel.

Soil workability (k)

Soil workability is the property governing the ease by which soil can be cultivated or tilled by machinery. It is mainly relevant to annual crop production.

The workability of a soil depends on a number of soil characteristics such as texture, depth, structure, consistence and the occurrence of gravels, stones or boulders within the surface layer. Slope angle, the depth of incision of gullies, surface rock outcrop and the susceptibility of soil to waterlogging may also act as limitations to the use of machinery.

Soft or loose sandy soils are generally easier to work than firm or hard-setting clayey soils. Well structured soils are easier than massive soils. Moisture content is also important and can determine the optimum time to work the soil. For example, soils with sandy to sandy loam textures are easy to work at nearby any moisture content, while self-mulching clays have a very narrow moisture range within which they can be worked.

Table A2.7. Assessment of Soil Workability

CHARACTERISTICS	RATING[1]		
	GOOD	FAIR	POOR
Surface texture	Sands and sandy loams (texture groups 1,2)	Loams and clay loams (texture groups 3,4)	Light and medium to heavy clays(texture groups 5, 6)
Surface condition	Soft-firm, self-mulching[2]	Hardset	Periodic cracking, or strongly undulating gilgai surface
Profile stone	Nib - few (0-10%)	Common (10-20%)	Many or more (> 20%)
Surface boulders	Nib - very few (0-2%)	Few (2-10%)	Common or more (> 10%)
Slope	0-5%	5-15%	> 15%

[1] The rating is determined by that of the most limiting characteristic.

[2] Favourable only over a narrow moisture range.

Rating modifier:

Areas subject to a very high waterlogging/inundation risk automatically have a poor soil workability rating. Other drainage conditions can generally be countered by variation in the time of soil working.

Erosion risk (during flooding) (e)

Water erosion is a process in which soil is detached and transported from the land principally by the action of rainfall, and run-off. In this study the principal agent for erosion is flooding of the Gascoyne River. Water erosion risk is the intrinsic susceptibility of land to erosion by water. This is determined by climatic, landform and soil factors. The risk of water erosion from flooding is of greater concern to annual vegetables and annual vines than to bananas or tree crops because of the frequency of soil disturbance by cultivation. Under bananas or tree crops, the system of soil management and weed control involves minimal soil disturbance by cultivation.

Within the Carnarvon area there are two factors which determine water erosion risk. These are flooding susceptibility, a band quality in its own right which is determined by geomorphic factors, and soil erodibility, which is a function of soil resistance to detachment and the amount of protective surface vegetative cover. However in order to assess relative erodibibity of soil, applicable to different crop types, the rating is made for bare soil. Soil erodibility is assessed from Table A2.8. To determine the risk of erosion during flooding, soil erodibibityis then combined, in Table A2.9, with flood risk which has been derived previously from Table A2.3.

Table A2.8. Assessment of Soil Erodibility.

SURFACE TEXTURE GROUP	SURFACE CONDITION	SOIL RESISTANCE	SOIL ERODIBILITY
Sands	Soft, loose or firm	Low	Moderate*
Sandy loams	Soft or loose	Low	High
	Firm, hardset or surface crust	Moderate	Moderate
Loams	-	Moderate	Moderate
Clay loams	-	High	Low
Light-heavy clays	Firm, hardset or surface crust	High	Low
	Self-mulching	Low	High

***** Even though sands have a bow resistance to detachment, only a moderate erodibibity results because of their very rapid permeability.

Table A2.9. Assessment of Erosion Risk During Flooding

FLOOD RISK	SOIL ERODIBILITY	EROSION RISK*
Very low	Low-moderate	Very low
	High	Low
Low	Low	Low
	Moderate	Moderate
	High	High
Moderate	Low-moderate	High
	High	Very high
High	Low-high	Very high

***** Risk is increased if flooding is channelled e.g. in major gullies or within drainage zones on mid-bevel terraces.

Wind damage risk (w)

Wind damage to crops may be the result of sandblasting by soil particles detached and transported from the band surface by wind (i.e. as a result of wind erosion). It may also be a direct result of wind pressure causing plant bruising or breakage.

Almost all horticultural crops, but particularly beans and cucumbers, are susceptible to wind damage. The most susceptible stages of crop growth are at flowering when fertilization can be prevented, and at fruit maturity when physical damage and bruising can occur.

The crop damage risk assessed here is a direct result of soil movement by wind erosion within the subject soil mapping unit. The intrinsic susceptibility of land to erosion by wind depends on a combination of climatic, landform and soil factors. Vegetative cover is not considered as the risk is to ‘bare soil’.

A simple assessment of relative wind damage risk can be derived from two factors, exposure and soil erodibility. In general, exposure to wind is affected by topography and relief. In the Carnarvon area however, only very minor variation occurs in these factors. Hence emphasis is given to assessment of soil erodibility which is based on the relative resistance of the surface soil to detachment.

Particle size distribution (soil texture) is the principal factor affecting resistance to detachment by wind, although surface conditions such as crusts or a hard-setting condition are also relevant. The percentage of particles in the 0.1 to 0.15 mm or fine sand range is important since they are most easily moved by saltation (Bagnold, 1941). Soils composed of finer particle sizes (heavier soil texture groups) are relatively resistant to erosive detachment because of the strong cohesive forces between particles with relatively large surface area to volume ratios. Soils composed of coarser particles are also relatively resistant to detachment because of their weight. For this reason, coarse

river-bed sands and gravels are commonly placed as a protective layer over the soil surface on vehicular access tracks within the Carnarvon plantations.

Table A2.10. Assessment of Wind Damage Risk (resulting from erosion)

SURF ACE TEXTURE	SURFACE CONDITION	WIND DAMAGE RISK*
Sands - with a relatively high fine sand component	Loose or soft	Very high
Sands - with a relatively high coarse sand component	Loose or soft	High
Loamy sands	Loose or soft Firm	High Moderate
Sandy loams or loams	Soft to loose (e.g. 'morrel soils')	High
	Firm to hardset or surface crust	Moderate
Clay loams or clays	Self-mulching with very fine peds	High
	Firm to hardset or surface crust	Low

***** Risk is increased one level if soils are particularly exposed by virtue of topography or if they have an appreciable fine sand content. Risk is decreased if soils are protected (e.g. in drainage depressions).

Appendix 3. Description Of Representative Soil Profiles

Descriptions follow of representative profiles of five major soils occurring within the study area. Soil colours are described in the moist state using notations from the Munsell Soil Color Charts (1954). Soils are classified according to the factual key nomenclature of Northcote (1979) and given descriptive names used by CSIRO in the 'Atlas of Australian Soils' Northcote et al. (1975).

Gascoyne 'light textured' soils

(Map units Gb, Gbc, Gb+, Gtl) with predominantly sand to sandy loam textures throughout

Site 109 Uc 5.21 - Earthy Sand

DEPTH (cm)	HORIZON	DESCRIPTION
0 - 10	A1	Dark reddish brown (5YR 3/4) sandy loam; weak subangular blocky structure with rough ped fabric; pH 8.0
10 - 30	A3	Dark reddish brown (5YR 3/4) fine sandy loam; massive with earthy fabric, slight amounts of finely dispersed lime, pH 8.0
30 - 110	B1	Reddish brown (5YR 4/4) fine sandy loam; massive with earthy fabric, slight amounts of finely dispersed lime, pH 9.0
110 - 180	B2	Reddish brown (5YR 4/4) loam fine sandy; massive with earthy fabric, slight amounts of finely dispersed lime, pH 9.0

Variations

- Textures within 1m of the surface vary from sands to light sandy clay barns. Below this, textures from sand to clay loams may be encountered.
- Within map unit Gb+ (Gascoyne bight over buried soil) the 'buried' soil material, which is encountered within 1m of the surface commonly consists of a 10-70 cm thick sand layer overlying loam or clay loam.
- In lightest textured soils fabric is sandy and lime is absent.
- Soil colour varies little, generally within dark reddish brown, reddish brown or yellowish red (5YR 3/4 - 4/6).
- In map unit Glc (Gascoyne bight -calcareous soil) some minor calcrete fragments occur within subsoil.
- Topsoil pHs vary from 7.0 to 8.5 and subsoibs 8.0 to 9.0.

- Other classifications include Uc 5.32, Uc 1.23, Gn 2.13 (Earthy Sands; Siliceous Sands; Red massive earths).

Cascoyne 'medium textured' soils

(map units Gm, Ginc, Gm+, Gtrn) with predominantly loamy textures throughout

Site 424 Um 5.22 - Non calcareous loam

DEPTH (cm)	HORIZON	DESCRIPTION
0 - 10	A1	Reddish brown (5YR 4/4) fine sandy loam; weak platy structure with rough ped fabric; powdery when dry: pH 7.5
10 - 30	A3	Reddish brown (5YR 4/4) loam fine sandy; massive with earthy fabric: powdery when dry: pH 8.0
30 - 90	B1	Yellowish red (5YR 4/6) loam fine sandy; massive with earthy fabric: pH 8.0
90 - 150	B2	Yellowish red (5YR 4/6) loam fine sandy; massive with earthy fabric: pH 8.5

Variations

- Textures within 1m of surface vary from sandy loams to clay barns but are predominantly loams over that depth. Below this, textures from sands to clay barns may be encountered.
- Within map unit Gm+ (Gascoyne medium over buried soil) 'buried' soil material is encountered within 1 m of the surface and commonly consists of a 20-50 cm thick sand or sandy loam layer overlying loam or clay loam.
- Subsoils may be slightly to moderately calcareous, however in soils of map unit Gmc (Gascoyne medium cabcareous soils), subsoils are highly calcareous and calcrete fragments are common.
- Topsoil pHs vary from 7.5-9.0 and subsoils 8.0-9.5.
- Pulverulent, powdery nature of soils encountered sporadically.
- Soil colour varies little, generally within dark reddish brown, reddish brown or yellowish red (5YR 3/4 - 4/6) however, 'buried' soils may be redder (2.5YR 4/4, 2.5YR 4/6).
- Other classifications include Urn 5.52, Urn 5.51, Urn 5.12, Gn 2.13 (Earthy Loams;

Gascoyne 'heavy textured' soils

(maps units Gh, Chc, Gh+, Ghd) with predominantly clay loam to light clay textures throughout

Site 210 Uf 6.12 – Non-cracking friable clay

DEPTH (cm)	HORIZON	DESCRIPTION
0 - 10	A1	Dark reddish brown (5Th 3/4) clay loam fine sandy; weak subangular blocky structure with rough ped fabric; pH 8.0
10 - 20	A3	Dark reddish brown (5Th 3/4) light clay; massive with earthy fabric; pH 8.0
20 - 80	B2	Reddish brown (5Th 4/4) light clay; weak polyhedral structure with rough ped fabric; pH 8.5
80 - 150	B3	Yellowish red (5Th 4/6) clay loam fine sandy; massive with earthy fabric; fine lime throughout; pH 9.0

Variations

- Textures within 1m of surface vary from clay loam to bight clays. Below this, textures from sandy clay barns to silty clays may be encountered.
- Subsoils may be slightly to moderately calcareous, however in soils of map unit Ghc (Gascoyne heavy calcareous soils), subsoils are highly calcareous and calcrete fragments are common.
- Topsoil pHs vary from 7.0-8.5, subsoils 8.0-9.0.
- Soil surfaces may exhibit minor cracking (not sufficient for Ug classification).
- Soil colour varies little, generally within dark reddish brown, reddish brown or yellowish red (5Th 3/4 - 4/6) however 'buried' soil (in Gh+), may be redder (2.5Th 3/6, 4/4, 4/6).
- Other classifications include Uf 1.4, Uf 6.7. Non-cracking clays of minimal development. Non-cracking coherent porous clays.

Coburn soils

(map units C, Cel, Ce2, Cdp) Saline duplex soils

Site l36 Dr 2.13 - Hard, pedal red duplex soil

DEPTH (cm)	HORIZON	DESCRIPTION
0 - 10	A1	Reddish brown (5Th 4/4) fine sandy loam; weak subangular blocky with rough ped fabric; pH 8.0
10 - 40	A3	Reddish brown (5YR 4/4) light sandy clay loam; moderate angular blocky structure with rough ped fabric; pH 8.5
40 - 80	B21	Reddish brown (5YR 4/4) bight clay; strong angular blocky structure with rough ped fabric; minor gypsum fragments; pH 8.5
80 - 120	B22	Reddish brown (5Th 4/4) light medium clay; strong angular blocky structure with rough ped fabric; minor gypsum fragments; pH 8.5

Variations

- Topsoil textures vary from loamy sand to sandy clay loam fine sandy, and subsoils from clay loam fine sandy to light-medium clays. Below 1m, 20-50 cm thick lenses of ‘lighter’ soil material, loamy sands, sandy barns or sandy clay loams, may be encountered.
- In lighter, sandier surfaced variants, surfaces are not hardset and often represent a wind-blown veneer. In eroded areas, topsoibs are reduced, or in scalds, are completely absent.
- As with Gascoyne soils, colour varies little, generally within dark reddish brown, reddish brown or yellowish red (5YR 3/4 – 4/6.
- Topsoil pHs vary from 7.0 to 8.5 and subsoils from 8.0 to 9.5.
- Subsoibs may only be weakly structured or apparently apedab. Gypsum, salt crystals or minor quartz grit may occur.
- Other classifications include Dr 2.53, Dr 4.13, Gn 2.13, Uf 6.12, Uf 1.4.
- Hard apedal red duplex soils; Friable red duplex soils; Red massive earths;
- Non-cracking friable clays; Non-cracking clays of minimal development.

Brown soils

(map units Br, Bsp)

Site l4 Uc 1.23 - Red siliceous sand

DEPTH (cm)	HORIZON	DESCRIPTION
0 - 10	A	Dark red (2.5YR 3/6) sands; apedal with sandy fabric; pH 7.5
10 - 150	B	Red (2.5YR 4/6) sand; apedal with sandy fabric; pH 7.5

Variations

- Textures within profile may be fine, coarse or clayey sands. Earthy rather than sandy fabric may be present.
- Soil colours may be reddish brown (5Th 4/4) or, in subsoils, yellowish red (5YR 4/6).
- Topsoil pHs vary from 7.5 to 8.5 and subsoils 7.5-9.0.
- Other classifications include Uc 5.11, Uc 5.21, Uc 1.43 (Brownish sands, Earthy sands and Firm siliceous sands).

Appendix 4. Land Use Rating Tables

Table A4.1. Land use rating table: TOMATOES

LAND QUALITIES (SUBCLASS)		RATING*				
		1 (NIL)	**2**	**3**	**4**	**5 (SEVERE)**
Waterlogging/inundation risk	(i)	N	L	M	MH	H VH
Salinity risk	(y)					
- Shallow 0 – 50 cm	(ys)	NS	PS	MS	SS	
- Moderate 50 – 100 cm	(ym)	NS	PS	MS	SS	
- Deep > 100cm	(yd)	NS PS	MS	SS		
Rooting conditions	r	E	M	D		VD
Nutrient retention ability	(n)	MH H	M	L VL		
Moisture availability	(m)	H MH	L VL			
Soil workability	(k)	G	F	P		
Erosion risk during flood	(e)	VL	L M			H VH
Wind damage risk	(w)	VL L	M H	VH		

***** Capability class, expressed in Roman numerals, is determined by the most limiting band quality.

Key to abbreviations within table

D	Difficult	M	Moderate	P	Poor
E	Easy	MR	Moderately high	PS	Possibly susceptible
F	Fair	ML	Moderately low	SS	Strongly susceptible
G	Good	MS	Moderately susceptible	VD	Very difficult
H	High	N	Nil	VH	Very high
L.	Low	NS	Not susceptible	VL	Very low

Table A4.2. Land use rating table: BEANS

LAND QUALITIES (SUBCLASS)		RATING*				
		1 (NIL)	2	3	4	5 (SEVERE)
Waterlogging/inundation risk	(i)	N	L	M	MH	H VH
Salinity risk	(y)					
- Shallow 0 – 50 cm	(ys)	NS			PS	MS SS
- Moderate 50 – 100 cm	(ym)	NS			PS MS	SS
- Deep > 100cm	(yd)	NS	PS	MS	SS	
Rooting conditions	r	E	M	D	VD	
Nutrient retention ability	(n)	MH H	M	L VL		
Moisture availability	(m)	H MH M ML	L VL			
Soil workability	(k)	G	F	P		
Erosion risk during flood	(e)	VL	L M			
Wind damage risk	(w)	VL L	M	H	VH	

***** Capability class, expressed in Roman numerals, is determined by the most limiting band quality.

Key to abbreviations within table

D	Difficult	M	Moderate	P	Poor
E	Easy	MR	Moderately high	PS	Possibly susceptible
F	Fair	ML	Moderately low	SS	Strongly susceptible
G	Good	MS	Moderately susceptible	VD	Very difficult
H	High	N	Nil	VH	Very high
L.	Low	NS	Not susceptible	VL	Very low

Table A4.3. Land use rating table: CAPSICIUMS

LAND QUALITIES (SUBCLASS)		RATING*				
		1 (NIL)	**2**	**3**	**4**	**5 (SEVERE)**
Waterlogging/inundation risk	(i)	N	L	M	MH	H VH
Salinity risk	(y)					
- Shallow 0 – 50 cm	(ys)	NS		PS	MS SS	
- Moderate 50 – 100 cm	(ym)	NS		PS	MS SS	
- Deep > 100cm	(yd)	NS	PS	MS	SS	
Rooting conditions	r	E	M	D	VD	
Nutrient retention ability	(n)	MH H	M	L VL		
Moisture availability	(m)	H MH M ML	L VL			
Soil workability	(k)	G	F	P		
Erosion risk during flood	(e)	VL	L M			H VH
Wind damage risk	(w)	VL L	M H	VH		

***** Capability class, expressed in Roman numerals, is determined by the most limiting band quality.

Key to abbreviations within table

D	Difficult	M	Moderate	P	Poor
E	Easy	MR	Moderately high	PS	Possibly susceptible
F	Fair	ML	Moderately low	SS	Strongly susceptible
G	Good	MS	Moderately susceptible	VD	Very difficult
H	High	N	Nil	VH	Very high
L.	Low	NS	Not susceptible	VL	Very low

Table A4.4. Land use rating table: CUCUMBERS

LAND QUALITIES (SUBCLASS)		RATING*				
		1 (NIL)	**2**	**3**	**4**	**5 (SEVERE)**
Waterlogging/inundation risk	(i)	N	L		M MH	H VH
Salinity risk	(y)					
- Shallow 0 – 50 cm	(ys)	NS		PS	MS SS	
- Moderate 50 – 100 cm	(ym)	NS		PS	MS SS	
- Deep > 100cm	(yd)	NS	PS	MS	SS	
Rooting conditions	r	E	M	D	VD	
Nutrient retention ability	(n)	MH H	M	L VL		
Moisture availability	(m)	H MH M ML	L VL			
Soil workability	(k)	G	F	P		
Erosion risk during flood	(e)	VL	L M			H VH
Wind damage risk	(w)	VL L	M	H	VH	

***** Capability class, expressed in Roman numerals, is determined by the most limiting band quality.

Key to abbreviations within table

D	Difficult	M	Moderate	P	Poor
E	Easy	MR	Moderately high	PS	Possibly susceptible
F	Fair	ML	Moderately low	SS	Strongly susceptible
G	Good	MS	Moderately susceptible	VD	Very difficult
H	High	N	Nil	VH	Very high
L.	Low	NS	Not susceptible	VL	Very low

Table A4.5. Land use rating table: BANANAS

LAND QUALITIES (SUBCLASS)		RATING*				
		1 (NIL)	2	3	4	5 (SEVERE)
Waterlogging/inundation risk	(i)	N L	M	MH	M	VH
Salinity risk	(y)					
- Shallow 0 – 50 cm	(ys)	NS		PS	MS SS	
- Moderate 50 – 100 cm	(ym)	NS		PS	MS SS	
- Deep > 100cm	(yd)	NS	PS	MS	SS	
Rooting conditions	r	E		M	D	VD
Nutrient retention ability	(n)	MH H	M	L VL		
Moisture availability	(m)	H MH M ML	L	VL		
Soil workability	(k)	G F	P			
Erosion risk during flood	(e)	VL	L M		H	VH
Wind damage risk	(w)	VL L	M H	VH		

***** Capability class, expressed in Roman numerals, is determined by the most limiting band quality.

Key to abbreviations within table

D	Difficult	M	Moderate	P	Poor
E	Easy	MR	Moderately high	PS	Possibly susceptible
F	Fair	ML	Moderately low	SS	Strongly susceptible
G	Good	MS	Moderately susceptible	VD	Very difficult
H	High	N	Nil	VH	Very high
L.	Low	NS	Not susceptible	VL	Very low

Table A4.6. Land use rating table: MANGOES

LAND QUALITIES (SUBCLASS)		RATING*				
		1 (NIL)	**2**	**3**	**4**	**5 (SEVERE)**
Waterlogging/inundation risk	(i)	N L M	MH	H	VH	
Salinity risk	(y)					
- Shallow 0 – 50 cm	(ys)	NS	PS	MS	SS	
- Moderate 50 – 100 cm	(ym)	NS	PS	MS	SS	
- Deep > 100cm	(yd)	NS PS	MS	SS		
Rooting conditions	r	E		M	D	VD
Nutrient retention ability	(n)	MH H	M	L VL		
Moisture availability	(m)	H MH M ML	L	VL		
Soil workability	(k)	G F	P			
Erosion risk during flood	(e)	VL	L M	H		VH
Wind damage risk	(w)	VL L M	H	VH		

***** Capability class, expressed in Roman numerals, is determined by the most limiting band quality.

Key to abbreviations within table

D	Difficult	M	Moderate	P	Poor
E	Easy	MR	Moderately high	PS	Possibly susceptible
F	Fair	ML	Moderately low	SS	Strongly susceptible
G	Good	MS	Moderately susceptible	VD	Very difficult
H	High	N	Nil	VH	Very high
L.	Low	NS	Not susceptible	VL	Very low

Appendix 5. Land Quality Ratings

Land use: Tomatoes

LAND QUALITIES		MAP UNITS																	
		G1	Gc	G1+	Gm	Gmc	Gm+	Gh	Ghc	Gh+	Ghd	Gr	Gtl	Gtm	Gsc	Gg1	Gg2	Gdz	Gtd
Waterlogging/ inundation	i	2	2	2	2	2	3	3	3	3	4	1	2	2	4	4	4	2	2
Salinity risk 0-50	ys	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity 50-100	ym	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity >100	yd	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rooting conditions	r	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1
Nutrient retention	n	2	2	2	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1
Moisture availability	m	2	2	2	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1
Soil workability	k	1	1	1	2	2	2	3	3	2	2	3	1	2	2	2	2	2	2
Erosion risk	e	2	2	2	2	2	2	2	2	2	2	1	5	5	5	5	5	5	5
Wind damage risk	w	2	2	2	2	2	2	1	1	1	1	3	2	2	2	1	1	2	2
Most limiting rating		2	2	2	2	2	3	3	3	3	4	3	5	5	5	5	5	5	5

Land use: Tomatoes (continued)

LAND QUALITIES		MAP UNITS											
		C	Ce1	Ce2	Cdp	Cr	Csc	Cdz	GC1	GC2	GC3	Br	Bsp
Waterlogging/ inundation	i	3	4	4	4	2	4	4	3	2	3	1	1
Salinity risk 0-50	ys	1	4	2	4	1	3	4	1	2	1	1	1
Salinity 50-100	ym	4	4	4	4	1	3	4	2	3	3	1	1
Salinity >100	yd	3	3	3	3	1	3	3	2	3	2	1	1
Rooting conditions	r	2	2	3	2	1	2	2	2	2	2	1	1
Nutrient retention	n	1	1	1	1	2	1	1	1	1	1	2	2
Moisture availability	m	1	1	1	1	2	1	1	1	1	1	2	2
Soil workability	k	2	2	3	3	1	2	2	1	1	3	3	1
Erosion risk	e	2	2	2	2	2	5	5	2	2	2	1	1
Wind damage risk	w	2	2	2	2	2	2	2	2	2	2	2	2
Most limiting rating		4	4	4	4	2	5	5	3	3	3	3	2

Land use: Beans

LAND QUALITIES		MAP UNITS																	
		G1	Gc	G1+	Gm	Gmc	Gm+	Gh	Ghc	Gh+	Ghd	Gr	Gtl	Gtm	Gsc	Gg1	Gg2	Gdz	Gtd
Waterlogging/ inundation	i	2	2	2	2	2	3	3	3	3	4	1	2	2	3	3	3	2	2
Salinity risk 0-50	ys	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity 50-100	ym	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity >100	yd	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rooting conditions	r	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1
Nutrient retention	n	2	2	2	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1
Moisture availability	m	2	2	2	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1
Soil workability	k	1	1	1	2	2	2	3	3	2	2	3	1	2	2	2	2	2	2
Erosion risk	e	2	2	2	2	2	2	2	2	2	2	1	5	5	5	5	5	5	5
Wind damage risk	w	2	2	2	2	2	2	1	1	1	1	4	2	2	2	1	1	2	2
Most limiting rating		2	2	2	2	2	3	3	3	3	4	4	5	5	5	5	5	5	5

Land use: Beans (continued)

LAND QUALITIES		MAP UNITS											
		C	Ce1	Ce2	Cdp	Cr	Csc	Cdz	GC1	GC2	GC3	Br	Bsp
Waterlogging/ inundation	i	3	4	4	4	2	4	3	3	2	3	1	1
Salinity risk 0-50	ys	1	5	4	5	1	5	5	1	4	1	1	1
Salinity 50-100	ym	5	5	5	5	1	4	5	4	4	4	1	1
Salinity >100	yd	4	4	4	4	2	4	4	3	4	3	1	1
Rooting conditions	r	2	2	3	2	1	2	2	2	2	2	1	1
Nutrient retention	n	1	1	1	1	2	1	1	1	1	1	2	2
Moisture availability	m	1	1	1	1	2	1	1	1	1	1	2	2
Soil workability	k	2	2	3	3	1	2	2	1	1	3	3	1
Erosion risk	e	2	2	2	2	2	5	5	2	2	2	1	1
Wind damage risk	w	3	3	3	2	3	2	3	2	2	2	3	3
Most limiting rating		5	5	5	5	3	5	5	4	4	4	3	3

Land use: Capsicums

LAND QUALITIES		MAP UNITS																	
		G1	Gc	G1+	Gm	Gmc	Gm+	Gh	Ghc	Gh+	Ghd	Gr	Gtl	Gtm	Gsc	Gg1	Gg2	Gdz	Gtd
Waterlogging/ inundation	i	2	2	2	2	2	3	3	3	3	4	1	2	2	3	3	3	2	2
Salinity risk 0-50	ys	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity 50-100	ym	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity >100	yd	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rooting conditions	r	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1
Nutrient retention	n	2	2	2	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1
Moisture availability	m	2	2	2	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1
Soil workability	k	1	1	1	2	2	2	3	3	2	2	3	1	2	2	2	2	2	2
Erosion risk	e	2	2	2	2	2	2	2	2	2	2	1	5	5	5	5	5	5	5
Wind damage risk	w	2	2	2	2	2	2	1	1	1	1	3	2	2	2	1	1	2	2
Most limiting rating		2	2	2	2	2	3	3	3	3	4	3	5	5	5	5	5	5	5

Land use: Capsicums (continued)

LAND QUALITIES		MAP UNITS											
		C	Ce1	Ce2	Cdp	Cr	Csc	Cdz	GC1	GC2	GC3	Br	Bsp
Waterlogging/ inundation	i	3	4	4	4	2	4	3	3	2	3	1	1
Salinity risk 0-50	ys	1	4	3	4	1	4	4	1	3	1	1	1
Salinity 50-100	ym	4	4	4	4	1	4	4	3	4	4	1	1
Salinity >100	yd	4	4	4	4	2	4	4	3	4	3	1	1
Rooting conditions	r	2	2	3	2	1	2	2	2	2	2	1	1
Nutrient retention	n	1	1	1	1	2	1	1	1	1	1	2	2
Moisture availability	m	1	1	1	1	2	1	1	1	1	1	2	2
Soil workability	k	2	2	3	3	1	2	2	1	1	3	3	1
Erosion risk	e	2	2	2	2	2	5	5	2	2	2	1	1
Wind damage risk	w	2	2	2	2	2	2	2	2	2	2	2	2
Most limiting rating		4	4	4	4	2	5	5	3	4	4	3	2

Land use: Cucumbers

LAND QUALITIES		MAP UNITS																	
		G1	Gc	G1+	Gm	Gmc	Gm+	Gh	Ghc	Gh+	Ghd	Gr	Gtl	Gtm	Gsc	Gg1	Gg2	Gdz	Gtd
Waterlogging/ inundation	i	2	2	2	2	2	3	4	4	4	4	1	2	2	4	4	4	2	2
Salinity risk 0-50	ys	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity 50-100	ym	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity >100	yd	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rooting conditions	r	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1
Nutrient retention	n	2	2	2	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1
Moisture availability	m	2	2	2	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1
Soil workability	k	1	1	1	2	2	2	3	3	2	2	3	1	2	2	2	2	2	2
Erosion risk	e	2	2	2	2	2	2	2	2	2	2	2	1	5	5	5	5	5	5
Wind damage risk	w	2	2	2	2	2	2	1	1	1	1	4	2	2	2	1	1	2	2
Most limiting rating		2	2	2	2	2	3	4	4	4	4	4	5	5	5	5	5	5	5

Land use: Cucumbers (continued)

LAND QUALITIES		MAP UNITS											
		C	Ce1	Ce2	Cdp	Cr	Csc	Cdz	GC1	GC2	GC3	Br	Bsp
Waterlogging/ inundation	i	4	4	4	4	2	4	4	4	2	4	1	1
Salinity risk 0-50	ys	1	4	3	4	1	4	4	1	3	1	1	1
Salinity 50-100	ym	4	4	4	4	1	4	4	3	4	4	1	1
Salinity >100	yd	4	4	4	4	2	4	4	3	4	3	1	1
Rooting conditions	r	2	2	3	2	1	2	2	2	2	2	1	1
Nutrient retention	n	1	1	1	1	2	1	1	1	1	1	2	2
Moisture availability	m	1	1	1	1	2	1	1	1	1	1	2	2
Soil workability	k	2	2	3	3	1	2	2	1	1	3	3	1
Erosion risk	e	2	2	2	2	2	5	5	2	2	2	1	1
Wind damage risk	w	3	3	3	2	3	2	3	2	2	2	3	3
Most limiting rating		4	4	4	4	3	5	5	4	4	4	3	3

Land use: Bananas

LAND QUALITIES		MAP UNITS																	
		G1	Gc	G1+	Gm	Gmc	Gm+	Gh	Ghc	Gh+	Ghd	Gr	Gtl	Gtm	Gsc	Gg1	Gg2	Gdz	Gtd
Waterlogging/ inundation	i	1	1	1	1	1	2	2	2	2	3	1	1	1	2	2	2	1	1
Salinity risk 0-50	ys	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity 50-100	ym	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity >100	yd	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rooting conditions	r	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	1	1	1
Nutrient retention	n	2	2	2	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1
Moisture availability	m	2	2	2	1	1	1	1	1	1	1	3	2	1	1	1	1	1	1
Soil workability	k	1	1	1	1	1	1	2	2	1	1	2	1	1	1	1	1	1	1
Erosion risk	e	2	2	2	2	2	2	2	2	2	2	1	4	4	5	4	5	4	5
Wind damage risk	w	2	2	2	2	2	2	1	1	1	1	3	2	2	2	1	1	2	2
Most limiting rating		2	2	2	2	2	2	3	3	3	3	3	4	4	5	4	5	4	5

Land use: Bananas (continued)

LAND QUALITIES		MAP UNITS											
		C	Ce1	Ce2	Cdp	Cr	Csc	Cdz	GC1	GC2	GC3	Br	Bsp
Waterlogging/ inundation	i	2	3	3	3	1	3	2	2	1	2	1	1
Salinity risk 0-50	ys	1	4	3	4	1	4	4	1	3	1	1	1
Salinity 50-100	ym	4	4	4	4	1	4	4	3	4	4	1	1
Salinity >100	yd	4	4	4	4	2	4	4	3	4	3	1	1
Rooting conditions	r	3	3	4	3	1	3	3	3	3	3	1	1
Nutrient retention	n	1	1	1	1	2	1	1	1	1	1	2	2
Moisture availability	m	1	1	1	1	2	1	1	1	1	1	2	2
Soil workability	k	1	1	2	2	1	1	1	1	1	2	2	1
Erosion risk	e	2	2	2	2	2	5	4	2	2	2	1	1
Wind damage risk	w	2	2	2	2	2	2	2	2	2	2	2	2
Most limiting rating		4	4	4	4	2	5	4	3	4	4	2	2

Land use: Mangoes

LAND QUALITIES		MAP UNITS																	
		G1	Gc	G1+	Gm	Gmc	Gm+	Gh	Ghc	Gh+	Ghd	Gr	Gtl	Gtm	Gsc	Gg1	Gg2	Gdz	Gtd
Waterlogging/ inundation	i	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1
Salinity risk 0-50	ys	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity 50-100	ym	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salinity >100	yd	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rooting conditions	r	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	1	1	1
Nutrient retention	n	2	2	2	1	1	1	1	1	1	1	2	2	1	2	1	1	1	1
Moisture availability	m	2	2	2	1	1	1	1	1	1	1	3	2	1	1	1	1	1	1
Soil workability	k	1	1	1	1	1	1	2	2	1	1	2	1	1	1	1	1	1	1
Erosion risk	e	2	2	2	2	2	2	2	2	2	2	1	3	3	5	3	5	3	5
Wind damage risk	w	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1
Most limiting rating		2	2	2	2	2	2	3	3	3	3	3	3	3	5	3	5	3	5

Land use: Mangoes (continued)

LAND QUALITIES		MAP UNITS											
		C	Ce1	Ce2	Cdp	Cr	Csc	Cdz	GC1	GC2	GC3	Br	Bsp
Waterlogging/ inundation	i	1	2	2	2	1	2	1	1	1	1	1	1
Salinity risk 0-50	ys	1	4	2	4	1	3	4	1	2	1	1	1
Salinity 50-100	ym	4	4	4	4	1	3	4	2	3	3	1	1
Salinity >100	yd	3	3	3	3	1	3	3	2	3	2	1	1
Rooting conditions	r	3	3	4	3	1	3	3	3	3	3	1	1
Nutrient retention	n	1	1	1	1	2	1	1	1	1	1	2	2
Moisture availability	m	1	1	1	1	2	1	1	1	1	1	2	2
Soil workability	k	1	1	2	2	1	1	1	1	1	2	2	1
Erosion risk	e	2	2	2	2	2	5	3	2	2	2	1	1
Wind damage risk	w	2	2	2	1	2	1	2	1	1	1	2	2
Most limiting rating		4	4	4	4	2	5	4	3	3	3	2	2