Department of **Environment** and **Resource Management**

Landscape and suitability study of the Woongoolba – Rocky Point Area
South East Queensland

Queensland Government

Land Resources Bulletin

Landscape and Suitability study of the Woongoolba–Rocky Point Area, South East Queensland

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Department of Environment & Resource Management
Queensland, 2010

RKP2_1
ISBN: 9 1166 2189 462

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Acknowledgements

The authors wish to thank the following individuals for their valuable contributions to the project:

- Rob Ellis for assistance with geostatistcal analysis
- Jon Walton, Terri Svensson, John Loi, Jon Burgess and Hari Kishore for assistance with field work and the validation exercise
- David Huth, Victor Schwenke, Tony Huth, Peter Kaddatz, Barry Brooking, Richard Skopp, David Keith and Greg Zipf for their contribution to the identification of landscape attributes, management options and review of the project products
- Landholders in the Rocky Point area for their cooperation and access to their properties
- Maria Zann for the production of maps for the report and finalisation of the validation results
- Diane Bray, Fiona McCartney and Sue-Ellen Dear for editorial comment

Summary

The South East Queensland Regional Plan and Gold Coast City Council have identified the need to plan for urban and industrial development, long term viability of rural activities in the Shire and desired regional environmental outcomes. This includes the identification of Good Quality Agricultural Land (GQAL) for determining the urban footprint, alternative patterns of development, constraints to infrastructure and desired natural resource management for regional and local planning.

The Rocky Point land resource assessment aimed to supply land resource information in a uniform format to support planning needs. All project outputs of a spatial nature should be used at a scale of 1:50 000.

Soil and landscape attributes were assigned to map units using a variety of information sources including: 745 ASS site morphology descriptions, field tests and laboratory analysis; interpretation of data from 96 sites collected during field investigations; pedotransfer functions; expert opinion and local knowledge. To facilitate communication, a suite of conceptual soil types known as Soil Profile Classes are described.

To complement the predictions of soil and landscape attribute distribution, the suitability of a wide range of agricultural and forestry land uses were assessed. Based on the land suitability framework developed for this project, 3269 ha are suitable for rainfed sugar cane and 5833 ha suitable for irrigated sugar cane (spray irrigated). Sugar cane represents the main rural land use in the area and is supported by the Woongoolba Sugar Mill. However, the future viability of the sugar industry in the study area is threatened by the lack of land suitable for expansion and strong competition between alternative (mainly non-rural) land uses.

This study has identified the lands suitable for alternative agricultural and forestry land uses. This information together with the basic resource information and required resource management requirements will help in the regional and local planning processes. Future planning decisions for the Rocky Point area need to consider possible impacts from a range of land management constraints and degradation processes associated with shallow groundwater, acid sulfate soils, flooding and salinity. These impacts may affect infrastructure, urban development, agricultural production, human health and the coastal environment.

Introduction

The Woongoolba–Rocky Point area is assigned to the Regional Landscape and Rural Production Area in the South East Queensland Regional Plan. Urban expansion and other major non-rural developments in the adjacent Urban Footprint is placing significant pressure on the rural production area. Consequently, there is considerable uncertainty associated with long term economic viability of the rural industries and landholders in the area.

The aims of this suitability study were to identify development constraints for alternative land uses and to provide key scientific information for informed future planning decisions.

Location

The Woongoolba–Rocky Point area is located within the Gold Coast City Council area, approximately 30 km southeast of Brisbane (Figure 1).

Figure 1. Location of the Woongoolba–Rocky Point Study Area

The study area of 17 604 ha is bounded by the Albert and Logan Rivers to the north, Moreton Bay to the east, the Coomera River to the south and the Pacific Highway to the west.

Land use

Currently, agriculture is the dominant land use within the study area (Figure 2) with the majority of the land under sugar production. All sugar is processed at the Woongoolba Sugar Mill. Other agricultural land uses include cropping of soybean and small crops, and grazing.

Non-agricultural land uses include urban development (including industrial and rural residential development), marinas, sand extraction, and aquaculture. Urban development is encroaching upon the cane lands in the Rocky Point area with significant areas to the north of the Albert River and along the Coomera River already converted to urban development.

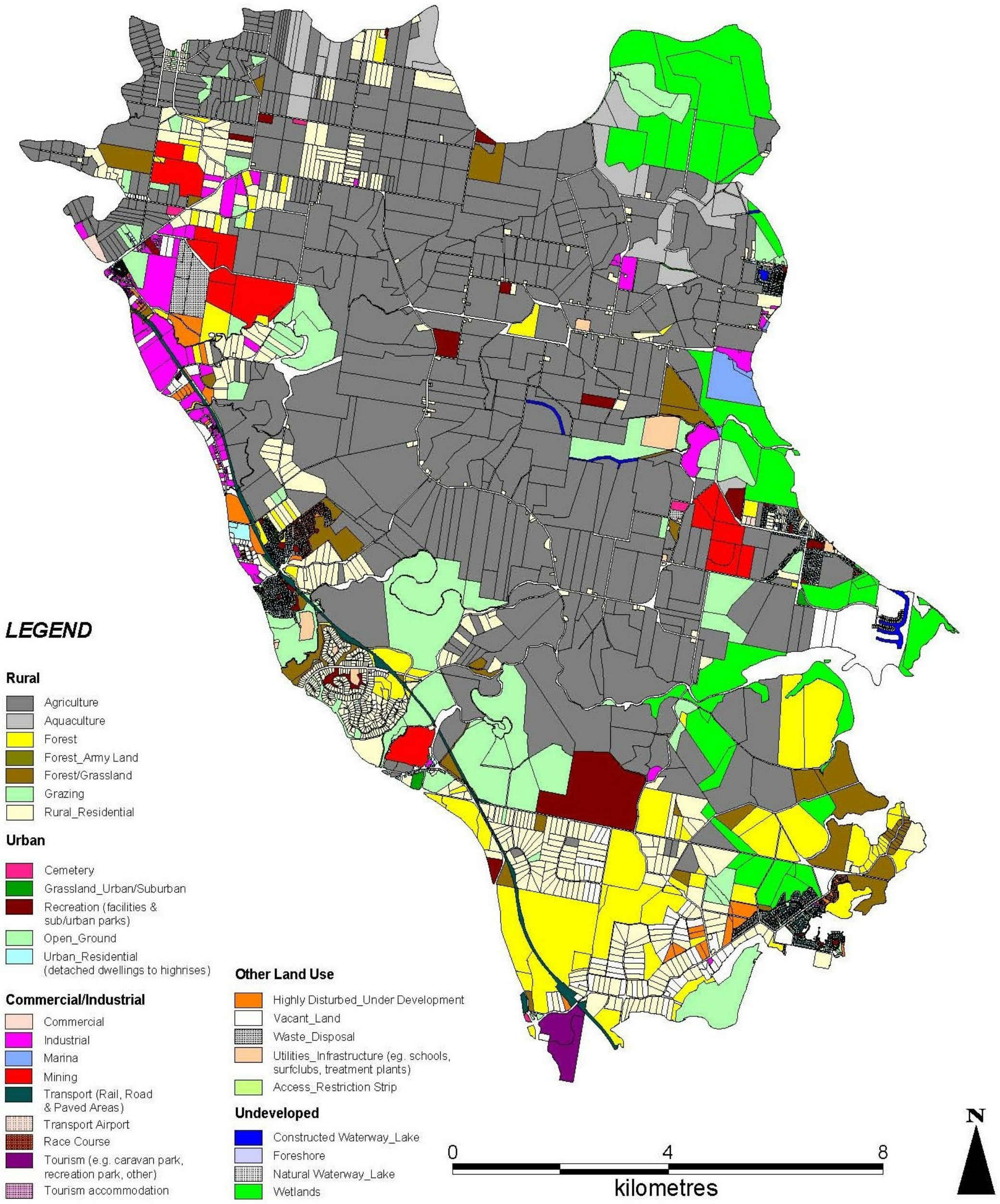

Figure 2. Land use (2006) in the Rocky Point study area (map supplied by Gold Coast City Council)

Pre-existing Land Resource Information

The Holz (1979) Sugar cane Land Suitability Study of the Rocky Point area identified 9010 ha suitable for cane production.

An additional study by Forster (1989) expanded upon the information from the previous survey by Holz (1979) and recommended that suitable agricultural land be protected against development pressures in order to retain viable cane production.

More recently, Manders *et al*. (2002) completed an acid sulfate soil (ASS) investigation of the Rocky Point area. This 1:25 000 scale survey consisted of 764 described sites, of which 745 were sampled for laboratory analysis. The study identified 8778 ha of ASS within the Woongoolba–Rocky Point area, including 4787 ha of actual ASS and 7892 ha of potential ASS. Actual ASS soils have a pH of 4 or less due to the oxidation of the sulfides to sulfuric acid, whereas potential acid sulfate soils contain unoxidised iron sulfides (FeS_2) and may have elevated pH (pH 4.0 to >7.0). An actual ASS may have potential ASS at depth.

Methodology

The mapping in this study was based on the mapping originally surveyed by Holz (1979) and amended by Forster (1989). Each of the 10 map units described by Forster (1989) has a particular landform and soil type. These map units were subdivided for the purpose of this study with boundaries modified using the ASS mapping (Manders *et. al.* 2002), Landsat TM satellite imagery, aerial photograph interpretation and field observations. Map units and associated landform and soils are described in the next section.

Soil and land attributes were assigned to each unique map area (UMA) using a variety of information sources including: 745 ASS site morphology descriptions, field tests and laboratory analysis (Manders *et. al.* 2002); interpretation of data from 96 sites collected during field investigations; pedotransfer functions; expert opinion and local knowledge.

The soil and landscape attributes assessed were:

- acid drainage – actual and potential (ASS mapping and site data)
- flooding (Gold Coast Regional Council and local knowledge)
- plant available water capacity (PAWC) (ASS site data)
- precipitation (Bureau of Meteorology)
- radiation (Bureau of Meteorology)
- rooting depth (ASS site data and field sites)
- salinity (ASS site data)
- slope (digital elevation model)
- soil drainage and permeability (ASS site data)
- frost (digital elevation model and local knowledge)
- soil erodibility (field sites)
- microrelief (field sites)
- rockiness (field sites)
- soil adhesiveness (field sites)
- soil workability (field sites)
- soil surface properties (field sites)
- nutrient deficiencies (local knowledge and field sites)
- nutrient fixation (local knowledge and field sites)
- nutrient leaching (local knowledge and field sites)
- nutrient toxicity (local knowledge and field sites)

Some soil and landscape attributes that were necessary to determine land suitability were not recoded in the site data. Therefore, these attributes were reinterpreted from available soil and landscape data by applying simple rule sets (Appendix 3).

The soil and land attributes assigned to UMAs were checked against information collected at 96 new verification sites to determine the level of accuracy of the results. Soil morphology at each site was observed up to a depth of 1.5 m using a 2 inch diameter hydraulic push tube. Soil and landscape properties were described according to the Australian Soil and Land Survey Field Handbook (McDonald *et. al.* 1990) and soil classification using the Australian Soil Classification (Isbell, 1996). This information was entered into the Queensland Soils and Land Information (SALI) database.

All 10 map units described by Forster (1989) had verification sites (Table 1) but sampling effort was biased towards map Units 2.1 and 2.2 due to their importance for agricultural production. Map units 1, 5.1, 5.2 and 5.3 have severe limitations for agricultural production, and therefore required minimal sampling.

Table 1. Number of site descriptions sampled on each map unit described by Forster (1989)

Map Unit (Forster 1989)	Area (ha)	% of total area	New sites	% of new sites collected
1	2892.9	14.0	2	2.1
2.1	5641.7	27.3	48	49.4
2.2	2140.8	10.4	21	21.6
2.3	1334.4	6.5	5	5.2
2.4	761.9	3.7	7	7.2
3	991.3	4.8	3	3.0
4	826.5	4.0	5	5.2
5.1	21.9	0.1	2	2.1
5.2	549.9	2.7	2	2.1
5.3	4497.0	21.8	2	2.1
Not surveyed	972.3	4.7	-	-
Total	20631.0	100.0	97	100.0

The suitability framework (Appendix 2) as based on the framework developed by Burgess and Wilson (in prep.) for the Maroochy catchment on the Sunshine Coast, outlines the ‘rules’ used to determine crop suitability from the soil and land attributes. Additional crops currently grown in the study area were added to the framework. In total, 21 limitations were assigned to each polygon unique mapping area (UMA) using the methods described in section *Soil and Landscape Attributes*.

Because the Woongoolba–Rocky Point and Maroochy floodplain have similar soils, limitations to crop production and management practices, the methodology for determining soil and land attributes and the suitability framework used during the Maroochy catchment survey (Burgess and Ellis, in prep.) was adapted and applied in this study.

Soils

The soils of the study area have been previously mapped and described by Beckmann (1967), Isbell *et. al.* (1967) and Franks (1971). The scale used in these reports is too small to address current land use issues.

As described in the previous section, the soils mapping for this study are based on the mapping units originally surveyed by Holz (1979) and amended by Forster (1989). Each of the 15 map units and associated landform and soil types are described in Table 2 and on the attached map (map reference 07-RKP2-B-A1 5543).

A major subdivision of the original map units is associated with the occurrence of sand or clay subsoils. Sand or clay subsoil is strongly correlated with differences in soil water holding capacity, salinity, fresh watertables and ASS properties. Map units 2.1, 2.2, 2.3 and 2.4 were split into two and a suffix (.1 for sandy subsoils or .2 for non sandy subsoils) was added to the map unit code to identify their subsoil properties.

Table 2. Brief description of soil properties and landform for each map unit

Map Unit (modified from Forster 1979)	Landform	Soil description	Soil classification
1	Tidal lands including saline flats, mangroves, swamps, tidal creeks	Saline marine muds and sands	Sulfidic Intertidal, Supratidal or Extratidal Hydrosols
2.1.1	Alluvial plains	Black extremely acid to medium acid sandy light clay to sand medium clay, occasionally clay loam sandy surface over a mottled grey extremely acid to medium acid sandy light clay to sandy medium clay, occasionally clay loam sandy subsoil over a mottled grey extremely acid to neutral sand to sandy clay loam D horizon at predominantly <1 m. Watertable at 1–1.5 m. Jarosite at >1 m and/or iron sulfide at 1–3 m.	Dermosolic or Kandosolic Redoxic Hydrosol
2.1.2	Alluvial Plains and minor terraces	Black strongly to extremely acid light clay to medium clay surface over a mottled grey extremely acid to neutral light clay to medium clay subsoil. Watertable at 1–1.5 m. Jarosite at >1 m and/or iron sulfide at 1–3 m.	Sulfuric Redoxic Hydrosol, Sulfidic Redoxic Hydrosol
2.2.1	Alluvial plains and swamps	Black extremely acid to medium acid fine sandy clay loam to light medium clay over a mottled grey extremely acid to medium acid fine sandy clay loam to fine sandy light clay and medium clay over a mottled grey extremely acid to neutral sand to sandy clay loam D horizon at <1m. Watertable at 0.5–1.5 m. Jarosite at 0.5–1 m and/or iron sulfide at 0.5–2 m.	Dermosolic or Kandosolic Redoxic Hydrosol, Sufuric Redoxic Hydrosol
2.2.2	Alluvial plains and swamps	Black strongly to extremely acid light clay to medium clay surface over a mottled grey extremely acid light clay to medium clay subsoil. Watertable at 0.5–1.5m. Jarosite at 0.5–1 m and/or iron sulfide at 0.5–2 m.	Sulfuric Redoxic Hydrosol
2.3.1	Freshwater swamps and drainage lines	Black extremely acid to neutral sandy clay loam to light medium clay over a mottled grey extremely acid to medium acid sandy clay loam to medium clay over a mottled grey medium acid to neutral sandy loam to sandy clay loam C or D horizon at predominantly <1 m. Watertable at <0.5–1 m. Jarosite at <0.5 m and/or iron sulfide at <0.5–1 m.	Sulfidic/Sulfuric Redoxic Hydrosol

Table 2. Continued

Map Unit (modified from Forster 1979)	Landform	Soil description	Soil classification
2.3.2	Freshwater swamps and drainage lines	Black strongly to extremely acid light clay to medium clay surface over a mottled grey extremely acid light clay to medium clay subsoil. Watertable at <0.5–1m. Jarosite at <0.5 m and/or iron sulfide at <0.5–1 m.	Sulfuric Redoxic Hydrosol
2.4.1	Brackish swamps	Black extremely acid to slightly acid sandy clay loam to light clay over a mottled grey strongly acid to neutral sandy clay loam to light medium clay over a grey alkaline sand to clay loam D or C horizon at predominantly <1 m,. Watertable at <0.5–1 m. Jarosite at <0.5 m and/or iron sulfide at <0.5–1 m.	Sulfidic/Sulfuric Redoxic Hydrosol
2.4.2	Brackish swamps	Black strongly to extremely acid light clay to medium clay surface over a mottled grey strongly acid to extremely acid light clay to medium clay subsoil. Watertable at <0.5–1 m. Jarosite at <0.5 m and/or iron sulfide at <0.5–1 m.	Sulfidic/Sulfuric Redoxic Hydrosol
3	Terrace plain	Black or brown acid light clay to medium clay surface over a mottled grey medium clay to heavy clay subsoil.	Vertic Eutrophic Grey Dermosol
4.1	Low sand ridges on beach ridge plain	Black sand surface over a conspicuously bleached A2 horizon over a black coffee rock pan at 1–1.5 m. Watertable at 1–1.5 m.	Humic Aquic Podosol
4.2	Low sand ridges on beach ridge plain	Black sand surface over a conspicuously bleached A2 horizon over a grey sand. Watertable at 0.5–1 m. Iron sulfide at 1–2 m.	Sulfidic Redoxic Hydrsol Sulfidic Oxyaquic Hydrosol.
5.1	Gently undulating low hills and rises on sandstones of the *Woogaroo Formation*	Black or brown sandy clay loam to clay loam sandy surface over a pale A2 horizon over a red light clay to medium clay subsoil over weathered sandstone.	Red Kandosol, Red Chromosol, Yellow Kandosol, Brown Chromosol
5.2	Lower slopes of gently undulating to undulating low hills and rises on *Nerenleigh–Fernvale Beds*	Black or grey clay loam surface over a bleached A2 horizon over a mottled grey medium to medium heavy clay over weathered rock.	Beached-sodic Magnesic-natric Grey Kurosol
5.3	Upper slopes of gently undulating to undulating low hills and rises on *Nerenleigh–Fernvale Beds*	Black light sandy clay loam to clay loam surface over a conspicuously bleached A2 horizon over weathered rock or light medium clay to medium clay B2 horizon over weathered rock.	Bleached Leptic Tenosol or Brown Chromosol/Kurosol

Soil Profile Class (SPC) descriptions are outlined in Appendix 1.

Map units on marine wetlands

Map unit 1 includes all marine plains subject to tidal inundation at regular to infrequent periods (below the highest astronomical tide). Soils are saline sands and muds often containing iron sulfides. Vegetation in marine wetlands is protected under the *Fisheries Act 1994* and therefore, this map unit has not been assessed under this suitability framework.

Map units on alluvial plains

The alluvial plains associated with the Albert and Logan Rivers are predominantly old delta and estuarine deposits subject to periodic flooding. Map units have been subdivided on landscape position and soil properties. The ‘sandy’ soils correspond to the old stream channels where active flood and tidal current deposition of sands were deposited under similar conditions to the current estuary channels and waterways. The 'clayey' soils were deposited under slow flowing conditions in old tidal backwaters and swamps, similar to current mangrove muds and swamps.

Map unit 2.1.1 is associated with slightly elevated plains mainly in the Woongoolba area and minor terraces of the Albert and Logan Rivers. The soils have a strongly acidic black clay surface over a mottled grey clay subsoils over sandy subsoils at predominantly <1m below the soil surface. Fresh watertables usually provide soil water for crop growth during the drier part of the year. These soils are subject to seasonal wetness and occasional flooding (depending on location). Acidic conditions are due to the presence of iron sulfides at >1 m. These soils are highly productive for wetness-tolerant crops.

Map unit 2.1.2 are very similar to unit 2.1.1 but have clay subsoils and mainly occur to the south and west of the Woongoolba area. Acidic conditions are due to the presence of iron sulfides at >1 m.

Map unit 2.2.1 occurs as 'shallow' drainage depressions in association with 2.1.1 map unit. Watertables are generally fresh occurring at 0.5–1.5 m corresponding to the occurrence of jarosite and/or iron sulfide at >0.5 to 1 m. These soils are poorly drained and subject to seasonal flooding.

Map unit 2.2.2 has clay subsoils and are associated with the ASS clay soils to the west and south west of the area. Soils have jarosite and/or iron sulfide at >0.5 to 1 m.

Map unit 2.3.1 occurs in well defined fresh water swamps and drainage lines generally associated with map units 2.1.1 and 2.2.1. The soils are poorly drained with a sandy subsoil, subject to regular flooding and have jarosite and/or iron pyrite at <0.5 m. Soil salinity often occurs due to evaporation from the shallow brackish watertable and accumulation of salts on the soil surface.

Map unit 2.3.2 occurs as well defined freshwater swamps and drainage lines in the western and south western part of the study area. Soils have jarosite and/or iron pyrite at <0.5 m. These areas are also subject to severe and regular flooding originating from the adjacent urban areas. As for map unit 2.3.1, salinity may be an issue.

Map unit 2.4.1 is associated with brackish swamps and drainage lines in the eastern part of the area. This unit is or was subject to tidal influence. Most of these areas have flood gates to prevent tidal exchange. The soils are saline, very poorly drained clay over sandy subsoils, subject to regular flooding and have jarosite and/or iron pyrite at <0.5 m.

Map unit 2.4.2 mainly occurs in the southern part of the area adjacent to tidal marine wetlands. As for 2.4.1, the soils are saline, very poorly drained clays subject to regular flooding and have jarosite and/or iron pyrite at <0.5 m.

Map units on old high river terraces

The old high river terraces are characteristic of the slightly elevated alluvial plains on the Logan River from Beaudesert to the study area. Much of this area is subdivided into small rural lots.

Map unit 3 has impermeable, acid grey clays that are very deep, imperfectly drained and subject to flooding only in extreme events. Some of the cane growing area has supplementary effluent irrigation.

Map units on low sand ridges

Beach ridge plains with low sand ridges occur in the Jacobs Well area. These beach ridges have originated from wave action during the Pleistocene period (approximately 100 000 years before present) and the last sea level rise (approximately 8–10 000 years before present). Much of the area supports urban development and sand extraction while the remainder is under sugar cane or native vegetation. Fresh watertables occur at shallow depths (<1–1.5 m)

Map unit 4.1 has a sand surface over a conspicuously bleached sand subsurface over a black coffee rock pan at 1–1.5m, corresponding to the depth of the watertable. Soils are freely drained above the watertable. Bare cultivated soil surfaces are subject to regular frosts during cold winter nights due to the pale sandy surface reflecting the suns radiation and soils not heating up adequately to radiate heat at night.

Map unit 4.2 occurs on the edge of the beach ridges and have watertables at <1 m. These soils are often salinised due to the close proximity of the marine wetlands.

Map units on hills and rises

The hills and rises in the study area have been subdivided on geology and landscape position. The Woogaroo Sandstone is confined to isolated hills and rises in the north and eastern parts of the study area. The *Nerenleigh–Fernvale Beds* are metamorphosed sedimentary rocks occurring extensively in the western part.

Map unit 5.1 occurs on sandstones where soils have a loamy surface over moderately permeable, moderately well drained, massive to structured mottled red clay subsoils. Soils may have imperfectly drained mottled yellow subsoils on lower slopes.

Map unit 5.2 is confined to the gently undulating lower slopes of the hills and rises on metamorphosed sedimentary rocks. The hard setting loamy surfaced, acidic sodic texture contrast soils are imperfectly drained and slowly permeable.

Map unit 5.3 occurs extensively on the upper slopes of the hills and rises on metamorphosed sedimentary rocks. The bleached loams and brown texture contrast soils overlie rock at shallow depths, usually with rock fragments throughout the profile.

Suitability Framework

Using procedures described by Land Resources Branch Staff (1990), a framework has been developed to assess the suitability of land in the Woongoolba–Rocky Point area for growing a wide variety of existing and potential crops. The framework is based on a standard set of land use requirements that relate to plant growth, machinery use, land preparation, irrigation and the prevention of land degradation.

Attributes of land that contribute to less than optimal conditions for crop growth/production, for a particular use are known as limitations. Management is concerned with overcoming or reducing the effects of these limitations.

The suitability framework developed for the Maroochy catchment on the Sunshine Coast (Burgess and Wilson, in prep.) was adapted and modified to include extra limitations to agricultural production that apply to certain areas of the Woongoolba–Rocky Point area (Appendix 2). This classification scheme provides a summary of each limitation and describes its effect on plant growth, machinery use and land degradation. It also details the soil/land attributes used in the assessment of each limitation and some background and rationale as to how the limitation subclasses have been determined.

In all, 21 limitations to agricultural and forestry production have been identified as potentially important for soil landscapes on the Rocky Point area. The agricultural and environmental land use requirements associated with each limitation and the soil and land attributes used in their assessment are listed in Table 3 below.

Five land suitability classes have been defined for use in Queensland, with suitability for a particular land use decreasing progressively from Class 1 to Class 5. Land is classified on the basis of a specified land use and a suitable rating assumes production is optimal with minimal degradation to the land resource and wider environment in the long term. The suitability of a particular parcel of land depends directly on the number and severity of limitations associated with the land use being considered. These in turn are determined by the land use requirements of the crop and the inherent characteristics of the land. Final suitability is determined by the most severe limitation.

The severity of each limitation (ie. suitability subclasses on a scale from 1 to 5) has been individually assessed according to the following definitions:

Class 1	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.
Class 2	Suitable land with minor limitations, which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production.
Class 3	Suitable land with moderate limitations which either further lower production or require more than those management practices of Class 2 land to maintain economic production.
Class 4	Marginal land which is presently considered unsuitable due to severe limitations. The long term or precise effects of these limitations on the proposed land use are unknown. The use of this land is dependent upon either undertaking additional studies to determine its suitability for sustained production or reducing the effects of the limitation(s) to achieve production.
Class 5	Unsuitable land with extreme limitations that preclude its use.

Table 3. Land use requirements, limitations and soil and land attributes used in assessing land suitability in the Rocky Point area

Land use requirements	Limitations	Soil and land attributes used to assess each limitation
Frost-free	**frost (cf)**	frequency of damaging frosts, landform, landscape position
Adequate rainfall (rainfed crops only)	**precipitation (cp)**	amount and distribution of rainfall, evaporation, crop modelling
Maximise solar radiation	**solar radiation (cr)**	Prescott Index, DEM, assessment of northern landscape aspects
Avoid environmental harm from acid drainage water from actual acidity	**acid drainage water hazard actual (da)**	texture, depth to oxidisable sulfur (%), presence of existing acidity (pH <4.0)
Avoid environmental harm from acid drainage water from potential acidity	**acid drainage water hazard potential (dp)**	texture, depth to oxidisable sulfur (%), presence of potential acidity
Minimise soil loss from erosion	**water erosion (e)**	slope/soil erodibility (Universal Soil Loss Equation (K factor), soil stability groups)
Absence of damaging floods	**flooding (f)**	depth/frequency of flooding based on average recurrence interval (ARI), flood velocity
Adequate soil aeration	**wetness (w)**	soil drainage and permeability
Level land surface	**microrelief (tm)**	size and proportion of microrelief, microrelief variability
Land surface of acceptable slope for safe machinery use	**topography (ts)**	slope (%), variation in slope length and direction
Adequate water supply	**water availability (m)**	PAWC, ERD, crop modelling
Adequate soil depth for physical support	**soil depth (pd)**	depth to C horizon, hard rock or other impermeable layer; depth to high salt concentrations (>0.8 dS/m), watertable or very low pH (<4.0)
Rock-free	**rockiness (r)**	size and content (%) of coarse fragments, % rock outcrop
Favourable levels of soluble salts	**soil salinity (sa)**	average salt content (dS/m) of the profile (mean, water uptake weighted)
Ability to harvest underground crops	**soil adhesiveness (pa)**	texture, structure, consistence and clay mineralogy of the surface soil (<0.3 m)
Suitable timing for cultivation	**narrow moisture range (pm)**	surface condition, surface soil texture (<0.3 m), soil drainage
Ease of seedbed preparation and plant establishment	**soil surface condition (ps)**	surface condition, surface soil texture and structure (<0.3 m), susceptibility to compaction
Adequate nutrients	**nutrient deficiency (nd)**	nutrient levels in soils
Low nutrient fixing conditions	**nutrient fixation (nf)**	humic/organic material or high levels of free Fe/Al oxides
Adequate retention of added nutrients against leaching	**nutrient leaching (nl)**	soil permeability, absence of shallow watertables (> 1.5 m)
Low levels of toxic elements	**element toxicity (nt)**	soil pH in the surface soil (<0.3 m)

Land is considered less suitable as the severity of limitations for a particular land use increase, reflecting either:

- reduced potential for production; and/or
- increased inputs to achieve an acceptable level of production; and/or
- increased inputs to prevent land degradation.

The combination and severity of limitations identified for a specified land use will determine the final suitability that applies to a particular parcel of land.

The first three classes (1–3) are considered suitable for the specified land use, because the benefits from using the land for that use outweigh the inputs required to initiate and maintain production in the long term. Decreasing land suitability within a location often reflects the need for increased inputs rather than decreased potential production.

Class 4 is marginal land presently considered unsuitable where it is doubtful that the benefits from using the land in the long term will outweigh the inputs required to achieve and maintain sustainable production. It is also used for land where actions to specifically reduce the effect of a limitation may allow the land to be upgraded to a higher suitability class. However, additional studies would be required to determine the feasibility of such actions.

Class 5 is considered unsuitable land due to limitations that in aggregate are so extreme that the benefits from using the land do not justify the inputs required to initiate and maintain production in the long term. It would require a major change in economics, technology or management expertise before the land could be considered suitable for the specified land use. Some class 5 lands (eg. steep escarpments) however will always remain unsuitable for agriculture.

Soil and Landscape Attributes

The land suitability framework (Appendix 2) identifies the soil and land attributes used to determine the severity of the limitations to agricultural land uses in the study area.

Acid drainage hazard - actual (da)

Acid sulfate soils contain iron sulfides. When exposed to air, iron sulfides oxidise and produce sulphuric acid which reacts with the soil. Toxic quantities of acid, aluminium, iron and heavy metals may contaminate land and adjacent waterways when acid sulfate soils are disturbed or drained. Such contamination can injure and destroy aquatic flora and fauna, affect or kill vegetation and crops, and accelerate structural failure of pipes, foundations, bridges and road surfaces.

A soil pH of 4 or less and the presence of jarosite are usually indicators of actual ASS, but pH does not measure the volume of existing or potential acid. Existing acidity can however, present a significant hazard to plant growth, therefore depth to pH <4 is recorded as a polygon based (ie. UMA) attribute only.

The potential for acid drainage was determined for each map unit using the soil acidity (pH<4) and depth (m) to pH<4 from the ASS Mapping (Manders *et. al.,* 2002).

Each UMA was assigned a ***da*** attribute level according to the mapping value that took up the largest area (mode, based on area) using the following rules:

Acid sulfate soil Mapping Code	da Code	Description
A0	0	Soil pH <4 at 0.0–0.5 m
A1	1	Soil pH <4 at 0.5–1.0 m
A2	2	Soil pH <4 at 1–2 m
A3	3	Soil pH <4 at 2–3 m
A4	4	Soil pH <4 at 3–4 m
A5	5	Soil pH <4 at 4–5 m
All others	6	Deeper than 5 m or none at all

Note: * represents all suffixes and/or prefixes

Acid drainage hazard - potential (dp)

Potential acid sulfate soils (PASS) which contain unoxidised iron sulfideas pyrite (FeS_2) may have elevated pH (pH 4.0 to >7.0) and no jarosite. Field testing involves reaction of soil material with peroxide (H_20_2) to rapidly oxidise the iron sulfide and generate acidity. Comparison of field pH changes between the oxidised sample and an unreacted sample provides a guide as to the presence of pyrite. A pH change of at least 1 unit below the field pH may indicate the presence of iron sulfides. PASS is indicated by a pH <3 after reaction with hydrogen peroxide, particularly if accompanied by a visible reaction during oxidation.

Quantitative assessment of the hazard posed by ASS is based on the depth to and quantity of oxidisable sulfur (from unoxidised iron sulfide) for particular texture categories. Depth to oxidisable sulfur levels above the action criteria is recorded as a polygon based (ie. UMA) attribute. Further information on action criteria is available in the sampling guidelines for lowland acid sulfate soils (Ahern 1998) and the ASS soil management guidelines (Dear 2002).

The level and distribution of pyrite (FeS_2) within acid sulfate soils are usually highly variable within the landscape, within the soil profile and from point to point within pyritic layers. Elevation (<5 m), geomorphology (coastal marine plains, swamps) and hydrology (poorly drained horizons) may indicate the spatial extent of the risk.

Potential acid drainage was calculated for each map unit using the action criteria for oxidisable sulfur (or equivalent existing H^+ plus potential acidity) values of 0.03% and depth (m) to the action criteria. All values are derived from the ASS mapping.

Each UMA was assigned a ***dp*** attribute level according to the mapping that took up the largest area (mode, based on area) using the following rules:

QASSIT Mapping Code	dp Code	Description
S0, *SW*	0	>0.03% oxidisable S at 0.0–0.5 m
S1	1	>0.03% oxidisable S at 0.5–1.0 m
S2	2	>0.03% oxidisable S at 1–2 m
S3	3	>0.03% oxidisable S at 2–3 m
S4	4	>0.03% oxidisable S at 3–4 m
S5	5	>0.03% oxidisable S at 4–5 m
All others	6	Deeper than 5m or none at all

Note: * represents all suffixes and/or prefixes

Mapping was then refined by observing the ASS site data and using expert opinion. The following polygons were changed:

RKP2 UMA Number	Change to dp Code	Description
176, 106, 112	0	0.0–0.5 m
20, 25, 82, 195	1	0.5–1.0 m

Climate - rainfall (cp)

Rainfall amount and distribution largely control cropping and grazing productivity, and particularly cropping success in rainfed (dryland) situations. The ***cp*** limitation only applies to crops that can be grown on a regular basis without supplementary irrigation.

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The amount of rainfall, rainfall distribution between years, seasonal distribution of rainfall within years and losses form evaporation have been used to determine if climatic conditions provide adequate rainfall opportunities for:

- successful planting rain events; and
- sufficient in-crop rainfall for crop establishment and growth to produce some level of product that is economic to harvest.

The ability of soils to store moisture is also important, but available soil water capacity simply extends climatic inputs by influencing the amount of time over which rainfall is made available to plants (see m limitation).

The Rocky Point study area falls within the 1100–1200 isohyet. All map units were assigned a value representing a rainfall of 1000–1200 mm per annum.

Solar radiation (cr)

Solar radiation affects the growth potential of plants. Extremes of radiation and temperature may cause stress periods for crops and livestock, particularly where temperate species experience continued high temperatures or tropical species are subject to continued periods of low temperature. The ***cr*** limitation assesses the effect that differences in aspect and elevation (eg. north versus south facing slopes) have on crop productivity. Such differences are the result of variations in:

- the amount of solar radiation received; and
- associated seasonal temperature effects.

This limitation is not concerned with climatic extremes such as frost or heatwaves.

The ***cr*** limitation specifically aims to assess:

- relative differences in the level of solar radiation received due to changes in aspect and elevation; and
- the effect such differences may have on crop productivity.

The Rocky Point study area has a low lying flat to undulating topography and therefore solar radiation is not impeded by surrounding hills. All map units were assigned a value that represented sunny slopes during winter solstice at midday.

Frost (cf)

Frosts may kill plants, suppress growth and reduce yield. The incidence and severity of frosts in relation to landscape position are used to distinguish affected areas.

A meeting with the local landholders was held to discuss the location and frequency of frosting in the Rocky Point study area. This local knowledge was used to develop the frost limitation map. The frost limitation map was then refined according to expert opinion.

Map unit	Area	cf value
1	West	1
2.1*	West	2
2.2*	West	2
2.3*	West	3
2.4*	West	3
3	West	2
4*	West	2
5*	West	1
1	Far west	1
2.1*	West	3
2.2*	Far west	3
2.3*	Far west	3
2.4*	Far west	2
3	Far west	3
4	Far west	2
5.1	Far west	1
5.2	Far west	2
5.3	Far west	1
1	East	1
2*	East	1

Map unit	Area	cf value
3	East	1
4*	East	1
5	East	1

Note: * Represents all suffixes

Water erosion (e)

Land degradation and long term productivity decline will occur on unprotected sloping arable land due to excessive soil erosion.

Soil loss will depend on soil drainage characteristics, surface and subsoil erodibility, land slope, land use (ie. particular crop) and agronomic management (eg. surface management system). Soil surface condition, infiltration and soil permeability largely determine the potential for runoff from a soil, while rainfall intensity, slope (gradient and length), surface cover and inherent erodibility/soil stability influence the extent and severity of erosion.

For a particular soil type there is a maximum slope above which soil loss cannot be controlled to within acceptable levels (<10 t/ha/yr), either by erosion control measures or surface management practices. Assessment of this limitation (see slope categories and suitability subclasses listed in Appendix 2) assumes standard surface management and erosion control measures are practised (eg. stable sward management under orchards, cover crops and surface residue management in cultivated crops, graded/parallel rows and/or banks etc.). Suitable slope categories listed for each land use (subclasses 1–3) are based on soil conservation research, predicted soils loss using the Universal Soil Loss Equation (USLE), and experience, and represent the slope limits below which soil loss will be within acceptable limits (<10 t/ha/yr).

Soil stability was assigned to map units originally described by Forster (1989) and the following rules from expert opinion:

Map unit	Soil Stability Code	Description
1	2	Stable soils
2	2	Stable soils
3	2	Stable soils
4	2	Stable soils
5.1	2	Stable soils
5.2	3	Unstable soils
5.3	3	Unstable soils

Slope was calculated from a digital elevation model (DEM – refer to ts: Slope), the slope was averaged for each map unit and then categorised according to the suitability scheme.

Flooding (f)

Flood events typically involve inundation from overbank stream flows (or associated backup waters) for periods of at least 1–2 days to a week for major floods. The effects of flooding include yield reduction or plant death caused by anaerobic conditions and/or high water temperature and/or silt deposition during inundation. Other effects include physical removal of or damage to the crop by flowing water, floodplain erosion and damage to infrastructure such as irrigation equipment. The permanency of the crop (eg. mature tree crop versus short-lived small crops) and the relative difficulty and cost of replacement following flood damage also need to be considered.

Average recurrence interval (ARI), which is a measure of flood frequency, is useful in distinguishing between suitable and unsuitable land in situations where either flood frequency is extreme or crops are particularly intolerant.

Flood modelling data for planning and infrastructure purposes was not in a format suitable for suitability assessment and therefore, was not readily available. A meeting with the local landholders was held to discuss the location and frequency of flooding in the Rocky Point study area. This local knowledge was used to develop the flooding limitation map which was then refined according to expert opinion.

The following rules were applied.

Land unit	F value
1	3
2.1*	1
2.2*	2
2.3*	3
2.4	3
3	1
4	0
5	0

Note: * Represents all suffixes

Moisture availability (m)

PAWC

Plant yield can be severely affected by periods of water stress, particularly during critical growth periods.

Plant available water capacity (PAWC) is used as a measure of the amount of soil water available to plants within the effective rooting depth. PAWC is based on predicted values (Littleboy 1997, Shaw and Yule 1978) modelled using inputs that include particle size analysis (clay, silt and sand %), 15 bar measurements and the % of coarse fragments in the profile. Generally, soil texture (clay %) has the largest influence on PAWC. The influence of fresh watertables on PAWC is based on the depth at which the watertable resides during most of the year (particularly through the drier months) and the corresponding length of time this occurs within the root zone. A fresh watertable within or immediately below the root zone can supply significant water for crop growth irrespective of PAWC.

Rooting depth and PAWC were inferred for each site using soil morphological descriptions, field tests and laboratory analysis. PAWC for each UMA was calculated by taking the average PAWC for each site within the polygon. The data was reviewed and updated as required according to expert opinion.

For UMAs with no site data, PAWC was assigned using values from surrounding similar UMAs and also from expert opinion. For map units with little or no site data, the following general rules were applied:

Map unit	Criteria	PAWC
1	All	5
5.1*	All	2
5.2*	All	3
5.3*	All	5

Note: * Represents all suffixes

Depth to fresh watertable

Depth to watertable was inferred for each site using site descriptions, soil morphology and interpreted ASS data (Appendix 3). Depth to watertable for each UMA was calculated by averaging the watertable depth for each site within the polygon.

Depth to water was inferred for UMAs with no site data, according to surrounding similar map units, depth to PASS and Rooting Depth.

Once depth to watertable was calculated, a decision was made as to whether the watertable was salty or fresh based on the lab $EC_{1:5}$ (soil: water) values. If an $EC_{1:5}$ (soil: water) value of greater or equal to 0.60 dS/m was recorded below the watertable, then the watertable for that site was considered salty. The number of salty and fresh watertable sites were summarised for each UMA and the most dominant value was used for the whole polygon.

For UMAs which did not have site data to determine if the watertable was salty or fresh, the watertable was determined to be salty or fresh according to similar surrounding UMAs.

Final Moisture Limitation

Plant available water capacity and depth to fresh watertable were combined to determine the overall moisture availability of each map unit.

Nutrient deficiency (nd)

Reduced crop growth may be associated with nutrient deficiencies (ie. restricted levels of one or more available soil nutrients) in certain soils. Addition of fertilisers is an accepted practice for many land uses. This limitation is used where nutrient levels are inherently low and amelioration to improve soil fertility and crop yield requires large initial fertiliser application. Fertility data from the original study (Holz 1979) indicates some of the unfertilised soils require additional phosphorus and potassium application. The level of application will depend on the type of land use and intensity of production proposed.

Limitation classes for nutrient deficiency (Appendix 2) are based on critical levels of phosphorus and potassium. Undeveloped soils low in mineral nutrients, particularly P and K, will require additional fertiliser initially (or the addition of aglime or sulfate fertilisers to correct low P availability associated with low pH <4.5 or high pH 7.0–8.5 respectively) for cultivated crops and sown pastures. Nitrogen was not considered as large initial application rates are usually not necessary due to the rapid mineralisation of soil organic matter. Trace elements were not considered as they represent a minor cost to production.

Nutrient fixation (nf)

Reduced crop growth may be associated with nutrient deficiencies (ie. restricted levels of one or more available soil nutrients) caused by the fixation of mineral nutrients in certain soils. Livestock production may also be affected under such conditions as a result of reduced pasture yield and/or pasture quality and/or lowered nutrient intake in animals.

Soil nutrient fixation assesses the need for additional fertiliser treatment in excess of standard application rates and practices. Humose and/or organic horizons (Isbell 1996) within some soils have the potential to adsorb nutrients such as phosphorus and limit its supply for crop use. Soils high in free iron (which do not occur in the study area) suffer similar problems with phosphorus fixation and phosphorus availability.

Soils in the study area subject to specific nutrient fixation (***nf*** limitation) problems, including:

- sorption of phosphorus in humose/organic soils (eg. Podosols, some Redoxic Hydrosols)

Clearing and long term cultivation can dramatically change surface soil organic matter levels. Undisturbed soils under native vegetation may have (depending on soil morphology) different soil organic matter levels compared to disturbed sites. Therefore, certified Regional Ecosystem Mapping, Version 5.0, current as of 12 March 2007 was used to determine areas under remnant vegetation. Polygons that had over 50% mapped as remnant vegetation were considered to be under remnant vegetation. Polygons with an area <50% mapped as remnant vegetation were not considered to be under remnant vegetation.

The following rules were then applied to infer nutrient fixation.

Map uunit	Under remnant vegetation	nf Code	Description
1	Either	1	Soils that are not humic/organic or high in free iron/aluminium oxides
2*	Yes	2	Humic/organic soils (coastal swampy soils)
2*	No	1	Soils that are not humic/organic or high in free iron/aluminium oxides
3	Either	1	Soils that are not humic/organic or high in free iron/aluminium oxides
4*	Either	1	Soils that are not humic/organic or high in free iron/aluminium oxides
5*	Either	1	Soils that are not humic/organic or high in free iron/aluminium oxides

Note: * Represents all suffixes

In the Rocky Point area, the Redoxic Hydrosols associated with the alluvial plains and swamps (map unit 2.1, 2.2, 2.3, 2.4) originally had humic surfaces under native vegetation. The brackish swamps are the main unit with remnant vegetation. Long term cultivation resulting in the reduction of organic matter and the long term application of fertiliser has alleviated any phosphorus fixation problems.

Nutrient leaching (nl)

Reduced crop growth may be associated with nutrient deficiencies (ie. restricted levels of one or more available soil nutrients) caused by the severe leaching of mineral nutrients in certain soils. Livestock production may also be affected under such conditions as a result of reduced pasture yield and/or pasture quality and/or lowered nutrient intake in animals.

Soil nutrient leaching assesses the need for fertiliser treatment in excess of standard application rates and additional practices to reduce the loss of nutrients through leaching. Soils that are highly permeable (coarse sandy soils of map unit 4) to depths greater than the effective rooting depth have a high leaching potential. Loss of applied nutrients from the root zone often occurs in such soils. In some situations, improved drainage characteristics may modify the leaching potential for a particular soil (eg. a shallow watertable within the effective rooting depth can provide leached nutrients to plants).

Depth to watertable was determined for each site using site descriptions, soil morphology and interpreted ASS data. Depth to watertable for each UMA was calculated by averaging the watertable depth for each site within the polygon.

For soils subject to nutrient leaching (***nl*** limitation), specific problems assessed include:

- low nutrient retention capacity associated with high leaching rates.

Depth to watertable was inferred for UMAs with no site data, according to surrounding similar map units, depth to PASS and rooting depth.

The following rules were then applied to highly permeable soils to infer nutrient leaching:

Map unit	Depth to Watertable	nl
1	N/A	1
2*	N/A	1
3	N/A	1
4.1	>=1.5	2
4.1	<1.5	1
4.2	N/A	1
5*	N/A	1

Note: * Represents all suffixes

Element toxicity (nt)

Reduced crop growth may be associated with the oversupply or toxicity (ie. excessive levels) of some mineral nutrients, particularly where soil pH is low (pH <5.5). Livestock production may be also be affected under such conditions as a result of reduced pasture yield and/or pasture quality and/or lowered nutrient intake in animals.

Soil element toxicity assesses the need for additional soil treatment in excess of standard practices. Low pH affects nutrient availability and some elements such as aluminium and manganese become toxic at very low pH levels. Applications of lime to correct toxicity problems in the surface soil (0–0.3 m) can be undertaken at relatively low cost in most cropping situations. Due to the relatively low returns per unit area for sown pastures however, aglime is unlikely to be a cost effective option and species selection should consider adaptation to low pH conditions (especially in the case of legumes).

For soils subject to element toxicity (***nt***), specific problems assessed include:

- low pH <5.5 in the surface soil (ie. strongly acidic surface soil to 0.3 m) as an indicator of possible element toxicity (particularly Al and/or Mn).

Surface pH was used to indicate element toxicity. Soil pH was measured in the laboratory using a 1:5 soil/water sample. The lowest recording of pH within the top 0.3 m of the soil profile was used to determine the surface pH of the site. Element toxicity was then calculated for each UMA by averaging all surface pH values within the polygon.

Surface pH was inferred for UMAs with no site data, according to surrounding similar map units and ASS mapping (Manders *et. al.* 2002).

Soil adhesiveness (pa)

Soil adhesiveness can cause harvest difficulties with underground root and stem crops, and can affect the quality and treatment of harvest material (***pa***). In addition, adhesive soils are prone to significant levels of soil disturbance during harvest and may be subject to increased compaction and declining structural stability. This limitation applies only to sweet potato within the Rocky Point area.

Indicative soil morphological properties such as texture, structure, sand fraction, clay mineralogy and sub-surface cation chemistry (eg. whether the soil to 0.3 m is sodic) are used to group soils on the basis of inherent adhesiveness. These characteristics of the soil are then evaluated in terms of local landholder/industry experience and typical harvest techniques.

The soil adhesiveness categories used in the assessment of this limitation are defined as:

Soil adhesiveness categories		Inherent soil morphological properties affecting adhesiveness
pa1	No restrictions	Strongly structured surface soils high in free iron (Ferrosols); sandy surfaced soils (<SL) low in organic matter; humic surface soils very high in organic matter.
pa2	Slightly adhesive soils	Moderate to strong surface structure (granular or blocky) with a soft, firm or weakly hard setting surface condition (friable Dermosols).
pa3	Moderately adhesive soils	Moderately strong hard setting, massive to weak (granular, blocky) surface structure (silty or fine sandy textured soils)
pa4	Strongly adhesive soils	Sticky and/or sodic clay within 0.3 m of the surface (within the plough zone) (non-cracking/cracking clays Dermosols/Vertosols)

Clearing and long term cultivation can dramatically change surface soil adhesiveness through destruction of soil structure, removal of organic matter and mixing of clay subsoils. Undisturbed soils under native vegetation may have (depending on soil morphology) different soil adhesiveness compared to disturbed sites. Therefore, certified Regional Ecosystem Mapping, Version 5.0, current as of 12 March 2007 was used to determine areas under remnant vegetation. Polygons that had over 50% mapped as remnant vegetation were considered remnant vegetation. Polygons with an area <50% mapped as remnant vegetation were not considered to be under remnant vegetation.

In the Rocky Point area, the Redoxic Hydrosols associated with the brackish swamps (map unit 2.4) originally had relatively thick humic surfaces under native vegetation with no restrictions on soil adhesiveness. The brackish swamps are the main unit with remnant vegetation. Under long term cultivation and the mixing of the relatively thin humic surface with the clay subsoil for the other Redoxic Hydrosols associated with the alluvial plains and swamps (map unit 2.1, 2.2, 2.3), moderate soil adhesiveness results.

The following rules were then applied to infer soil adhesiveness:

Map unit	Veg	pa Code	Description
1	Either	1	No restrictions
2.1*	Either	3	Moderately adhesive surface soil (0–0.3 m)
2.2*	Either	3	Moderately adhesive surface soil (0–0.3 m)
2.3*	Either	3	Moderately adhesive surface soil (0–0.3 m)
2.4*	Yes	1	No restrictions
2.4*	No	2	Slightly adhesive surface soil (0–0.3 m)
3	Either	4	Strongly adhesive surface soil (0–0.3 m)
4*	Either	1	No restrictions
5.1	Either	2	Slightly adhesive surface soil (0–0.3 m)
5.2	Either	3	Moderately adhesive surface soil (0–0.3 m)
5.3	Either	3	Moderately adhesive surface soil (0–0.3 m)

Note: * Represents all suffixes

Soil depth (pd)

Shallow soils limit root proliferation and anchorage. Plants may lodge or become uprooted during strong winds.

Effective soil rooting depth is defined as the:

- depth to decomposing rock (C horizon), hard pan or other impermeable layer (very slowly permeable);
- depth to high salt concentrations ($EC_{1:5}$ >0.8 dS/m, often associated with strongly alkaline pH >8.5 and strongly sodic subsoils); or
- depth to very strongly acid subsoil material (pH <4.0); or
- depth to watertable.

Rooting depth was inferred for each site using soil morphological descriptions, field tests and laboratory analysis. The soil depth for each UMA was calculated by taking an average of all rooting depth values within the polygon. A maximum rooting depth of 1.5 m was used in the calculation; any values greater than 1.5 m were adjusted to equal 1.5 m.

For UMAs with no site data, soil depth was inferred according to surrounding similar map units; depth to PASS; depth to AASS (ph<4.0); depth to watertable; wetness at 0.5 m, 1.0 m and 1.5 m; or expert opinion.

The following rules were applied for Map units 5.2 and 5.3:

Map unit	pd Code	Description
5.2	2	Moderately deep soil (0.5 to <1 m)
5.3	3	Shallow soil (0.25 m to <0.5 m)

UMA rooting depth was calculated for each site using rules for calculating rooting depth in the Maroochy catchment on the Sunshine Coast (Chamberlain and Wilson 2007).

Narrow moisture range (pm)

The workability limitation relates to the ease and timeliness with which a soil may be cultivated. Successful soil tillage depends largely on the inherent characteristics of the surface soil as it dries following a wetting cycle and the length of time during which the moisture range of the surface material is appropriate for mechanical disturbance. The time period following rainfall or irrigation during which a soil is capable of being successfully cultivated to achieve favourable seedbed conditions (ie. adequate depth of ploughed layer and favourable tilth) is known as the tillage window.

Some soils have only a narrow tillage window while other soils may be cultivated at any time. Such differences relate directly to the inherent morphological properties of the surface soil including texture, structure, sand fraction, clay mineralogy and sub-surface cation chemistry (eg. soil sodicity to 0.3 m). How easily a soil works up and the width of the tillage window become particularly important for crops where land preparation is required to fit a distinct cropping cycle, such as strictly defined planting times. Typically, workability is only an issue for crops that require cultivation on a regular basis (ie. annually). As such, it is largely irrelevant for perennial tree and vine crops.

Local landholder or industry experience is a valuable guide to problems associated with certain soils in a district or for particular land uses. Assessment of this limitation attempts to identify soils where only a narrow timeframe exists between when soils are too wet and then too dry to undertake tillage. Assessment is land use specific due to the different tillage requirements of different crops.

Inherent soil workability categories used in the assessment of this limitation are defined as:

Moisture range/workability categories		Inherent soil morphological properties affecting workability
pm1	No restrictions	Strongly structured surface soils high in free iron (Ferrosols); sandy surfaced soils (<SL) low in organic matter; humic surface soils very high in organic matter; moderate to strong surface structure (granular or blocky) with a soft, firm or weakly hard setting surface condition (friable Dermosols).
pm2	Moderate moisture range	Moderately strong hard setting, massive to weak (granular, blocky) surface structure (silty or fine sandy textured soils)
Pm3	Narrow moisture range	Sticky and/or sodic clay within 0.3m of the surface (within the plough zone) (non-cracking/cracking clays Dermosols/Vertosols)

Narrow moisture range was based on map units described by Forster (1989) and expert opinion.

The following rules were applied to infer narrow moisture range:

Map unit	pm Code	Description
1	1	No restriction - cultivation at any moisture range
2*	2	Moderate moisture range for timing of cultivation
3	3	Narrow moisture range for timing of cultivation
4*	1	No restriction - cultivation at any moisture range
5.1	1	No restriction - cultivation at any moisture range
5.2	2	Moderate moisture range for timing of cultivation
5.3	2	Moderate moisture range for timing of cultivation

Note: * Represents all suffixes

Surface condition (ps)

Problems with germination and seedling development during crop establishment are typically associated with adverse physical conditions in the surface soil, such as hard setting behaviour, coarse aggregates and crusting.

Soils with indicative morphological properties are evaluated in the context of local landholder or industry experience, particularly planting techniques and planting material (eg. seed versus vegetative planting, seed size, length of crop cycle between plantings etc). Typically, local experience provides a useful guide to problem soils and their characteristics within a particular district. This will vary from district to district due to changes in geology, soil type and dominant land use, as well as local differences in agronomic management.

Inherent surface condition categories used in the assessment of this limitation are defined as:

Surface condition categories		Inherent soil morphological properties affecting surface condition
ps1	No restrictions	No restriction to seedling emergence and/or establishment
ps2	Hard setting low strength surface soils	Hard setting massive soils with sandy loam to clay loam surface textures with dry moderately firm consistency – medium to coarse sand fraction
ps3	Hard setting moderate strength surface soils	Hard setting massive soils with fine sandy loam to clay loam fine sandy surface textures with dry very firm consistency
ps4	Hard setting high strength surface soils	Crusting soils – silty surfaced or sodic <0.3 m
ps5	Coarse surfaced soils with poor seed soil contact	Large aggregate size >20 mm – either coarsely structured clays or soils with very coarse blocky surface structure

Clearing and long term cultivation can dramatically change surface condition through destruction of soil structure, removal of organic matter and mixing of clay subsoils all resulting in hard setting surfaces or coarse structure. Undisturbed soils under native vegetation may have (depending on soil morphology) different soil surface properties compared to disturbed sites. Therefore, certified Regional Ecosystem Mapping, Version 5.0, current as of 12 March 2007 was used to determine areas under remnant vegetation. Polygons that had over 50% mapped as remnant vegetation were considered to be under remnant vegetation. Polygons with an area <50% mapped as remnant vegetation were not considered to be under remnant vegetation.

The following rules were then applied to infer soil condition:

Map unit	Veg	ps Code	Description
1	Either	1	No restrictions
2.1*	Either	2	Hard setting massive soils with sandy loam to clay loam sandy surface (medium to coarse sand)
2.2*	Either	2	Hard setting massive soils with sandy loam to clay loam sandy surface (medium to coarse sand)
2.3*	Either	2	Hard setting massive soils with sandy loam to clay loam sandy surface (medium to coarse sand)
2.4*	Yes	1	No restrictions
2.4*	No	2	Hard setting massive soils with sandy loam to clay loam sandy surface (medium to coarse sand)
3	Either	1	No restrictions
4*	Either	1	No restrictions
5.1	Either	2	Hard setting massive soils with sandy loam to clay loam sandy surface (medium to coarse sand)
5.2	Either	3	Hard setting massive soils with fine sandy loam to clay loam fine sandy or silty clay loam surface (fine sand or silt)
5.3	Either	3	Hard setting massive soils with fine sandy loam to clay loam fine sandy or silty clay loam surface (fine sand or silt)

Note: * Represents all suffixes

In the Rocky Point area, the Redoxic Hydrosols associated with the brackish swamps (map unit 2.4) originally had relatively thick humic surfaces under native vegetation with no restrictions on soil surface condition. The brackish swamps are the main unit with remnant vegetation. Under long term cultivation and the mixing of the relatively thin humic surface with the clay subsoil for the other Redoxic Hydrosols associated with the alluvial plains and swamps (map unit 2.1, 2.2, 2.3), hard setting soils surface condition results.

Rockiness (r)

Coarse fragments (eg. pebbles, gravel, cobbles, stones and boulders) and rock in the plough zone can damage and/or interfere with the efficient use of agricultural machinery. Surface gravel, stone and rock are particularly important for root crops, macadamias, small crops, annual forage crops and sugar cane. Typically gravel, stone and rock only affects tree crops during ground preparation and planting. Macadamias are an exception however, because gravel can interfere significantly with harvest operations.

Assessment is based on the size, abundance and distribution of coarse fragments in the plough layer (McDonald *et. al.* 1990). Machinery tolerance to damage caused by rock and stone and farmer tolerance to stone or rock size and content are also important.

The following rules were applied to map units based on site data and observations:

Map unit	r Code	Description
1	0	No rocks
2*	0	No rocks
3	0	No rocks
4*	0	No rocks
5.1	0	No rocks
5.2	23	Medium gravel (6–20 mm), abundance 10–20%
5.3	44	Cobble (60–200 mm), abundance 20–50%

Note: * Represents all suffixes

Topography microrelief (tm)

Microrelief such as melon holes, swamp hummock, rills and small gullies cause irregular and reduced crop productivity. This mainly results from uneven water distribution (eg. water ponding in depressions), irregular cultivation and impeded trafficability. Effects associated with the presence of microrelief such as temporary waterlogging and poor surface condition are covered in the wetness (w) and soil physical (ps) limitations respectively.

In most cropping situations, levelling of uneven surface relief across a paddock is normally required:

- to improve access for cultivation and other agronomic activities (eg. planting, spraying, harvesting etc); and
- to improve irrigation efficiency and surface drainage.

The vertical interval (VI) of the microrelief typically dictates the amount of levelling required and/or the potential for reduced productivity.

Topography microrelief was based on Map units, land use (cultivation) and expert opinion. Only uncultivated map unit 3 (old high river terraces with acid grey clays) has gilgai microrelief. Any land under remnant vegetation was assumed to have microrelief.

The area under cultivation was determined using the South East Queensland 1999 Landuse mapping. Secondary land use areas ‘cropping’ and ‘irrigated cropping’ were considered under cultivation. All other secondary land uses were not considered cultivation.

Any polygon that had >50% under cultivation was considered under cultivation for the whole UMA. Polygons with an area <50% under cultivation were considered not to be under cultivation for the whole UMA. The following rules apply:

Map unit	Cultivation	tm code
3	Yes	1
3	No	2
All others (not 3)	Either	1

Topography slope (ts)

The safety and/or efficiency of farm vehicle operation are affected by:
- steep gradients in relation to roll stability and side-slip; and
- erosion control layouts on land with significant variability in the degree and direction of slopes (eg. complex slopes). It is particularly important with row crops where final layouts on such lands will involve short rows and sharp curves.

Assessment is based on:
- steepness of slope in relation to safety and efficiency;
- variation in slope causing short rows in erosion control layouts; and
- variation in slope direction causing excessive row curvature in erosion control layouts.

Percent slope was calculated from a hydrologically corrected 25 m DEM that was created from 1:25 000 drainage and 5 m contour lines, a coastline (used as a zero contour), and a water bodies layer.

The average slope was calculated for each UMA (using all cells falling within the UMA area).

Wetness (w)

Waterlogged soils reduce plant growth and delay effective machinery operations.

Internal and external drainage are assessed. Indicator attributes of internal drainage include texture, grade and type of structure, soil colour, mottles, segregations and impermeable layers. Drainage class and soil permeability (McDonald *et. al.* 1998) are assessed separately for summer and winter land uses to depths of 0.5 m, 1.0 m and 1.5 m. This allows for seasonal variability in soil wetness and better matches assessments of effective rooting depth for various crops

Drainage and permeability to 1.5 m was calculated per site using the Maroochy catchment rules (Burgess and Ellis, in prep). Drainage and permeability was inferred for each site using soil morphological descriptions, field tests and laboratory analysis.

Drainage and permeability to 1.5 m was calculated for each UMA by using the mode drainage and permeability value (where two values had equal occurrences, the more conservative approach was taken by using the larger value).

For UMAs with no sites or no data (and no general rules above), w1 was inferred from similar map unit in the surrounding area.

The following general drainage and permeability rules for w1 (wetness to 1.0 m) and w2 (wetness to 0.5 m) were applied to the following Map units (and these were used in preference of the calculated data):

Map unit	Drainage 1 m (w1)	Permeability 1 m (w1)
5.1	5	3
5.2	3	2
5.3	4	3

Map unit	Drainage 0.5 m (w2)	Permeability 0.5 m (w2)
5.1	5	3
5.2	3	2
5.3	4	3

The following general drainage and permeability rules for w3 (to1.5 m) were applied to the following map units (and these were used in preference of the calculated data):

Map unit	Drainage 1.5 m (w3)	Permeability 1.5 m (w3)
5.1	4	3
5.2	3	2
5.3	4	3

Salinity (sa)

Salinity refers to the presence of soluble salts in the soil profile. In many landscapes across Queensland inherent salt loads may exist at some depth within the upper 2 m of the regolith. Salt loads can originate from:

- the weathering of minerals in the underlying substrates;
- marine sediments;
- cyclic salt (windblown ocean salt) that has accumulated in slowly drained, relatively low relief landscapes.

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The dominant salt in coastal soil landscapes that are subject to higher rainfall and greater leaching is sodium chloride (NaCl). Sulfate salts (SO_4^{2-}) are also common in coastal ASS originating from the oxidation of iron sulfides in the soil and the release of sulphuric acid, and soluble aluminium and iron (Rosicky *et al.* 2006). Low solubility salts such as gypsum (calcium sulfate) are restricted to low rainfall catchments further west and have not been considered in this study.

Soluble salts within the root zone (defined as the upper 1.5 m of the soil profile) are measured either as $EC_{1:5}$ (dS/m) or soluble chloride (Cl ppm) values at standard depths down the profile. Significant levels of soluble salts in the profile can affect plants through:

- osmotic effects that limit water uptake;
- toxicity effects associated with specific ions (principally sodium chloride); and
- restrictions on root development down the profile.

Because of these effects, profile salinity (>0.8 dS/m 1:5 soil water) within the root zone (1.5m or shallower where rock or impermeable layers or watertable) forms an important criteria in the assessment of effective rooting depth (ERD). Estimated water table rooting depth also affects plant available water capacity (PAWC) (see the ***m*** limitation).

Because plant response and effects on crop yield are species specific, comparisons of average weighted root zone salinity values with yield reduction data (Salcon 1997) have been considered as part of this limitation. Forestry timber tree (Blackbutt, Dunn's gum, flooded gum, Gympie messmate, spotted gum) yield reductions were interpreted from the literature (House *et al.* 1998), Sun and Dickinson 1993). The average weighted root zone salinity value (ECse dS/m) was calculated from all 0.1 m depth increments to a depth of 0.9 m (or to ERD if shallower) from site analytical data ($EC_{1:5}$) and converted to ECse (electrical conductivity saturation extract) using soil texture and conversion factors (Salcon 1997). Site ECse in each UMA was than averaged to give a UMA average weighted root zone salinity value.

Rocky Point soils with significant salt loads in the upper profile (ie. ***sa*** 5 – ***sa*** 9) are generally associated with brackish swamps and areas subject to current or past tidal inundation. Some previously tidal areas are currently not subject to tidal inundation due to the construction of bund walls or flood gates.

Results

Modelled soil and landscape attributes

The fuzzy modelling approach used to predict the distribution of soil attributes within the landscape in a predictable and testable form relate directly to land management inputs and therefore limitations of the land for a particular use.

Climate (frost)

Anecdotal evidence, local knowledge and a few direct observations were used to predict the incidence and severity of frosts. Frosts occur most severely on valley flats in the western part of the study area. Frosts generally decrease in intensity and occurrence with increasing elevation and proximity to the coast. Figure 3 shows a typical distribution.

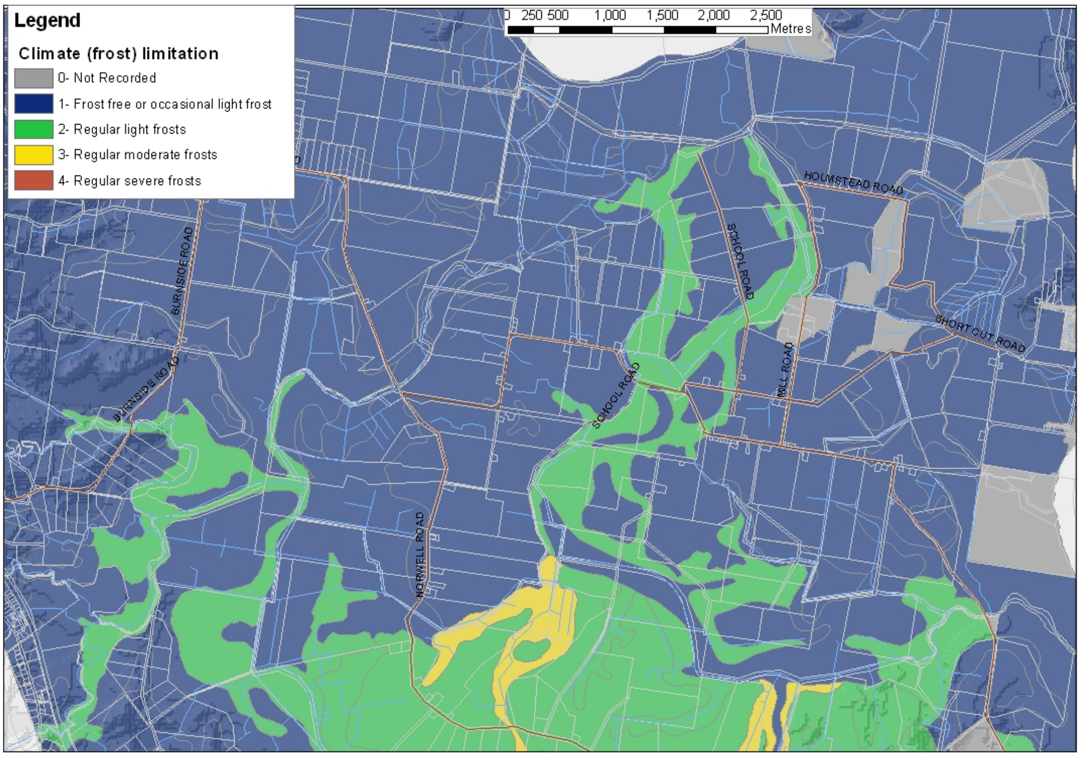

Figure 3. Distribution of frost in the study area

Rockiness

Rock fragments (size and amount) are likely to inhibit most land uses in the steeper upper slope and crest positions of the gently undulating low hills and rises on sandstones of the *Woogaroo Formation,* and upper slopes of gently undulating to undulating low hills and rises on *Nerenleigh–Fernvale Beds*. Figure 4 shows a typical distribution.

Figure 4. Distribution of rock size and amount in the study area

Rooting depth

Rooting depth in the study area is mainly limited by shallow soils, poor drainage and very low pH (<4.0) at shallow depths. Crest positions and steep upper slopes on the gently undulating to undulating low hills and rises on *Nerenleigh–Fernvale Beds* will have shallow rooting depths. This limits land uses other than pastures, horticultural small crops and sugar cane. Rooting depth is also limited to <0.5 m on map units 2.3 and 2.4 by poor drainage and very low pH (<4.0). High soil salinity also effectively limits rooting depth in map unit 2.4. Figure 5 shows a typical distribution.

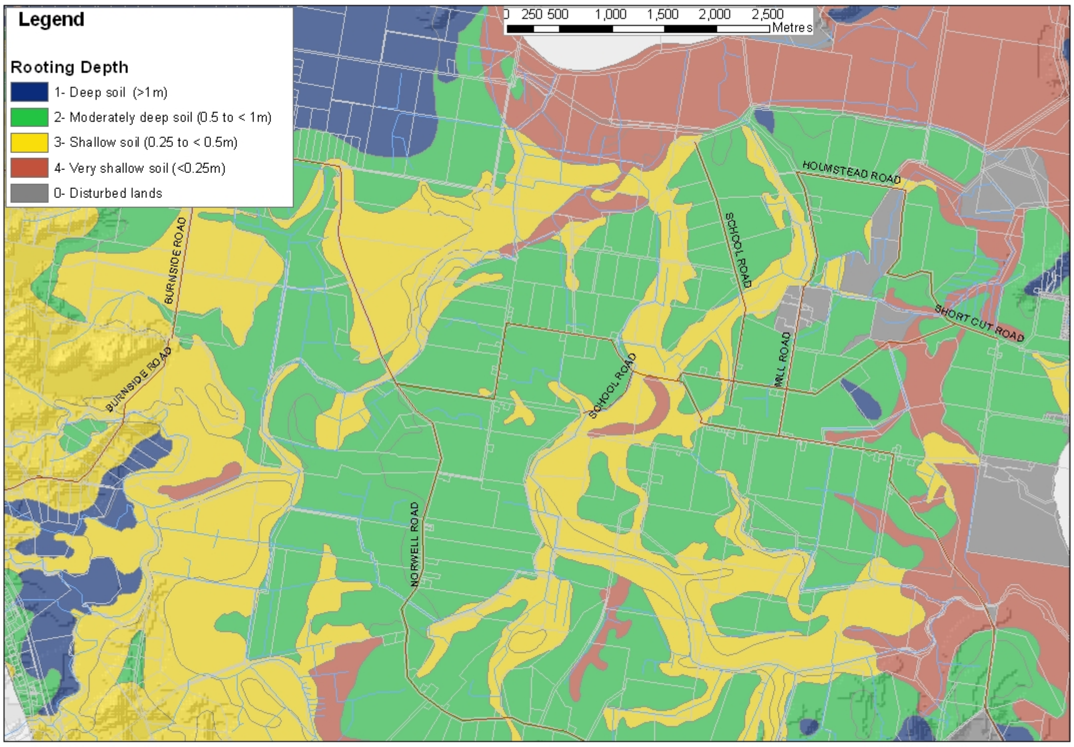

Figure 5. Distribution of rooting depth in the study area

Wetness

Soil drainage and permeability is mainly influenced by landscape and landscape position. The study area is dominated by soils with poor drainage.

Areas dominated by Red Dermosols on sandstones of the *Woogaroo Formation* (map unit 5.1) are typically moderately permeable and well drained to moderately well drained. The Tenosols on the upper slopes of the undulating low hills and rises on *Nerenleigh–Fernvale Beds* are moderately permeable and moderately well drained (map unit 5.3) becoming slowly permeable and imperfectly drained on lower slopes (map unit 5.2).

On the level alluvial plains, poorer drainage characteristics predominate. In general, the acid clays of the older river terraces (map unit 3) are slowly permeable and imperfectly drained. Slight elevation differences on the alluvial plains (map unit 2) determine subsurface drainage. The Redoxic Hydrosols on slightly elevated plains (map unit 2.1 mainly in the Woongoolba area and minor terraces of the Albert and Logan Rivers) are moderately permeable, imperfectly drained in the surface becoming poorly and very poorly drained (corresponding to watertables) at depths generally at 1–1.5 m. The ‘shallow’ drainage depressions (map unit 2.2) become poorly drained at 0.5–1.0 m while the well defined drainage depressions (map units 2.3, 2.4) are poorly drained at <0.5 m.

The Podosols of the beach ridges (map unit 4) are highly permeable and well drained in the surface but become poorly drained at 1–1.5 m corresponding to the depth of the coffee rock pan. These soils become poorly drained near the surface where they adjoin marine wetlands.

Figures 6–8 show a typical distribution of soil drainage at 0–0.5, 0–1.0 and 0–1.5 m respectively while Figures 9–11 show permeability at 0–0.5, 0–1.0 and 0–1.5 m respectively in the study area.

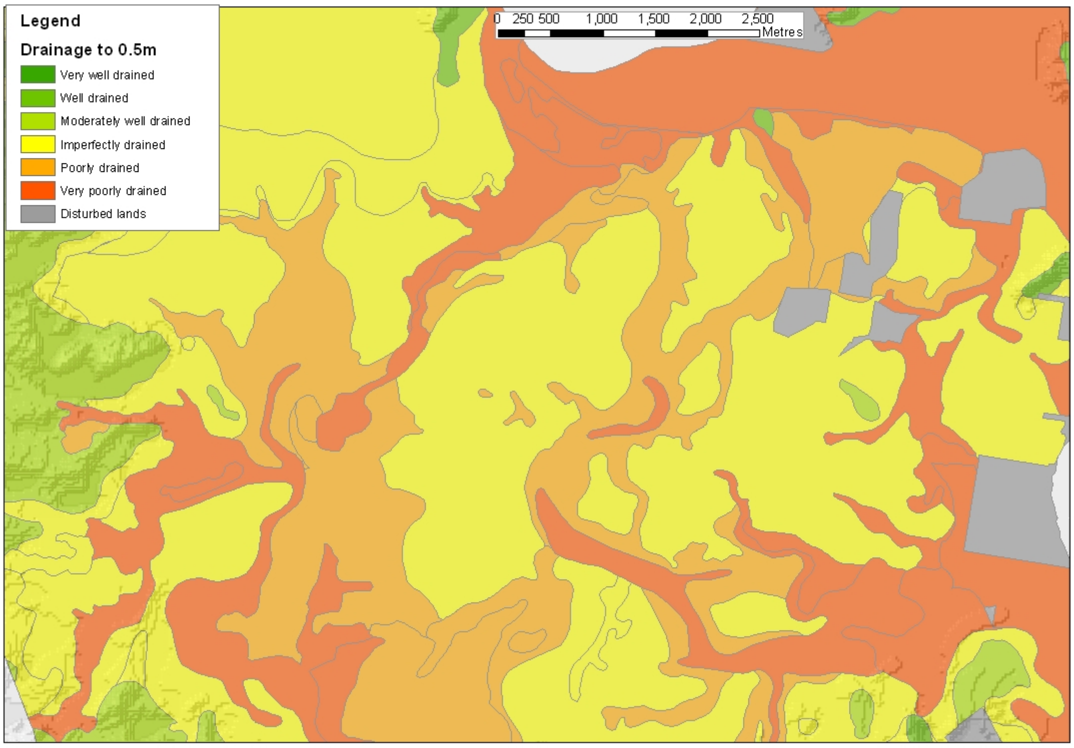

Figure 6. Distribution of soil drainage at 0–0.5 m in the study area

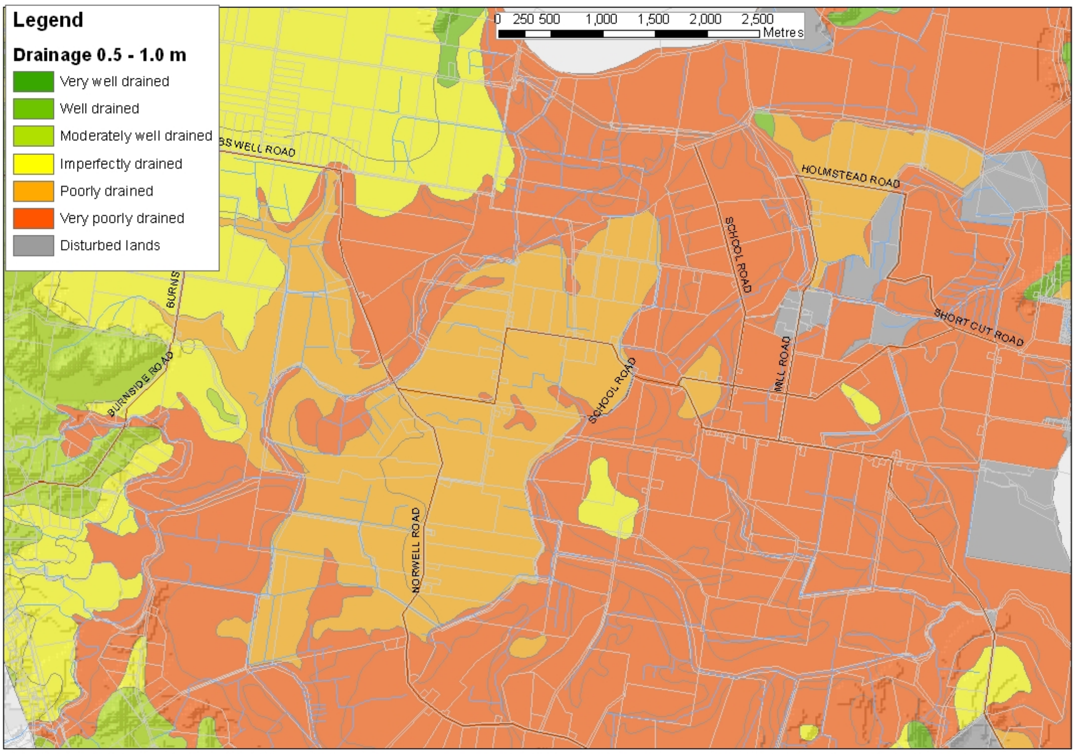

Figure 7. Distribution of soil drainage at 0–1.0 m in the study area

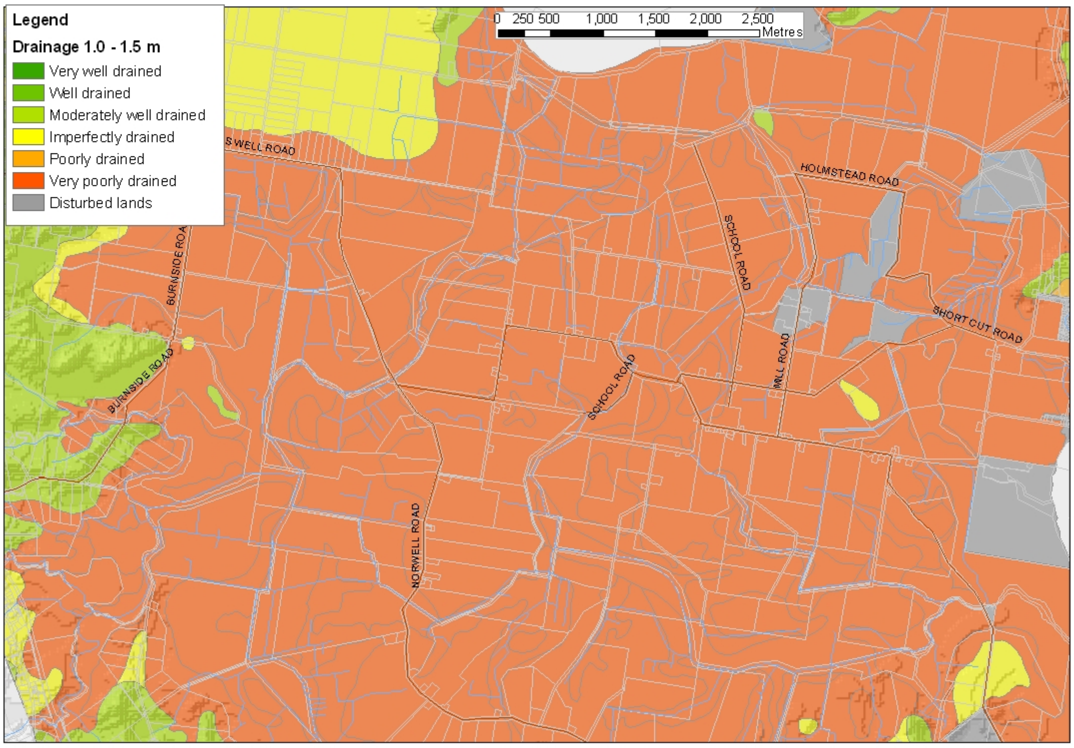

Figure 8. Distribution of soil drainage at 0–1.5 m in the study area

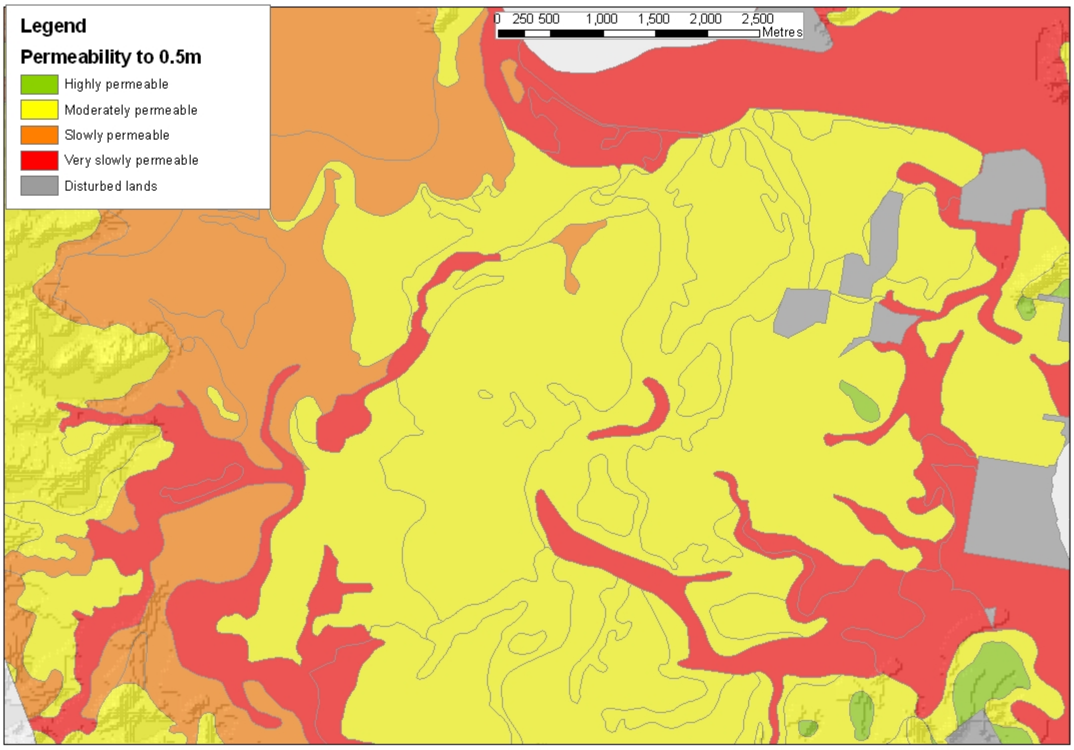

Figure 9. Distribution of soil permeability at 0–0.5 m in the study area

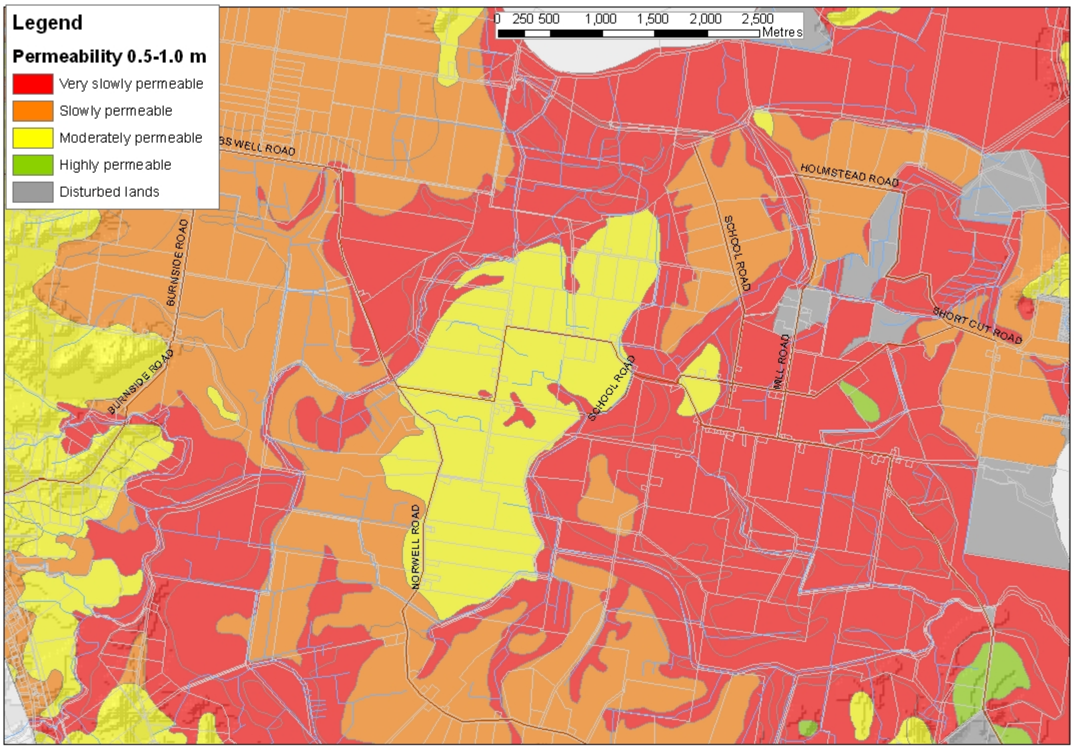

Figure 10. Distribution of soil permeability at 0–1.0 m in the study area

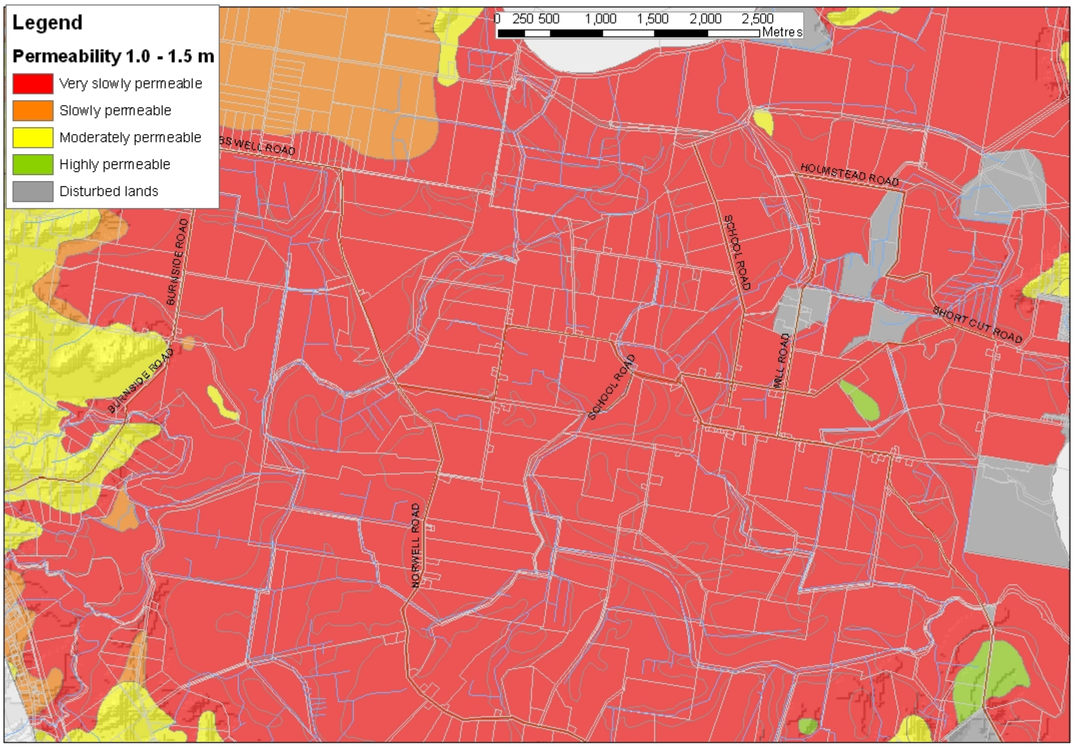

Figure 11. Distribution of soil permeability at 0–1.5 m in the study area

Plant available water capacity

As plant available water capacity (PAWC) is mainly affected by soil texture, rockiness and rooting depth, the spatial distribution of the PAWC attribute is governed by similar processes. Most steep areas are likely to have shallow soils and can contain high amounts of rock fragments, resulting in low moisture availability. Areas of gentler slope tend to have deeper soils and fewer rock fragments in lower landscape positions, resulting in higher PAWC. The 'wet' soils of the alluvial plains may have restricted rooting depth due to low soil pH or shallow watertables but have unrestricted PAWC where 'fresh' watertables occur within or immediately below the crop rooting depth. Soil water availability is restricted in salty soils or soils with salty watertable. The sands of the beach ridges (map unit 4) generally have very low PAWC; however the shallow watertable within or close to the rooting depth of some crops (at 1–1.5 m) increases the water available to moderate levels. Figure 12 shows a typical distribution.

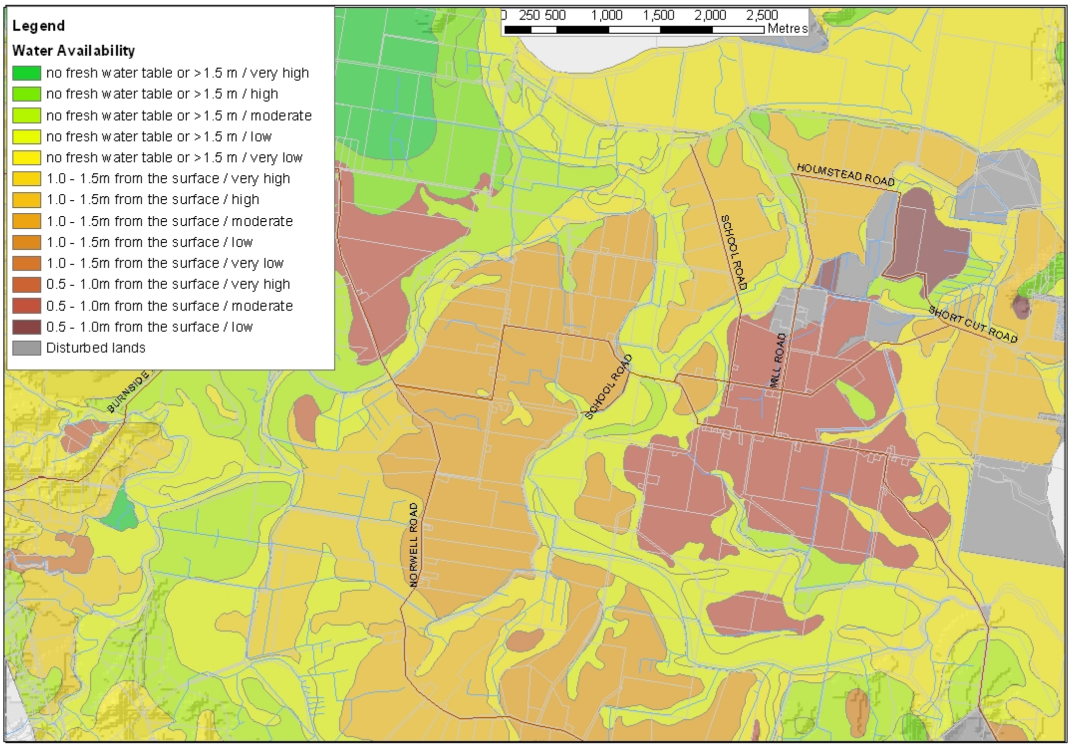

Figure 12. Distribution of plant available water capacity in the study area

Flooding

Local knowledge of flooding intensity and frequency has been used to assess the limitation. Flooding occurs frequently on the alluvial plains in the western parts of the study area due mainly to runoff from the undulating hills and rises. Much of the rises have been subdivided into urban or industrial lots (or are planned for development) resulting in high runoff from roads, roofs and other hard surfaces. During major flood events associated with the Logan River, all areas of recent alluvium are inundated for extended periods with low lying drainage depressions and swamps flooded for weeks. Figure 13 shows a typical distribution.

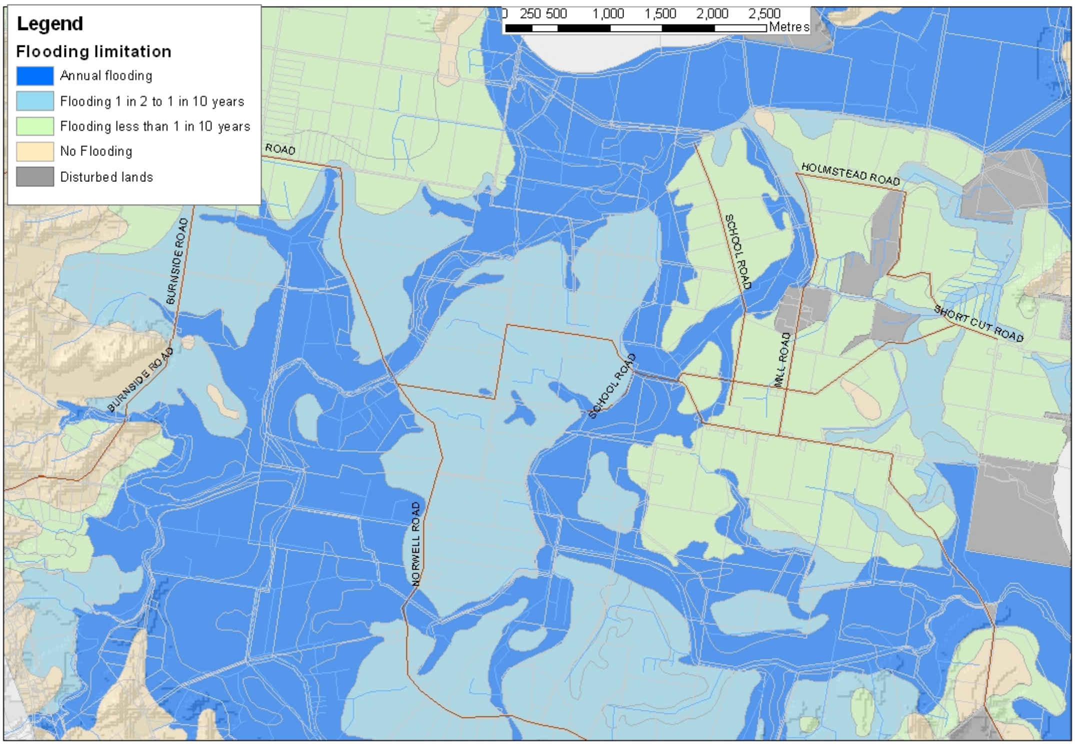

Figure 13. Distribution of flooding in the study area

Topography

Steep slopes (>15%) are uncommon and are expressed most strongly in the undulating low hills and rises on *Nerenleigh–Fernvale Beds,* with the level alluvial plains generally not affected (except the steep banks of the river terraces). Figure 14 shows a typical distribution.

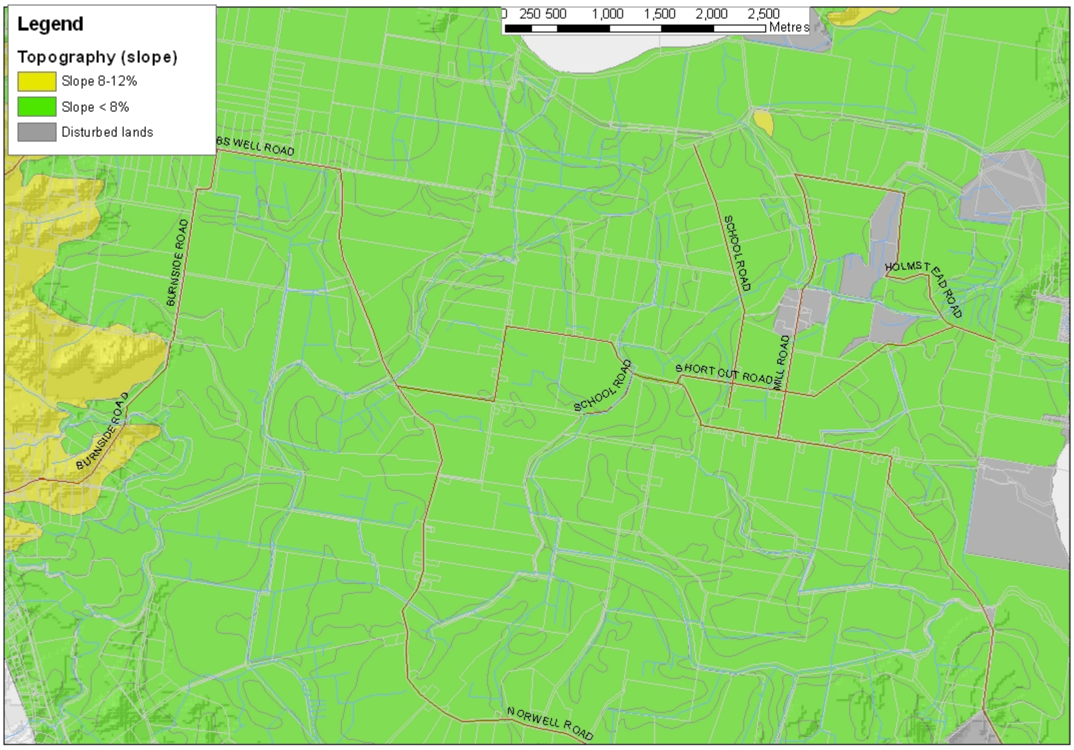

Figure 14. Distribution of slope in the study area

Salinity

Areas affected by soil salinity are located where drainage is poor; typically within drainage lines, and swamps with saline or brackish watertables. The clearing of the native vegetation has resulted in an increase in watertable levels and bare soil surfaces during crop rotations; these factors have further aggravated salinity due to evaporation and surface accumulation of salts. Secondary salinisation in discharge areas at breaks of slope or in regions of concave slope was not observed. Figure 15 shows a typical distribution.

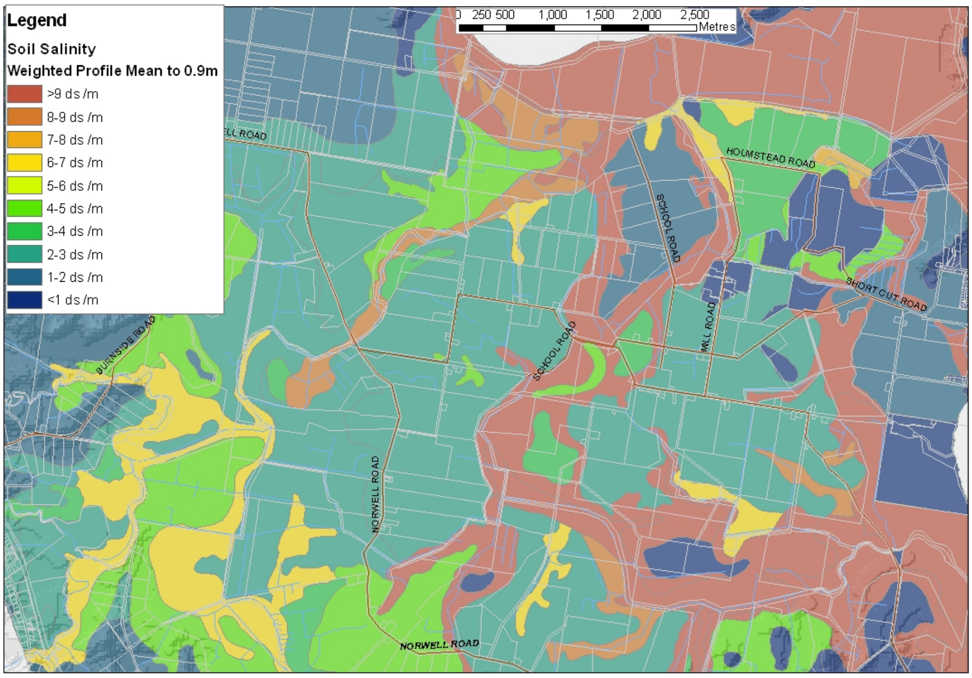

Figure 15. Distribution of salinity risk in the study area

Erosion

Areas susceptible to erosion are located where permeability is slow or very slow (unstable soils) and slopes are steeper. Figure 16 shows a typical distribution of soil erodibility (soil stability).

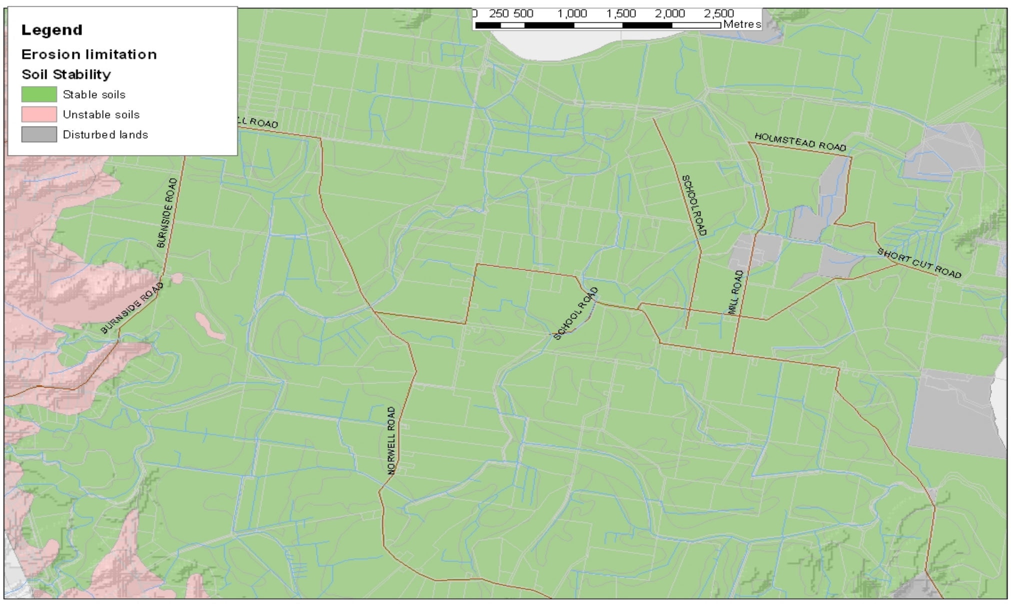

Figure 16. Distribution of soil erodibility in the study area

Validation

Soil surveyors from around south east Queensland recorded landscape features and soil morphology at 96 sites. Each survey team used a GPS and Geographic Information System (GIS) to allow easy navigation. Each team was also supplied data sets depicting mapped soil attributes modelled from the ASS survey sites.

Details recorded at each observation were kept to a minimum with emphasis placed on recording the soil and landscape attributes predicted by the landscape model (drainage, permeability, rooting depth and surface salinity). Spatial analysis of these observations with the predicted attributes has given a quantitative measure of prediction accuracy, however due to low number of sites used in analysis (77–96) error may be high/easily bias. Based on the results of this exercise some minor changes were made to the landscape model before producing final outputs.

The ASS site data used to predict the landscape attributes is highly variable within the mapping units due to the geomorphic history (flood/estuarine/delta deposits) of the area. As a result, the validation results are highly variable.

Results on spatial variability suggests that it will be unusual for land resource surveys to have more than medium confidence (33–67% prediction) when predicting soil properties at nominated locations (Minasny and Bishop 2008). The independent validation results for a limited range of attributes in the Rocky Point area consistently fall within the upper end of the medium confidence level.

Rooting depth (Pd)

Table 4. Independent validation results for rooting depth

Validation	**Number of Sites**	**% of all sites**
Predicted values match verification values (0–0.24 m, 0.24–0.5 m, 0.5–1.0 m, >1 m)	57	**59**
Predicted values were overestimated (rooting depth was observed shallower than predicted)	33	34
Predicted values were underestimated (rooting depth was observed deeper than predicted)	6	7
Total	96	100

Table 5. Number of independent validation sites corresponding to predicted rooting depth.

Validation site rooting depth	**Predicted rooting depth**			
	1 (>1.0 m)	**2** (0.5–1.0 m)	**3** (0.25–0.5 m)	**4** (<0.25 m)
1 (>1.0 m)	14	12	2	0
2 (0.5–1.0 m)	1	33	14	2
3 (0.25–0.5 m)	0	1	6	3
4 (<0.25 m)	0	0	4	4

The categorical nature of the rooting depth values means that validation sites that fall just outside a range (eg. 0.5–1.0 m) will not match the predicted values. Overall, 59% (57 sites) of verification sites fell within the predicted value range. Another 4 sites that had verified rooting depth outside the predicted values were within 0.1 m of the predicted value range.

The average difference between predicted rooting depth and observed rooting depth for all sites was plus or minus 0.22 m (ie. actual rooting depth – not values). Considering all sites irrespective of whether they match or do not matched predicted values, 66 verification sites (69%) had rooting depth within 0.25 m of predicted rooting depth. This includes 16 sites that did not match the predicted rooting depth value.

Wetness 1.0 m (w1)

Drainage to 1.0 m

Table 6. Independent validation results for drainage to 1.0 m

Validation	Number of Sites	% of all sites
Predicted values match observed values	56	**61**
Predicted values were overestimated (predicted drainage at 1.0 m is better drained then observed)	6	7
Predicted values were underestimated (predicted drainage at 1.0 m is more poorly drained than observed)	28	32
Total	92	100

Table 7. Number of independent validation sites corresponding to predicted drainage to 1.0 m

Verification site drainage to 1.0 m	Predicted drainage to 1.0 m					
	1 very poorly drained	**2** poorly drained	**3** imperfectly drained	**4** moderately well drained	**5** well drained	**6** rapidly drained
1 very poorly drained	34	3	1	0	0	0
2 poorly drained	27	11	2	0	0	0
3 imperfectly drained	1	0	8	0	0	0
4 moderately well drained	0	0	0	0	1	0
5 well drained	0	0	0	0	3	0
6 rapidly drained	0	0	0	1	0	0

The categorical nature of the drainage values means that validation sites that fall just outside a range (eg. poorly drained) will not match the predicted values. Overall, 61% (56 sites) of verification sites fell within the predicted value range.

The soil drainage to 1.0 metre is dominated by very poorly drained to poorly drained categories. Although soil drainage is subjectively based on soil morphology, the predicted values are within the upper end of the medium confidence level, and it is at very poorly drained sites where predicted drainage is significantly underestimating observed drainage.

Permeability to 1.0 m

Table 8. Independent validation results for permeability to 1.0 m

Validation	Number of Sites	% of all sites
Predicted values match observed values	49	**53**
Predicted values were overestimated (predicted drainage at 1.0 m is more permeable then observed)	13	14
Predicted values were underestimated (predicted drainage at 1.0 m is less permeable than observed)	33	33
Total	93	100

Table 9. Number of independent validation sites corresponding to predicted permeability to 1.0 m

Verification site permeability to 1.0 m	Predicted permeability to 1.0 m			
	V very slowly permeable	**S** slowly permeable	**M** moderately permeable	**H** highly permeable
V very slowly permeable	23	10	0	0
S slowly permeable	11	17	3	0
M moderately permeable	14	5	6	0
H highly permeable	1	0	0	3

The categorical nature of the permeability values means that validation sites that fall just outside a range (eg. slowly permeable) will not match the predicted values. Overall, 53% (49 sites) of verification sites fell within the predicted value range.

The soil permeability to 1.0 metre is dominated by very slowly permeable to moderately permeable categories. Although soil permeability is subjectively based on soil morphology, the predicted values are within the medium confidence level, and it is at very slowly permeable sites where predicted permeability is significantly underestimating observed permeability. The landscape complexity, long term cultivation and landscape modification may all be contributing to this variation.

Wetness 0.5 m (w2)

Drainage to 0.5 m

Table 10. Independent validation results for drainage to 0.5 m

Validation	Number of Sites	% of all sites
Predicted values match observed values	58	**63**
Predicted values were overestimated (predicted drainage at 0.5 m is better drained then observed)	1	1
Predicted values were underestimated (predicted drainage at 0.5 m is poorer drained than observed)	33	36
Total	92	100

Table 11. Number of independent validation sites corresponding to predicted drainage to 0.5 m.

Verification site drainage to 0.5 m	**Predicted drainage to 0.5 m**					
	1 very poorly drained	**2** poorly drained	**3** imperfectly drained	**4** moderately well drained	**5** well drained	**6** rapidly drained
1 very poorly drained	5	0	0	0	0	0
2 poorly drained	14	10	1	0	0	0
3 imperfectly drained	6	11	39	0	0	0
4 moderately well drained	0	0	1	0	0	0
5 well drained	0	0	0	0	4	0
6 rapidly drained	0	0	0	1	0	0

Overall, 63% (58 sites) of verification sites fell within the predicted value range.

The soil drainage to 0.5 metre is dominated by poorly drained to imperfectly drained categories. The predicted values are within the upper end of the medium confidence level.

Permeability to 0.5 m

Table 12. Independent validation results for permeability to 0.5 m

Validation	**Number of Sites**	**% of all sites**
Predicted values match observed values	46	**49**
Predicted values were overestimated (predicted drainage at 0.5 m is more permeable then observed)	22	24
Predicted values were underestimated (predicted drainage at 0.5 m is less permeable than observed)	25	27
Total	93	100

Table 13. Number of independent validation sites corresponding to predicted permeability to 0.5 m

Verification site permeability to 0.5 m	**Predicted permeability to 0.5 m**			
	V very slowly permeable	**S** slowly permeable	**M** moderately permeable	**H** highly permeable
V very slowly permeable	4	0	0	0
S slowly permeable	8	10	22	0
M moderately permeable	8	5	29	0
H highly permeable	0	0	4	3

Overall, only 49% (46 sites) of verification sites fell within the predicted value range.

The soil permeability to 0.5 metre is dominated by the moderately permeable category. Although the predicted values are within the medium confidence level, the predicted permeability is significantly underestimating observed permeability for the very slowly permeable and moderately permeable predicted groups. The landscape complexity, long term cultivation and landscape modification are all contributing to this variation.

Wetness 1.5 m (w3)

Drainage to 1.5 m

Table 14. Independent validation results for drainage to 1.5 m

Validation	Number of Sites	% of all sites
Predicted values match observed values	79	**87**
Predicted values were overestimated (predicted drainage at 1.5 m is better drained then observed)	3	3
Predicted values were underestimated (predicted drainage at 1.5 m is poorer drained than observed)	9	10
Total	91	100

Table 15. Number of independent validation sites corresponding to predicted drainage to 1.5 m

Verification site drainage to 1.5 m	Predicted drainage to 1.5 m					
	1 very poorly drained	**2** poorly drained	**3** imperfectly drained	**4** moderately well drained	**5** well drained	**6** rapidly drained
1 very poorly drained	74	0	0	0	0	0
2 poorly drained	6	0	3	0	0	0
3 imperfectly drained	2	0	2	0	0	0
4 moderately well drained	0	0	0	3	0	0
5 well drained	0	0	0	1	0	0
6 rapidly drained	0	0	0	0	0	0

Overall, 87% (79 sites) of verification sites fell within the predicted value range.

The soil drainage to 1.5 metre is dominated by the very poorly drained category. The predicted values are within the high confidence level (67–95%). This is because the alluvial map units have watertables at shallow depths.

Permeability to 1.5 m

Table 16. Independent validation results for permeability to 1.5 m

Validation	Number of Sites	% of all sites
Predicted values match observed values	56	**61**
Predicted values were overestimated (predicted drainage at 1.5 m is more permeable then observed)	1	1
Predicted values were underestimated (predicted drainage at 1.5 m is less permeable than observed)	34	37
Total	91	100

Table 17. Number of independent validation sites corresponding to predicted permeability to 1.5 m.

Verification site permeability to 1.5 m	Predicted permeability to 1.5 m			
	V very slowly permeable	**S** slowly permeable	**M** moderately permeable	**H** highly permeable
V very slowly permeable	48	1	0	0
S slowly permeable	17	3	0	0
M moderately permeable	17	0	4	0
H highly permeable	0	0	0	1

Overall, 61% (56 sites) of verification sites fell within the predicted value range. In general, accuracy improves as depth increases (49% at 0.5 m, 53% at 1.0 m, 61% at 1.5 m) due mainly to smaller landscape and soil modification and more consistency in the soil properties as depth increases.

The soil permeability to 1.5 metre is dominated by the very slowly permeable to slowly permeable categories. Although the predicted values are within the medium confidence level, the predicted permeability is significantly underestimating observed permeability for the very slowly permeable group. The variability in the distribution of sandy subsoils will be contributing to this factor.

Salinity

Surface salinity *(ECse 0–0.1 m)*

Table 18. Independent validation results for surface salinity 0–0.1 m

Validation	Number of Sites	% of all sites
Predicted values match observed values	27	**35**
Predicted values were overestimated (predicted salinity at 0–0.1 m is more saline then observed)	44	57
Predicted values were underestimated (predicted salinity at 0–0.1 m is less saline than observed)	6	8
Total	77	100

Table 19. Number of independent validation sites corresponding to predicted surface salinity 0–0.1 m

Verification site surface salinity 0–0.1 m (ECse)	Predicted surface salinity 0–0.1 m (ECse)			
	Non-saline (<2 dS/m)	Low (2–4 dS/m)	Moderate (4–8 dS/m)	Severe (>8 dS/m)
Non-saline (<2 dS/m)	12	32	4	0
Low (2–4 dS/m)	1	7	4	3
Moderate (4–8 dS/m)	1	3	4	1
Severe (>8 dS/m)	0	0	1	4

The categorical nature of the salinity values (ECse) means that validation sites that fall just outside a range (eg. 2–4 dS/m) will not match the predicted values. Overall, only 35% (27 sites) of verification sites fell within the predicted value range. This is at the lower end of the moderate confidence level (33–67%).

The soil salinity at 0–0.1 metre (ECse) is dominated by the non-saline (<2 dS/m) to low saline (2–4 dS/m) categories. The predicted salinity is significantly overestimating observed salinity in the low range, that is, a large number of verification sites have salinity lower than predicted values. As surface salts in the study area are dominated by very soluble sodium chloride and iron/aluminium sulfate salts that accumulate at the surface due to evaporation, these salts are highly mobile as affected by current and past weather conditions and land management practices. Predicted values are based on ASS samples collected in 1999–2001 while validation sites were collected in 2007.

Predicted values for each UMA are based on the average surface ECse for all sites within a UMA. For example, 10 sites in UMA 198 had a ECse range of 1.76 (non-saline) to 14.2 (severe) and an average of 5.36 (moderate). In total, 64 sites (83%) had a validation surface ECse within the salinity range for the UMA in which it occurred. For example, the validation site in UMA 198 had a salinity of 2.82 dS/m (slight) falling within the range for that UMA (1.76–14.2 dS/m) but outside the predicted range of moderate (5.36 dS/m).

Suitability results

The predicted soil and landscape attributes were used to assess land use suitability using the framework outlines in Appendix 2.

The agricultural and forestry land uses assessed include:

- Avocado
- Banana
- Blackbutt (*E. pilularis*)
- Capsicum (s) (w)
- Caribbean pine
- Citrus (lime, lemon)
- Cucurbits (melons, pumpkins, zucchini) (s) (w)
- Custard apple
- Dunn's white gum (*E. dunnii*)
- Flooded gum (*E. grandis*)
- Ginger (s) (w)
- Gympie messmate (*E. cloeziana*)
- Chokos
- Lychee
- Macadamia
- Maize (forage)
- Mango
- Papaw
- Passionfruit
- Persimmon
- Pineapple
- Sorghum (forage)
- Sown pastures (introduced)
- Soybean
- Spotted gum *(C. maculata*)
- Stone fruit (low-chill peaches, nectarines)
- Strawberries
- Sugar cane
- Sugar cane (rainfed)
- Sweet corn (s) (w)
- Sweet potato (s) (w)
- Tomato (s) (w)
- Turf

Note – Summer (s) and winter (w) land uses have been identified to allow assessment for seasonal adaptation and variation in soil/land attributes such as frosts, flooding, wetness and water availability.

These crops were assessed because they represent crops that are economically viable (farm size not considered) and climatically adapted to the area. Generally, if the land is suitable for the limited range of crops assessed, the suitable area will include areas suitable for other unassessed crops.

Many land uses require supplementary irrigation for economic production in the Rocky Point area. Irrigation methods include overhead spray, micro-sprinkler or drippers. Irrigation becomes critical to crop production mainly in the period from July through to November corresponding to flowering and fruit set. An assessment of the limitations and suitability ratings for each UMA and each of the different land uses is recorded on computer files. Table 20 shows the areas of various land suitability classes for the 32 land uses.

Table 20. Land suitability classes and areas (ha) for different land uses

Land use	Land suitability		
	Suitable (ha)	**Marginal (ha)**	**Unsuitable (ha)**
• Avocado (i)	0	262	16473
• Banana	1645	2351	12739
• Banana (i)	3335	4564	8836
• Blackbutt (*E. pilularis*)	0	0	16735
• Capsicum – summer (i)	202	5948	10585
• Capsicum – winter (i)	2957	3149	10629
• Caribbean pine	1442	5801	9492
• Chokos (i)	222	2941	13572
• Citrus (lime, lemon) (i)	264	5941	10530
• Cucurbits (melons, pumpkins, zucchini) – summer (i)	202	5948	10585
• Cucurbits (melons, pumpkins, zucchini) – winter (i)	3227	1272	12236
• Custard apple (i)	162	184	16389
• Dunn's white gum (*E. dunnii*)	362	2315	14058
• Flooded gum (*E .grandis*)	0	658	16077
• Ginger – summer (i)	368	4033	12334
• Ginger – winter (i)	270	4131	12334
• Gympie messmate (*E. cloeziana*)	222	98	16415
• Lychee (i)	203	1478	15054
• Macadamia (i)	162	184	16389
• Maize (forage)	146	2369	14220
• Mango (i)	1295	452	14988
• Papaw (i)	162	4057	12516
• Passionfruit (i)	4038	253	12444
• Persimmon (i)	262	5884	10489
• Pineapple	223	4993	11519
• Sorghum (forage)	1855	1263	13617
• Sown pastures (introduced)	1680	10802	4253
• Soybean	3297	2921	10517
• Spotted gum *(C. maculata*)	362	6372	10001
• Stone fruit (low-chill peaches, nectarines)	162	4129	12444
• Strawberries (i)	445	6141	10149
• Sugar cane (rainfed)	3269	4285	9181
• Sugar cane (i)	5833	2051	8851
• Sweet corn – summer (i)	146	2369	14220
• Sweet corn – winter (i)	1314	1805	13616
• Sweet potato – summer (i)	202	6004	10529
• Sweet potato – winter (i)	2963	3200	10572
• Tomato – summer (i)	202	5948	10585
• Tomato – winter (i)	2957	1541	12237
• Turf (i)	5446	1747	9542

Note – Land uses that require supplementary irrigation for economic production are indicated with an (i). Irrigation methods include overhead spray, mini-sprinkler or drippers.

Sugar cane is the main crop grown in the study area. From Table 20, 3269 ha is suitable for rainfed sugar cane while 5833 ha are suitable for irrigated sugar cane. A majority of the suitable lands are restricted to the relatively flat alluvial plains and associated gentle lower hillslopes. Economic farm production requires relatively large contiguous area (>100 ha). However, much of this area is fragmented with individual lots that are 'too small' to be practical to farm. Further analysis is required to determine sustainable production areas. Figure 17 shows an area suitable for rainfed sugar cane.

The areas assessed as suitable for sugar cane from this study is considerably less than the 9010 ha reported by Holz (1979). The difference is mainly due to the reduced size of the study area (excludes the Coomera and Logan–Albert River areas), and the detailed assessment for ASS and salinity.

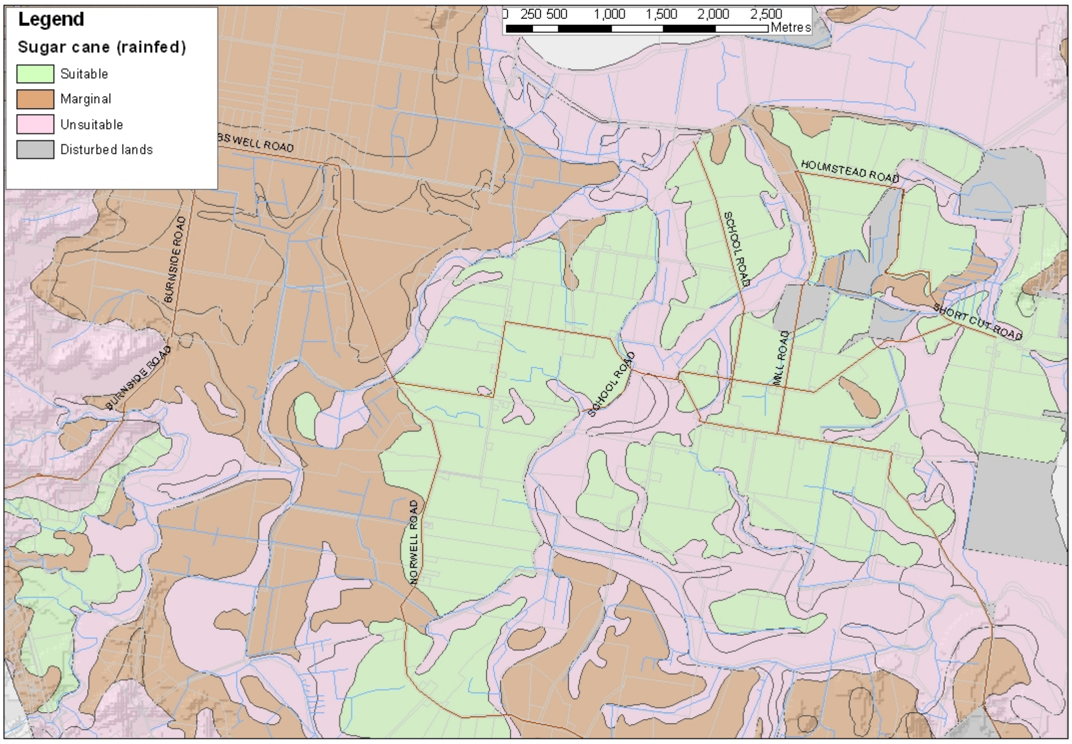

Figure 17. Distribution of land suitable for sugar cane in the study area

Horticultural small crops such as ***capsicums***, ***cucurbits***, ***sweet potato*** and ***tomato*** are not grown extensively in the study area. A total of 202 ha (Table 20) is suitable for growing summer small crops using micro-irrigation systems while 2957, 3227, 2963 and 2957 ha are suitable for growing winter capsicums, cucurbits, sweet potato and tomato respectively.

Economic farm production requires a relatively small area (20 ha). Figure 18 shows an area suitable for winter cucurbits.

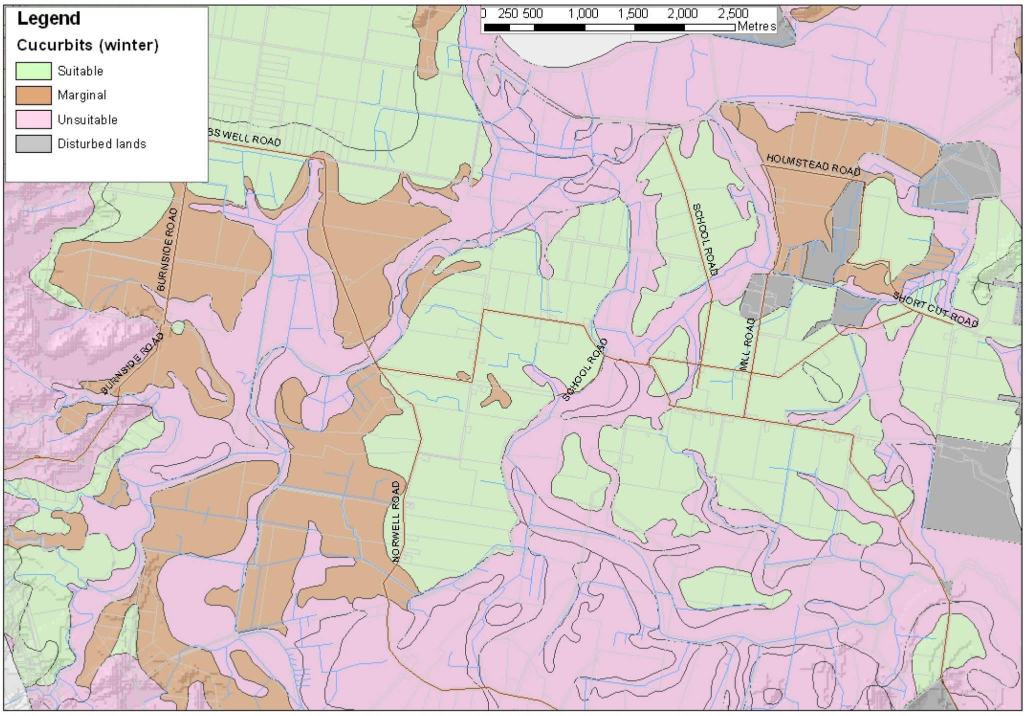

Figure 18. Distribution of land suitable for winter cucurbits in the study area

Soybeans are grown commercially to a limited extent, mainly as a break crop between sugar cane plantings to reduce disease and improve soil fertility. The areas suitable for this species are generally restricted to the 'better' drained lands. Economic production requires relatively large contiguous area but does provide economic returns in rotation with sugar crops and provides other advantages. Further analysis is required to determine practical areas. Figure 19 shows an area suitable for soybeans.

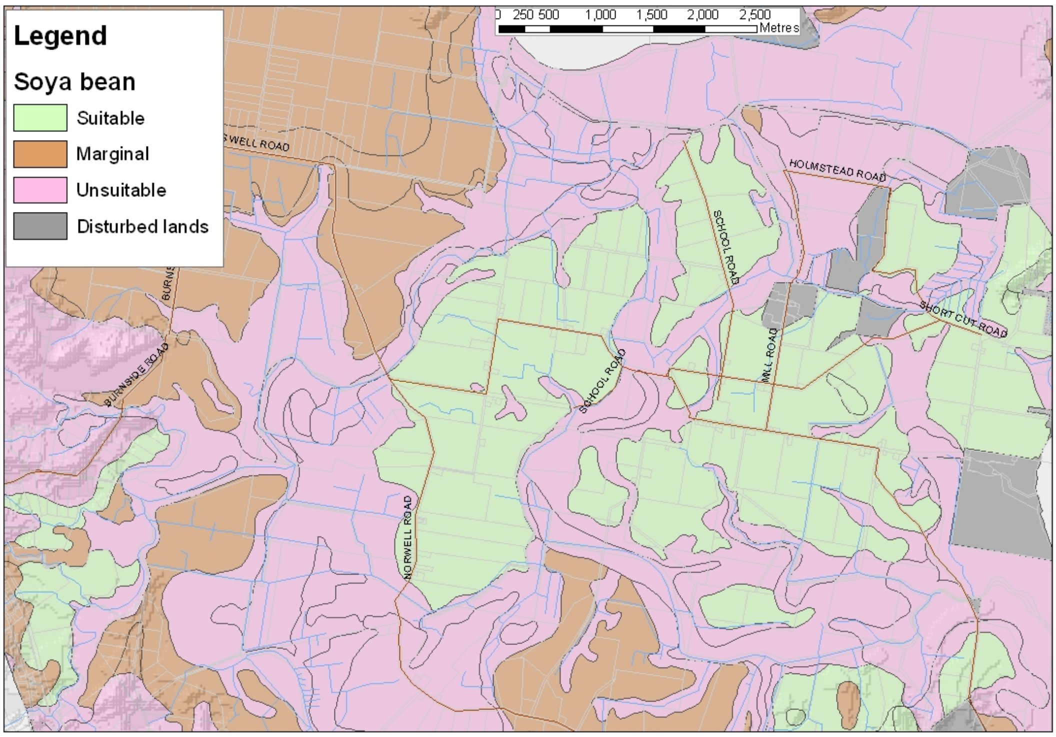

Figure 19. Distribution of land suitable for soybeans in the study area

Turf is a relatively 'high' value land use grown for the expanding urban market. Turf is suitable for a relatively large area (5446 ha) tolerating imperfectly drained soils and moderate frosts, but requires a reliable irrigation water supply. Economic production requires relatively small areas. Further analysis is required to determine practical areas. Figure 20 shows an area suitable for turf.

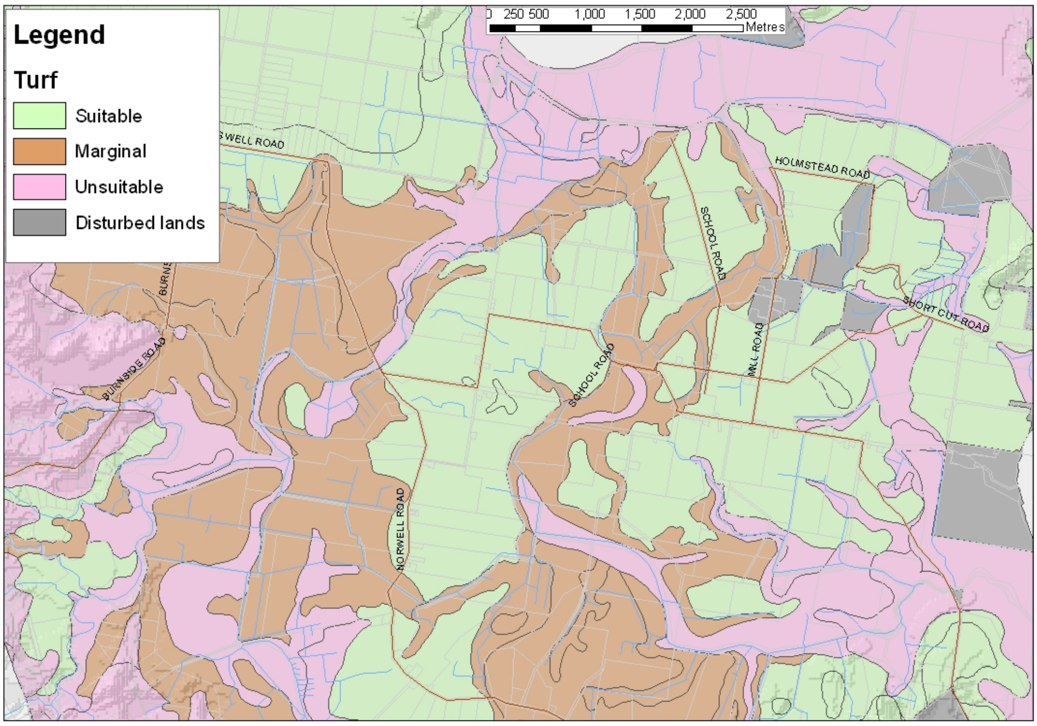

Figure 20. Distribution of land suitable for turf in the study area

Other land uses

Table 20 indicates that relatively small areas are suitable for other land uses. A suitable irrigation water supply is currently available from the sewerage treatment plant, and shallow ground water may be available especially from the beach ridge system at Jacobs Well.

All suitability maps are attached to the report.

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Appendix 1
Soil Profile Classes

Conventions used in the descriptions of the morphology, landscape and vegetation of the soil profile classes

A soil profile class (SPC) is a three dimensional soil body or group or soil bodies, such that any profile within the body(s) has a similar number and arrangement of major horizons whose attributes primarily morphological, are within a defined range. All profiles within the units have similar parent materials. The soil profile class may be at varying levels of generalisation depending primarily on the scale of the survey and density of ground observations.

A **soil variant** is a soil with profile attributes clearly outside the range of defined soil types but not extensive enough to warrant defining a new type.

A **soil phase** is a subdivision of a soil profile class based on attributes that have particular significance in the use of the soil, for example, rocky phase.

Australian Classification as described by Isbell (1996) are listed in order of frequency of occurrence.

Great Soil Group as described by Stace *et al.* (1968) are listed in order of frequency of occurrence.

Principle Profile Form (PPF) as defined by Northcote (1979) are listed in order of frequency of occurrence.

Geology as defined on the Brisbane 1:250 000 geology series map.

Surface characteristics as in McDonald *et al.* (1990).

Landform as in McDonald *et al.* (1990).

Vegetation structural formation as in McDonald *et al.* ((1990)

Vegetation species listed in order of frequency of occurrence. "/" means with or without.

The **pH profiles** are based on field determination for each horizon.

Horizons as in McDonald *et al.* (1990).

Textures are field textures as in McDonald *et al.* (1990)

Structure as in McDonald *et al.* (1990).

Segregation as in McDonald *et al*. (1990).

Boundary type as in McDonald *et al.* (1990).

Frequency of occurrence

Frequently = >30% of occasions
Occasionally = <30% of occasions

Colour codes (moist) are those of Munsel soil colour charts (1994) while colour nomenclature is based on the colour class limits of Isbell (1996).

References

Isbell RF (1996). ***The Australian Soil Classification***. CSIRO, Australia.

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Map unit and corresponding soil profile class (SPC)

Map Unit 2.1.1 Woongoolba
Map Unit 2.1.2 Norwell
Map Unit 2.2.1 Steigletz
Map Unit 2.2.2 Gilberton
Map Unit 2.3.1 Behm
Map Unit 2.3.2 Pimpama
Map Unit 2.4.1 Woogoompah
Map Unit 2.4.2 Coomera
Map Unit 3 Yawalpah
Map Unit 4.1 Jacobs
Map Unit 4.2 Bethania*
Map Unit 5.1 Tabby*
Map Unit 5.2 Ormeau*
Map Unit 5.3 Stapylton*

* Provisional – SPCs are provisional only. The ranges of soil properties in the descriptions provided are based on insufficient sites to quantify the full range of soil properties necessary to define a SPC.

Note - SPC descriptions are based on ASS and verification site morphology

Behm Bh (map unit 2.3.1)

Concept: Black extremely acid to neutral sandy clay loam to light medium clay over a mottled grey extremely acid to medium acid sandy clay loam to medium clay over a mottled grey medium acid to neutral sandy loam to sandy clay loam C or D horizon at predominantly <1m. Watertable at <0.5–1m. Jarosite or iron sulfide at <0.5m

Australian Classification: Sulfidic Redoxic Hydrosol, Sulfuric Redoxic Hydrosol

Great Soil Group: Humic Gley

Principle Profile Form: Uf6.41, Um5.52

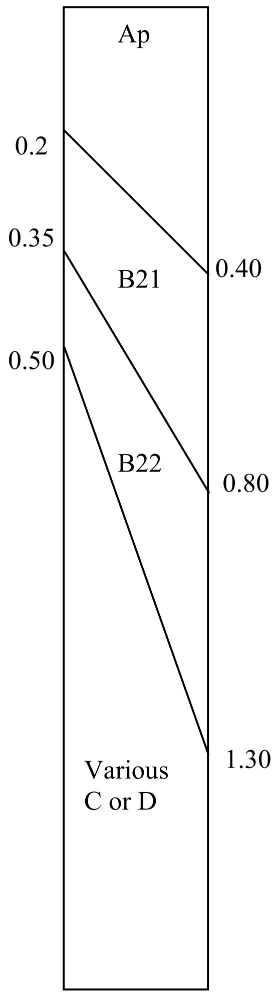
Geology: Quaternary alluvium (Qha).

Landform: Freshwater swamps and drainage lines

Surface characteristics -
- **Surface condition:** Firm
- **Coarse fragments:** Nil
- **Microrelief:** Nil

Vegetation: Mostly cleared

Depth (m)



Ap: Frequently faint mottled; black (7.5YR 3/1, 3/2, 10YR 2/1, 2/2, 3/1, 3/2, 2.5Y 2/1); fine sandy clay loam to light medium clay; massive or weak to moderate 2 to 10mm granular or subangular blocky; field pH 3.3 to 6.0; clear to abrupt change -

B21: Mottled, frequently jarosite; grey (7.5YR 5/1, 10YR 4/1, 4/2, 5/1, 5/2, 6/1, 2.5Y 4/1, 4/2, 5Y 4/1); fine sandy clay loam to medium clay; massive or weak to moderate 2 to 10mm subangular blocky; field pH 2.9 to 7.0; clear to gradual change -

B21: Mottled; grey (7.5YR 5/1, 10YR 4/1, 5/1, 5/2, 6/1, 2.5Y 4/1, 5/1, 6/1) fine sandy clay loam to medium clay; massive; field pH 3.1 to 7.0; clear to gradual change -

Various C or D: Faint mottled or not mottled; grey or occasionally black (10YR 4/1, 5/1, 5/2, 6/1, 2.5Y 4/1, 5/1, 5/2, 6/1, 5Y 5/1, 10Y 3/1, 4/1, 5/1, 6/1, N 3/-, 4/-, 5GY 3/1, 5/1); sand to fine sandy clay loam; massive; field pH 3.7 to 8.0.

Sites:

RK2 - 14, 73, 103, 142

SEA – 12, 20, 25, 26, 238, 348, 372, 375, 383, 406, 407, 449, 466, 468, 484, 486, 496, 499, 1500, 1682, 1754, 1763, 1767, 1772, 1788, 1837, 1841, 1851, 1910, 1913, 2062, 3008, 3016, 3032, 3035, 3042, 3043, 3048, 3188

Bethania Bt* (map unit 4.2)

Concept: Black sand surface over a conspicuously bleached, mottled B2 horizon over grey sand. Watertable at 0.5–1m.

Australian Classification: Sulfidic Redoxic Hydrosol, Sulfidic Oxyaquic Hydrosol.

Great Soil Group: Silicous sand.

Principle Profile Form: Uc 2

Geology: Quaternary Pleistocene coastal sand (Qpct/s) and Quaternary Holocene coastal sand (Qhct)

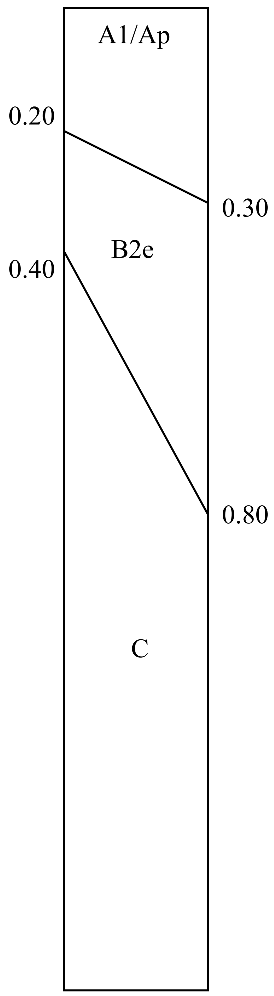
Landform: Low beach ridges on a beach ridge plain.

Surface characteristics -

- **Surface condition**: Loose
- **Coarse fragments**: Nil
- **Microrelief**: Nil

Vegetation:

Depth (m)



A1/Ap: Mottled, black (7.5YR 2/1, 10YR 2/1, 2/3); sandy loam; single grain; field pH 4.7 to 5.8; gradual change -

B2e: Conspicuously bleached. Mottled, grey (10YR 6/1, 2.5Y 5/2, 6/1); sand; single grain; field pH 5.0 to 6.5; clear to abrupt change -

C: Grey (10YR 7/2, 2.5YR 5/1, 6/1, 6/2, 5Y 7/1, 10Y 4/1, 6/1) sand; single grain; field pH 7.0.

Sites:

RK2 – 138

SEA – 289, 291, 1732, 1860

Note: Sulfidic sand with watertable at 0.6 to 1.25m. The soil has sufficient pedological development to classify as a Hydrosol.

Coomera Cm (map unit 2.4.2)

Concept: Black strongly to extremely acid light clay to medium clay surface over a mottled grey strongly acid to extremely acid light clay to medium clay subsoil. Watertable at <0.5–1m. Jarosite or iron sulfide at <0.5m. Saline surface

Australian Classification: Sulfidic Redoxic Hydrosol, Sulfuric Redoxic Hydrosol

Great Soil Group: Solonchak

Principle Profile Form:

Geology: Quaternary alluvium (Qha).

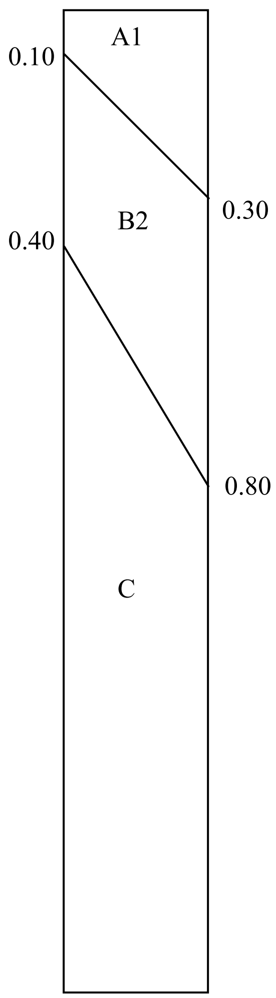
Landform: Brackish swamps.

Surface characteristics -

- **Surface condition:** Firm. Salt crust on the surface
- **Coarse fragments:** Nil
- **Microrelief:** Nil

Vegetation: Mostly cleared, minor *Casurina glauca* open forest

Depth (m)



A1 — Black (7.5 YR 2/2, 10YR 2/1, 2/2, 3/1, 3/2); loam, clay loam to light medium clay; massive to moderate 2 to 10mm subangular blocky; field pH 3.2 to 5.5. Abrupt change to -

B2 — Jarosite or occasionally no jarosite, mottled; black or grey (7.5 YR 4/1, 10YR 3/1, 4/1, 4/2, 2.5Y 3/1, 3/2, 4/1, 4/2); light clay to medium clay; massive to moderate 2 to 10mm subangular blocky; field pH 3.3 to 4.6. Gradual to diffuse change to -

C — Grey or black (2.5Y 2.5/1, 3/1, 5Y 3/1, 4/1, 10Y 3/1, 4/1, N 4/-, 5GY 3/1, 4/1); light clay to medium clay; massive; field pH 4.6 to 5.6 in the upper horizon increasing up to 8 in the lower horizon.

Sites: SEA – 46, 53, 221, 224, 225, 226, 227, 228, 342, 376, 382, 384, 385, 388, 389, 391, 392, 296, 442, 1575, 1577, 1787, 1879, 1904, 2036, 2042, 3005, 3182, 3183, 3189

Gilberton Gb (map unit 2.2.2)

Concept: Black strongly acid to extremely acid light clay to medium clay surface over a mottled grey extremely acid light clay to medium clay subsoil. Watertable at 0.5– 1.5m. Jarosite (if present) at 0.5–1m or iron sulfide at 0.5–2m

Australian Classification: Suffuric Redoxic Hydrosol

Great Soil Group: Humic Gley

Principle Profile Form: Uf 6.41

Geology: Quaternary alluvium (Qha).

Landform: Alluvial plain and swamps.

Surface characteristics -

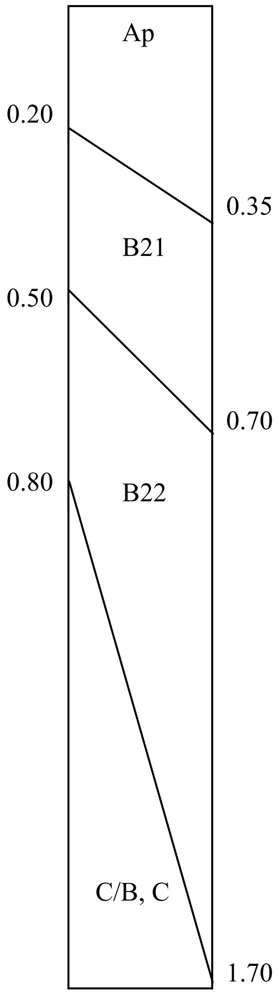
Surface condition: Firm

Coarse fragments: Nil

Microrelief: Nil

Vegetation: Cleared

Depth (m)



Ap: Black (7.5YR 2/1, 2/3, 3/1, 10YR 2/1, 2/2, 2/3, 3/1, 3/2); light clay to light medium clay; moderate to strong 2 to 10mm granular or subangular blocky; field pH 4.3 to 5.5; clear to abrupt change -

B21: Mottled, grey (7.5YR 4/1, 10YR 4/2, 5/1, 5/2, 6/1, 6/2); light medium clay to medium clay; weak to moderate 2 to 10mm subangular blocky or occasionally lenticular; field pH 3.6 to 5.0; clear to diffuse change -

B21: Mottled, frequently jarosite; grey (7.5YR 4/1, 10YR 4/1, 4/2, 5/1, 5/2, 6/1, 6/2, 2.5Y 4/1) light medium clay to medium clay; weak to moderate 2 to 10mm subangular blocky or occasionally lenticular; field pH 3.1 to 5.0; clear change -

C/B, C: Faint mottled, occasionally jarosite; grey or occasionally black (10YR 4/1, 5/1, 2.5Y 3/1, 4/1, 5/1, 5Y 3/1, 4/1, 6/1, 7.5 Y 3/1, 4/1, 10Y 3/1. 4/1); light clay to light medium clay; massive to weak 2 to 10mm subangular blocky; field pH 3.3 to 8.0.

Sites:

RK2 - 10, 19, 53, 56, 58, 106, 107, 108, 124, 127, 128, 129, 137

SEA – 6, 19, 24, 38, 49, 52, 257, 259, 277, 281, 285, 353, 354, 355, 356, 361, 362, 363, 364, 365, 367, 373, 386, 403, 404, 441, 443, 448, 470, 475, 478, 489, 490, 497, 1504, 1531, 1535, 1541, 1561, 1585, 1588, 1654, 1655, 1656, 1658, 1659, 1680, 1684, 1710, 1711, 1724, 1735, 1736, 1743, 1747, 1758, 1769, 1777, 1800, 1803, 1805, 1808, 1810, 1819, 1826, 1830, 1854, 1856, 1859, 1870, 1872, 1873, 1877, 1878, 1886, 1889, 1890, 1892, 1896, 1917, 2070, 2101, 3003, 3010, 3031, 3033, 3041, 3046, 3186, 3193, 3195, 3197

Jacobs Jb (map unit 4.1)

Concept: Black sand surface over a conspicuously bleached A2 horizon over a black coffee rock pan at 1–1.5m. Watertable at 1–1.5m.

Australian Classification: Humic Aquic Podosol

Great Soil Group: Podzol

Principle Profile Form: Uc 2.33

Geology: Quaternary Pleistocene coastal sand (Qpct/s) and Quaternary Holocene coastal sand (Qhct)

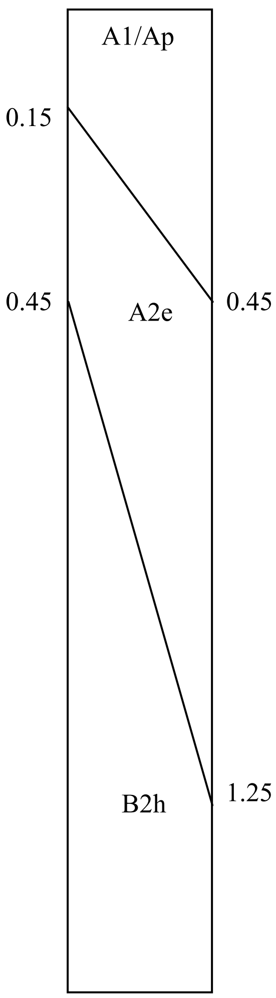
Landform: Low beach ridges on a beach ridge plain.

Surface characteristics -

- **Surface condition:** Loose
- **Coarse fragments:** Nil
- **Microrelief:** Nil

Vegetation:

Depth (m)



A1/Ap: Black (7.5YR 2/1, 3/1, 10YR 2/1, 2/2, 3/1, 3/2); sand to loamy sand; massive to single grain; field pH 4.0 to 6.5; clear to gradual change -

A2e: Conspicuously bleached. Grey (7.5YR 5/1, 6/1, 10YR 4/1, 5/2, 6/2, 8/1); sand; single grain; field pH 5.5 to 6.0; clear change -

B2h: Black or occasionally brown (5YR 3/2, 7.5YR 2/2, 3/1, 3/2, 10YR 2/1, 2/2, 3/1, 3/2, 3/3, 4/3, 5/4, 2.5Y 2/2) sand to loamy sand; massive; coffee rock pan; field pH 4.0 to 6.0.

Sites:

RK2 - 3, 4, 5, 11, 139, 140

SEA – 28, 43, 465, 1664, 1821, 1824, 1834, 1838, 1845

Norwell Nw (map unit 2.1.2)

Concept: Black strongly to extremely acid light clay to medium clay surface over a mottled grey strongly acid to extremely acid light clay to medium clay subsoil. Watertable at 1–1.5m. Jarosite (if present) at >1m or iron sulfide at 1–3 m

Australian Classification: Sufuric Redoxic Hydrosol, Sufidic Redoxic Hydrosol

Great Soil Group: Humic Gley

Principle Profile Form: Uf 6.41, Uf 6.42

Geology: Quaternary alluvium (Qha).

Landform: Alluvial plain and minor terraces.

Surface characteristics -

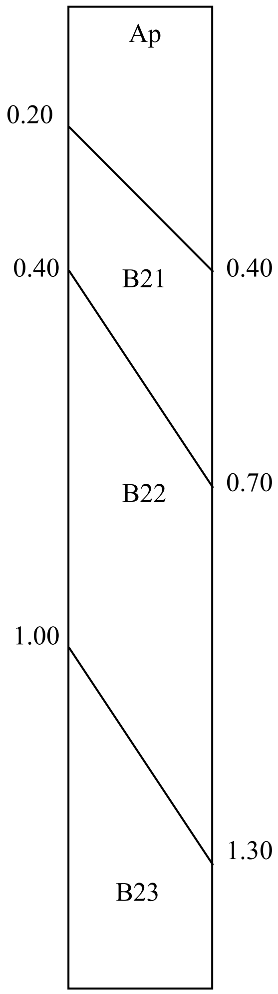
Surface condition: Firm

Coarse fragments: Nil

Microrelief: Nil

Vegetation: Cleared

Depth (m)



Ap: Black (7.5YR 2/1, 2/2, 3/1, 10YR 2/1, 3/1); light clay to medium clay; moderate 2 to 10mm granular or subangular blocky; field pH 4.0 to 6.0; clear to abrupt change -

B21: Mottled, grey or occasionally black (7.5YR 3/1, 4/1, 10YR 2/1, 3/1, 4/1, 4/2, 5/1); light medium clay to medium clay; weak to moderate 2 to 10mm subangular blocky; field pH 3.8 to 6.0; clear to diffuse change -

B22: Mottled; grey (7.5YR 4/1, 5/1, 10YR 4/1, 5/1, 5/2, 2.5Y 4/2, 5/1, 6/1); light clay to medium clay; massive to moderate 2 to 5mm subangular blocky; field pH 3.8 to 6.5; clear change -

B23: Frequently mottled, frequently jarosite; grey or occasionally black (7.5YR 4/1, 10YR 4/1, 5/1, 2.5Y 4/1, 5/1, 6/1, 5Y 3/1, 4/1); light clay to light medium clay; massive to moderate 2 to 5mm subanglar blocky; field pH 3.8 to 7.5.

Sites:

RK2 - 19, 60, 125, 133, 136

SEA – 1, 45, 232, 247, 258, 260, 261, 263, 357, 398, 399, 400, 401, 402, 447, 459, 472, 474, 488, 493, 1510, 1513, 1517, 1520, 1525, 1543, 1544, 1547, 1564, 1583, 1584, 1653, 1657, 1706, 1708, 1709, 1714, 1728, 1737, 1751, 1774, 1797, 1809, 1811, 1813, 1817, 1825, 1828, 1844, 1847, 1848, 1865, 1869, 1881, 1885, 1887, 1888, 1893, 1895, 1897, 1898, 1899, 2009, 2010, 2017, 3034, 3057, 3194

Ormeau Om* (map unit 5.2)

Concept: Black or grey clay loam surface over a bleached A2 horizon over a mottled grey medium to medium heavy clay over weathered rock.

Australian Classification: Bleached-sodic Magnesic-sodic Grey Kurosol

Great Soil Group: Soloth

Principle Profile Form: Dy 3.41, Dy 3.11p, Dy 3.31

Geology: Shale, mudstone and sandstone of the *Nerenleigh–Fernvale Beds* (DCn).

Landform: Lower slopes of gently undulating to undulating low hills and rises.

Surface characteristics -

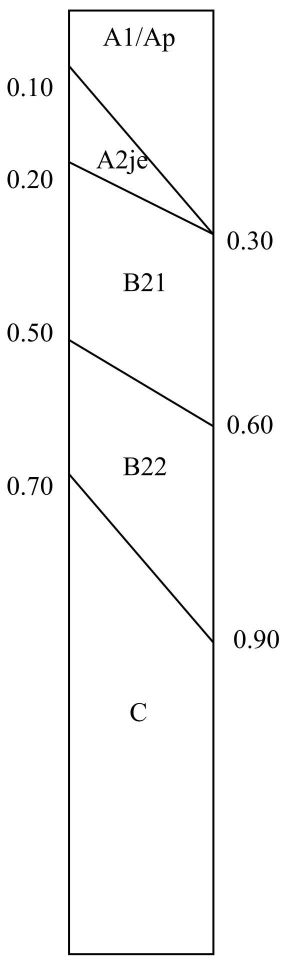
Surface condition: Hardsetting

Coarse fragments: 10 to 20% angular rock fragments 6 to 20mm.

Microrelief: Nil

Vegetation: Mostly cleared

Depth (m)



A1/Ap: Black (7.5YR 3/2, 2.5Y 3/2); sandy clay loam to clay loam; massive; 2 to 10% angular rock fragments 6 to 20mm; field pH 5.5; abrupt change -

A2j/e: Sporadically or conspicuously bleached. fine sandy clay loam, clay loam; sandy clay loam to clay loam; massive; 2 to 10% angular rock fragments 6 to 20mm; field pH 5.0 to 5.5; clear to abrupt change -

B21: Mottled; grey (10YR 4/2) medium clay to medium heavy clay; moderate 5 to 10mm subangular to angular blocky; field pH 4.5 to 5.4; clear to gradual change -

B22: Faint mottled; grey (10YR 5/1, 5/2); medium clay to medium heavy clay; moderate 2 to 10mm; field pH 4.5 to 5.0; abrupt to diffuse change

C Weathered rock

Sites: 123

Pimpama Pp (map unit 2.3.2)

Concept: Black strongly to extremely acid light clay to medium clay surface over a mottled grey extremely acid light clay to medium clay subsoil. Watertable at <0.5–1m. Jarosite or iron sulfide at <0.5m

Australian Classification: Sulfuric Redoxic Hydrosol

Great Soil Group: Humic Gley

Principle Profile Form: Uf 6.41

Geology: Quaternary alluvium (Qha).

Landform: Freshwater swamps and drainage lines

Surface characteristics -

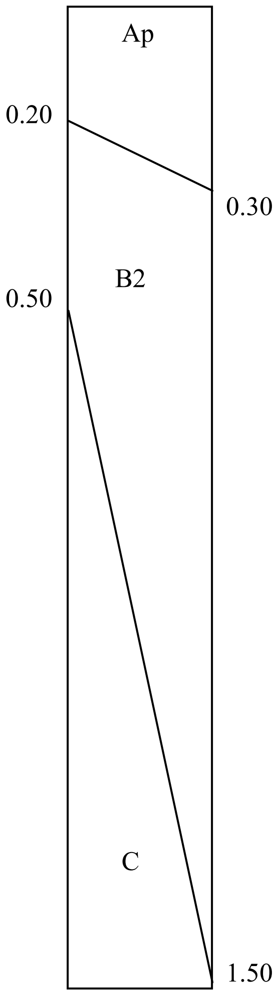
Surface condition: Firm

Coarse fragments: Nil

Microrelief: Nil

Vegetation: Cleared

Depth (m)



Ap: Black (7.5YR 2/1, 3/1. 10YR 2/1, 3/2); light clay to light medium clay; weak to moderate 2 to 10mm subangular blocky; field pH 3.8 to 5.5; clear change -

B2 Mottled, frequently jarosite; grey (7.5YR 4/1, 10YR 4/1, 4/2, 5/1, 2.5Y 4/1, 5Y 4/1, 5/1,); light clay to medium clay; weak to moderate 5 to 10mm subangular blocky in the upper horizon becoming massive to weak structure in the lower horizon; field pH 3.6 to 5.5; clear to diffuse change -

C Grey or occasionally black (10YR 4/1, 5/1, 2.5Y 3/1, 4/1, 5/1, 7.5Y 4/1, 5/1, 10Y 3/1, 4/1, N 4/-, 5GY 5/1); light clay to medium clay; massive; field pH 4.0 to 8.0.

Sites:

RK2 - 16, 20, 23, 24, 25, 54, 109, 110, 120

SEA – 10, 18, 23, 36, 37, 40, 50, 220, 239, 242, 243, 244, 245, 246, 280, 283, 346, 347, 349, 350, 352, 358, 359, 360, 374, 379, 380, 405, 444, 460, 473, 476, 495, 498, 1511, 1512, 1518, 1519, 1526, 1527, 1532, 1533, 1534, 1539, 1551, 1552, 1566, 1578, 1579, 1586, 1587, 1667, 1674, 1676, 1677, 1697, 1705, 1713, 1729, 1730, 1756, 1760, 1761, 1762, 1768, 1770, 1771, 1778, 1779, 1781, 1784, 1790, 1801, 1815, 1816, 1818, 1840, 1849, 1855, 1871, 1874, 1875, 1903, 1907, 2054, 3002, 3015, 3017, 3018, 3025, 3027, 3037, 3038, 3039, 3040, 3045, 3059, 3184, 3185, 3187

Stapylton Sp* (map unit 5.3)

Concept: Black light sandy clay loam to clay loam surface over a conspicuously bleached A2 horizon over weathered rock or light medium clay to medium clay B2 horizon over weathered rock.

Australian Classification: Bleached Leptic Tenosol, Brown Chromosol, Brown Kurosol

Great Soil Group: No suitable group - affinities with Lithosol; Brown Podsolic Soil

Principle Profile Form: Um 2.12, Db 3.41

Geology: Shale, mudstone and sandstone of the *Nerenleigh–Fernvale Beds* (DCn).

Landform: Upper slopes of gently undulating to undulating low hills and rises.

Surface characteristics -

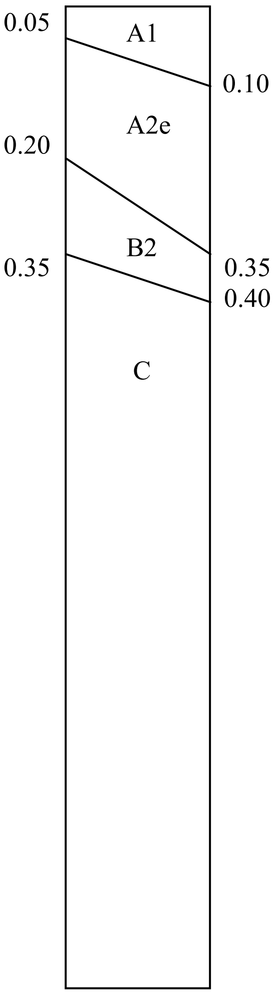
Surface condition: Hardsetting

Coarse fragments: 20 to 50% angular rock fragments 6 to 20mm.

Microrelief: Nil

Vegetation: Mostly cleared

Depth (m)



A1/Ap: Black (7.5YR 3/2); light sandy clay loam; weak 2 to 5mm cast structure; 2 to 10% angular rock fragments 2 to 6mm; field pH 5.5; gradual change -

A2e: Conspicuously bleached. Grey (10YR 5/2);); light sandy clay loam; massive; 10 to 20% angular rock fragments 6 to 20mm; field pH 5.5; clear to abrupt change to B2 or C horizons -

B2: Faint mottled; brown (10YR 4/3) sandy light medium clay to medium clay; moderate 5 to 10mm subangular blocky; 2 to 10% angular rock fragments 2 to 6mm; field pH 5.0 to 5.8; clear to abrupt change -

C: Weathered rock.

Sites: 135

Steigletz Sl (map unit 2.2.1)

Concept: Black extremely acid to medium acid fine sandy clay loam to light medium clay surface over a mottled grey extremely acid to medium acid fine sandy clay loam to fine sandy light clay and medium clay over a mottled grey extremely acid to neutral sand to sandy clay loam D horizon at <1m. Watertable at 0.5–1.5m. Jarosite (if present) at 0.5–1m or iron sulfide at 0.5–2 m

Australian Classification: Dermosolic Redoxic Hydrosol, Kandosolic Redoxic Hydrosol, Sufuric Redoxic Hydrosol

Great Soil Group: Humic Gley

Principle Profile Form: Uf 6.41, Um 5.52, Uf 6.42

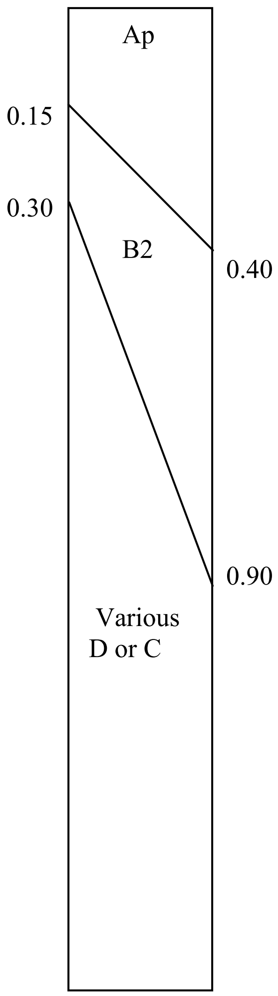
Geology: Quaternary alluvium (Qha).

Landform: Alluvial plain and swamps.

Surface characteristics -
- **Surface condition:** Firm
- **Coarse fragments:** Nil
- **Microrelief:** Nil

Vegetation: Cleared

Depth (m)



A1/Ap: Black (7.5YR 3/1, 10YR 2/1, 2/2, 3/1, 3/2); fine sandy clay loam to light medium clay; massive or weak to moderate 2 to 10mm subangular blocky; field pH 3.6 to 6.0; clear change -

B2: Mottled; grey or occasionally black (7.5YR 4/1, 5/2, 10YR 3/1, 3/2, 4/1, 4/2, 5/1, 5/2, 6/1, 6/2, 2.5Y 4/1, 4/2, 5/2) occasionally with jarosite in lower B2; fine sandy clay loam to fine sandy light clay and medium clay; massive or weak to moderate 2 to 10mm subangular blocky; field pH 3.0 to 6.0; clear to gradual change -

Various D or C: Mottled becoming non mottled at depth, occasionally jarosite in upper horizons; grey or occasionally black (10YR 4/1, 5/1, 5/2, 2.5Y 4/1, 5/1, 5Y 3/1, 4/1, 5/1, 7.5Y 4/1, 10Y 3/1, 4/1, N3/-, N4/-, N6/-); sand to fine sandy clay loam or layers of sand to light clay; massive or single grain; field pH 4.5 to 8.5

Sites:

RK2 - 2, 6, 9, 21, 22, 26, 63, 65, 66, 67, 69, 70, 71, 100, 101, 104, 115, 117, 141

SEA – 22, 44, 288, 345, 394, 461, 1503, 1509, 1559, 1567, 1648, 1649, 1666, 1668, 1681, 1689, 1696, 1698, 1700, 1702, 1718, 1719, 1720, 1721, 1723, 1725, 1733, 1741, 1745, 1749, 1750, 1753, 1759, 1764, 1766, 1783, 1786, 1789, 1799, 1814, 1857, 1891, 1894, 1911, 1918, 2024, 2039, 2040, 2044, 3012, 3019, 3047, 3050, 3061, 3190, 3198

Tabby Tb* (map unit 5.1)

Concept: Black or brown sandy clay loam to clay loam sandy surface over a pale A2 horizon over a red light clay to medium clay subsoil over weathered sandstone.

Australian Classification: Red Kandosol, Red Chromosol, Yellow Kandosol, Brown Chromosol

Great Soil Group: Red earth, Red Podzolic Soil, Yellow Earth, Yellow Podzolic Soil.

Principle Profile Form: Gn 2.11, Dr 2.11p, Dr 3.11p, Um 4.21, Gn 2.61, Dy3.21

Geology: Sandstones of the *Woogaroo Formation* (RJbw)

Landform: Gently undulating low hills and rises.

Surface characteristics -

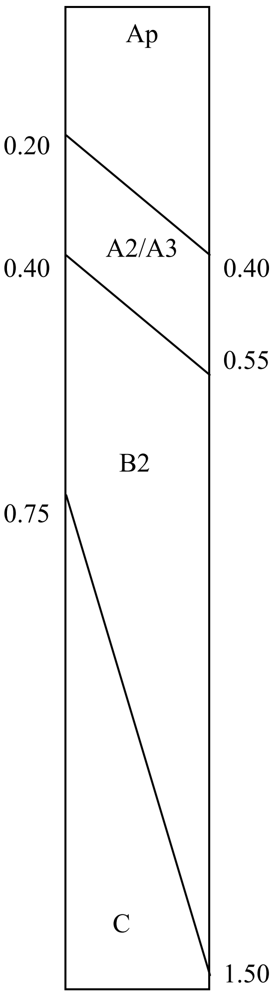
Surface condition: Firm

Coarse fragments: Nil

Microrelief: Nil

Vegetation: Mostly cleared

Depth (m)



A1/Ap: Black or brown (7.5YR 3/2, 3/3, 10YR 3/2, 4/2); sandy loam to clay loam sandy; massive to weak 2 to 5 mm subangular blocky; field pH 5.5 to 7.0; abrupt change -

A2/A3: Brown or red (5YR 3/3, 4/2, 7.5YR 3/3, 10YR 5/4, 6/4); sandy loam to clay loam sandy; massive; field pH 5.7 to 7.0; clear to gradual change -

B2: Occasionally mottled (especially in lower landscape positions); red, yellow or brown (2.5YR 4/4, 4/6, 5YR 4/4, 4/6, 10YR 5/5, 6/6); sandy clay loam to sandy light clay, medium clay; massive to moderate 5 to 10mm subangular blocky; frequently <2 to 50% rock fragments 6 to 20mm; field pH 5.5 to 6.5; gradual to diffuse change -

C: Weathered rock

Sites: 51, 52, 59, 126, 131

Woongoolba Wg (map unit 2.1.1)

Concept: Black extremely acid to medium acid sandy light clay to sand medium clay, occasionally clay loam sandy surface over a mottled grey extremely acid to medium acid sandy light clay to sandy medium clay, occasionally clay loam sandy subsoil over a mottled grey extremely acid to neutral sand to sandy clay loam D horizon at predominantly <1m. Watertable at 1–1.5m. Jarosite (if present) at >1m or iron sulfide at 1–3 m

Australian Classification: Dermosolic Redoxic Hydrosol, Kandosolic Redoxic Hydrosol

Great Soil Group: Humic Gley

Principle Profile Form: Uf 6.41, Um 5.52, Uf 6.42

Geology: Quaternary alluvium (Qha).

Landform: Alluvial plain.

Surface characteristics -

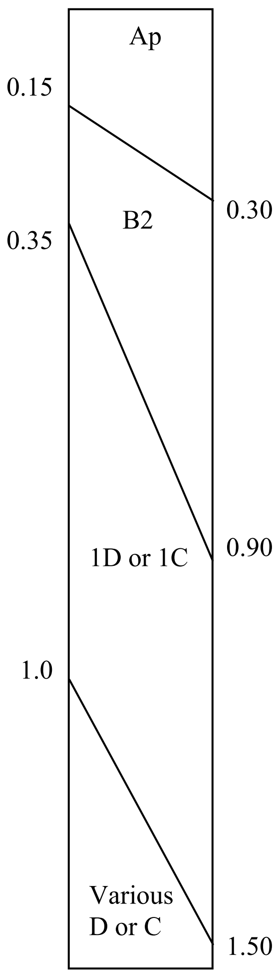
Surface condition: Firm

Coarse fragments: Nil

Microrelief: Nil

Vegetation: Cleared

Depth (m)



Ap: Black (7.5YR 2/1, 3/1, 10YR 2/1, 2/2, 3/1, 3/2); fine sandy clay loam to light medium clay; massive or weak to moderate 2 to 10mm subangular blocky; field pH 3.8to 6.0; abrupt to gradual change –

B2: Mottled, grey or occasionally black (10YR 3/1, 3/2, 4/1, 4/2, 5/1, 5/2, 6/1, 2.5Y 4/1, 5/1, 5/2); fine sandy clay loam to fine sandy light clay and medium clay; massive or weak to moderate 2 to 10mm subangular blocky; field pH 3.5 to 7.0; clear to diffuse change –

1D or 1C: Mottled, occasionally jarosite at >1m; grey (10YR 4/1, 4/2, 5/1, 5/2, 6/1, 6/2, 7/2, 2.5Y 6/2, 2.5Y 5/1, 6/1, 5Y 5/1); sand to fine sandy clay loam; massive; field pH 3.5 to 7.0; clear to diffuse change –

Various D or C: Faint mottles or no mottles; grey (10YR 4/1, 4/2, 5/2, 6/1, 2.5Y 4/1, 5/1, 6/1, 5Y 4/1, 5/1, 7.5Y 4/1, 5/1, 10Y 4/1, N3/-, N4/-, N5/-); sand to fine sandy clay loam; massive or single grain; field pH 4.0 to 8.0.

Sites:

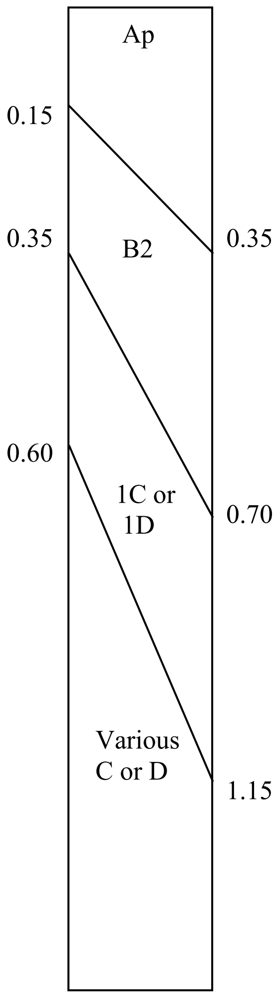
RK2 - 1, 7, 8, 13, 15, 27, 55, 61, 62, 64, 68, 76, 11, 112, 114, 116, 118

SEA – 30, 39, 41, 42, 234, 235, 278, 282, 287, 344, 368, 369, 370, 371, 378, 445, 463, 467, 477, 479, 485, 487, 491, 492, 494, 1505, 1507, 1536, 1538, 1553, 1557, 1558, 1560, 1565, 1576, 1581, 1582, 1650, 1660, 1663, 1669, 1670, 1671, 1672, 1673, 1686, 1687, 1688, 1690, 1691, 1694, 1695, 1699, 1701, 1703, 1715, 1726, 1727, 1731, 1734, 1738, 1739, 1742, 1744, 1746, 1748, 1752, 1755, 1757, 1765, 1775, 1776, 1780, 1782, 1795, 1796, 1798, 1802, 1807, 1820, 1833, 1839, 1842, 1843, 1846, 1850, 1852, 1853, 1858, 1862, 1863, 1864, 1866, 1868, 1876, 1883, 1884, 1900, 1901, 1902, 1905, 1906, 1908, 1909, 1912, 1915, 1916, 2001, 2002, 2003, 2004, 2005, 2020, 2022, 3006, 3007, 3009, 3011, 3014, 3020, 3021, 3026, 3028, 3029, 3049, 3052, 3055

Woogoompah Wp (map unit 2.4.1)

Concept:	Black extremely acid to slightly acid sandy clay loam to light clay over a mottled grey strongly acid to neutral sandy clay loam to light medium clay over a grey alkaline sand to clay loam D or C horizon at predominantly <1m,. Watertable at <0.5–1m. Jarosite or iron sulfide at <0.5m. Saline surface.
Australian Classification:	Sulfidic Redoxic Hydrosol, Sulfuric Redoxic Hydrosol
Great Soil Group:	Solonchak
Principle Profile Form:	Uf 6.41, Um 5.52
Geology:	Quaternary alluvium (Qha).
Landform:	Brackish swamps.
Surface characteristics -	
Surface condition:	Firm. Salt crust usually present.
Coarse fragments:	Nil
Microrelief:	Nil
Vegetation:	Mostly cleared, *Casurina glauca/Melaleuca quinquenervia* open woodland

Depth (m)



Ap: Black or occasionally grey (10YR 2/1,2/2, 3/1, 3/2, 4/1, 4/2); fine sandy clay loam to light clay; massive or weak to moderate 2 to 10mm subangular blocky; field pH 3.8 to 6.0; abrupt to gradual change -

B2: Mottled, occasionally jarosite; grey or occasionally black (10YR 3/1, 4/1, 5/1, 5/2, 2.5Y 4/1, 5/2); fine sandy clay loam to light medium clay; massive to weak 5 to 10mm angular blocky; field pH 3.1 to 6.0; clear change -

C or 1D: Faint mottled; occasionally jarosite; grey (10YR 5/1, 5/2, 2.5Y 4/1, 5/1, 5/2, 6/1, 7.5Y 4/1, N3/-, N4/-, N5/-) sand to fine sandy clay loam to medium clay; massive or single grain; field pH 2.7 to 7.5; clear to diffuse change -

Various C or D: Grey or occasionally black (10YR 4/1, 2.5Y 3/1, 4/1, 5/1, 5Y 3/1, 4/1, 5/1, 7.5Y4/1, 10Y 3/1, 4/1, N4/-, N5/-); sand to sandy clay loam or layers of sand to sandy clay; massive or single grain; field pH 4.3 to 8.0.

Sites:

RK2 - 17, 18, 72, 74, 75, 77, 113, 119

SEA – 16, 51, 380, 381, 390, 393, 395, 450, 462, 483, 1501, 1522, 1537, 1568, 1574, 1678, 1679, 1693, 1704, 1722, 1773, 1785, 1791, 1792, 1793, 2031, 2033, 2034, 2045, 2047, 3013, 3023, 3030, 3058, 3181

Yawalpah (Yp) (map unit 3)

Concept: Black or brown acid light clay to medium clay surface over mottled grey medium clay to heavy clay subsoil.

Australian Classification: Vertic Eutrophic Grey Dermosol

Great Soil Group: No suitable group - affinities with grey cracking clay

Principle Profile Form: Uf 6.41

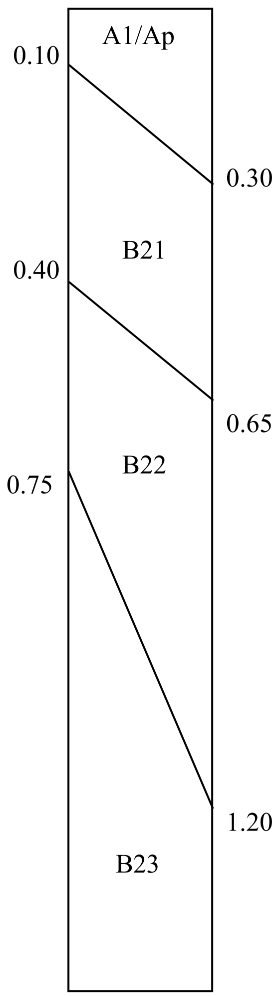
Geology: Quaternary alluvium (Qha).

Landform: Terrace plain.

Surface characteristics -
Surface condition: Firm
Coarse fragments: Nil
Microrelief: Normal Gilgai where undisturbed, vertical depth 0.1 to 0.2 m, horizontal interval 3 to 4 m.

Vegetation: Mostly cleared

Depth (m)



A1/Ap: Black, grey or brown (7.5YR 3/1, 3/2, 10YR 3/1, 3/2, 4/2, 4/3); light medium clay to medium clay; weak to moderate 2 to 10mm subangular blocky; field pH 3.7 to 6.0; clear to abrupt change -

B21: Mottled, grey or brown (10YR 4/1, 4/2, 4/3, 5/2, 5/3); medium clay to medium heavy clay; moderate 2 to 10mm subangular blocky or 2 to 5mm lenticular; field pH 3.6 to 5.5; clear to diffuse change -

B22: Mottled; grey (7.5YR 5/1, 10YR 4/2, 5/1, 5/2, 6/1, 2.5Y 4/2, 5/1, 5/2); medium clay to heavy clay; moderate 2 to 5mm lenticular; field pH 3.6 to 5.0; clear change -

B23: Mottled; grey (10YR 5/2, 6/1, 7/1, 2.5Y 5/1, 5/2, 6/1, 7/1, 5Y 5/2, 6/1); medium clay to medium heavy clay; moderate 2 to 5mm lenticular; field pH 3.6 to 5.0.

Sites:

RK2 - 50, 57, 121, 122, 130, 132, 134

SEA – 4, 7, 9, 14, 31, 34, 366, 408, 409, 410, 440, 481, 482, 1545, 1546, 1685, 1707, 1806, 1812, 1827, 1861, 2037, 2038, 2043, 3004, 3022

Appendix 2
Land Use Suitability Framework

Introduction

Using procedures developed by Land Resources Branch Staff (QDPI 1990), a suitability classification framework has been developed to assess the suitability of land in the Woongoolba–Rocky Point area of South East Region (Figure 1) for growing a wide variety of crops climatically adapted to the area. The framework is based on a standard set of land use requirements defined for agricultural land uses in Queensland (Land Resources Branch Staff 1990). These relate to plant growth, machinery use, land preparation, irrigation and the prevention of land degradation and other environmental hazards (eg. acid drainage).

To assess the suitability of any parcel of land for a particular use, it is necessary to consider each of these land use requirements. Landscape attributes that contribute to:

- less than optimal conditions for crop growth/production, for a particular land use or
- result in environmental harm as a result of land preparation or agronomic management of the crop are known as limitations. Management is concerned with overcoming or reducing the effects of these limitations.

This suitability framework was adapted from the Sunshine Coast framework (Burgess and Wilson, in prep).

Some crops currently grown in the study area are rainfed but most cultivated crops in the Rocky Point area require supplementary irrigation for economic production. Of the land uses listed below, those that typically utilise supplementary irrigation are indicated with an (i). Irrigation methods include overhead spray, micro-sprinkler or drip irrigation. Furrow irrigation is not used in the study area and has not been considered.

While species selection for sown pastures enables adaptation to a wide range of conditions, tropical grass/legume pastures are most suited to the area. Grass/legume species recommended by QDPI (G Elphinstone pers. comm.) include Callide Rhodes grass, Bisset creeping blue grass, Pangola grass, paspalum (*Paspalum dilatum*), kikuyu, white clover, joint vetch, Wynn cassia, stylos, *Lotononis*, Shaw creeping vigna and *Glycine*. *Setaria* species are not recommended because of bighead problems in horses, while tropical viney legumes such as *Siratro* or *Desmodium* are no longer used because of environmental weed concerns in non-grazed situations. Suitability for sown pastures is far less complex than for cropping and is largely restricted to the assessment of erosion hazard, nutrient deficiency, moisture availability, and acid drainage water hazard. These factors effectively control pasture and animal productivity and also the risk of land degradation following development to pasture.

The agricultural and forestry land uses assessed include:

- Avocado (i)
- Banana (i) (rainfed)
- Blackbutt (*E. pilularis*)
- Capsicum (s) (w)
- Caribbean pine
- Ginger (s) (w) (i)
- Gympie messmate (*E. cloeziana*)
- Lychee (i)
- Macadamia (i)
- Maize (forage)
- Sown pastures (rainfed)
- Soybean
- Spotted gum *(C. maculata*)
- Stone fruit (low-chill peaches, nectarines) (i)
- Strawberries (i)

- Chokos (i)
- Citrus (lime, lemon) (i)
- Cucurbits (melons, pumpkins, zucchini)(s)(w)(i)
- Custard apple (i)
- Dunn's white gum (*E. dunnii*)
- Flooded gum (*E. grandis*)
- Mango (i)
- Papaw (i)
- Passionfruit (i)
- Persimmon (i)
- Pineapple
- Sorghum (forage)
- Sugar cane (i) (rainfed)
- Sweet corn (s) (w) (i)
- Sweet potato (s) (w) (i)
- Tomato (s) (w) (i)
- Turf (i)

Note – Summer (s) and winter (w) land uses have been identified to allow assessment for seasonal adaptation and variation in soil/land attributes such as frosts, temperature, flooding, wetness and water availability.

This classification scheme details the soil/land attributes used in the assessment of each limitation and some background and rationale as to how the limitation subclasses have been determined.

There are 21 limitations (Table 3) to agricultural production recognised in this framework. Locally, within any particular catchment or sub-region some limitations may not be relevant depending on the nature of the landscape in that area and the land uses that are locally important. The background, rationale and assessment of these limitations are not presented as part of this study.

Land Suitability Classes

Five land suitability classes have been defined for use in Queensland, with suitability for a particular land use decreasing progressively from Class 1 to Class 5. Land is classified on the basis of a specified land use and a suitable rating assumes production is optimal with minimal degradation to the land resource and wider environment in the long term. The suitability of a particular parcel of land depends directly on the number and severity of limitations associated with the land use being considered. These in turn are determined by the land use requirements of the crop and the inherent characteristics of the land. Final suitability is determined by the most severe limitation.

The severity of each limitation (ie. suitability subclasses on a scale from 1 to 5) has been individually assessed according to the following definitions:

Class 1	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.
Class 2	Suitable land with minor limitations, which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production.
Class 3	Suitable land with moderate limitations which either further lower production or require more than those management practices of Class 2 land to maintain economic production.
Class 4	Marginal land which is presently considered unsuitable due to severe limitations. The long term or precise effects of these limitations on the proposed land use are unknown. The use of this land is dependent upon either undertaking additional studies to determine its suitability for sustained production or reducing the effects of the limitation(s) to achieve production.
Class 5	Unsuitable land with extreme limitations that preclude its use.

Table 3 (repeated from page 10). Land use requirements, limitations and soil and land attributes used in assessing land suitability in the Rocky Point area

Land use requirements	Limitations	Soil and land attributes used to assess each limitation
Frost-free	**frost (cf)**	frequency of damaging frosts, landform, landscape position
Adequate rainfall (rainfed crops only)	**precipitation (cp)**	amount and distribution of rainfall, evaporation, crop modelling
Maximise solar radiation	**solar radiation (cr)**	Prescott Index, DEM, assessment of northern landscape aspects
Avoid environmental harm form acid drainage water from actual acidity	**acid drainage water hazard actual (da)**	texture, depth to oxidisable sulfur (%), presence of actual acidity (pH <4.0)
Avoid environmental harm form acid drainage water from potential acid acidity	**acid drainage water hazard potential (dp)**	texture, depth to oxidisable sulfur (%), presence of potential acidity
Minimise soil loss from erosion	**water erosion (e)**	slope/soil erodibility (USLE (K factor), soil stability groups)
Absence of damaging floods	**flooding (f)**	depth/frequency of flooding based on average recurrence interval (ARI), flood velocity
Adequate soil aeration	**wetness (w)**	soil drainage and permeability
Level land surface	**microrelief (tm)**	size and proportion of microrelief, microrelief variability
Land surface of acceptable slope for safe machinery use	**topography (ts)**	slope (%), variation in slope length and direction
Adequate water supply	**water availability (m)**	PAWC, ERD, crop modelling
Adequate soil depth for physical support	**soil depth (pd)**	depth to C horizon, hard rock or other impermeable layer; depth to high salt concentrations (>0.8dS/m), watertable or very low pH (<4.0)
Rock-free	**rockiness (r)**	size and content (%) of coarse fragments, % rock outcrop
Favourable levels of soluble salts	**soil salinity (sa)**	average salt content (dS/m) of the profile (mean, water uptake weighted)
Ability to harvest underground crops	**soil adhesiveness (pa)**	texture, structure, consistence and clay mineralogy of the surface soil (<0.3m)
Suitable timing for cultivation	**narrow moisture range (pm)**	surface condition, surface soil texture (<0.3m), soil drainage
Ease of seedbed preparation and plant establishment	**soil surface condition (ps)**	surface condition, surface soil texture and structure (<0.3m), susceptibility to compaction
Adequate nutrients	**nutrient deficiency (nd)**	nutrient levels in soils
Low nutrient fixing conditions	**nutrient fixation (nf)**	humic/organic material or high levels of free Fe/Al oxides
Adequate retention of added nutrients against leaching	**nutrient leaching (nl)**	soil permeability, absence of shallow watertables (> 1.5 m)
Low levels of toxic elements	**element toxicity (nt)**	soil pH in the surface soil (<0.3 m)

The first three classes (1–3) are considered suitable for the specified land use, because the benefits from using the land for that use outweigh the inputs required to initiate and maintain production in the long term. Decreasing land suitability within a location often reflects the need for increased inputs rather than decreased potential production.

Class 4 is marginal land and is presently considered unsuitable and is used for marginal land where it is doubtful that the benefits from using the land in the long term will outweigh the inputs required to achieve and maintain production. It is also used for land where actions to specifically reduce the effect of a limitation may allow the land to be upgraded to a higher suitability class. However, additional studies would be required to determine the feasibility of such actions.

Class 5 is considered unsuitable land due to limitations that in aggregate are so extreme that the benefits from using the land do not justify the inputs required to initiate and maintain production in the long term. It would require a major change in economics, technology or management expertise before the land could be considered suitable for the specified land use. Some class 5 lands (eg. steep escarpments) however will always remain unsuitable for agriculture.

Frost (cf)

Effect

Frosts may kill plants, suppress growth and reduce yield.

Assessment

The incidence and severity of frosts in relation to landscape position are used to distinguish affected areas. Temperature limits associated with frosting are based on standard screen temperatures and not ground level values.

Limitation class determination

Crop tolerance and local experience have been used to determine the incidence and severity of frosts. For example, severe frosts cause severe damage to sugar cane stalk tissue and can significantly reduce sugar content unless it is harvested within two weeks, depending on weather conditions.

Crop specific comments

- Strawberries can tolerate regular moderate frosts but require night watering to avoid frost damage to flowers. This can lead to problems with excess wetness and a decline in fruit quality.
- Cucurbits, capsicums and tomatoes are highly susceptible to frost and careful management is required in frost prone areas to avoid all but occasional, very light frosts.

Code	Attribute level	Suitability subclasses for various crops								
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
cf 1	Frost free or occasional light frost >-1C (hill tops or near coastal areas, <3 events per year)	1	1	1	1	1	1	1	1	1
cf 2	Regular light frosts >-1°C (>/= 3 events per year)	5	4	3	2	1	1	1	2	1
cf 3	Regular moderate frosts -1° to -4°C (>/= 3 events per year)	5	5	4	3	2	1	1	4	2
cf 4	Severe frosts <-4°C (>/= 3 events per year)	5	5	5	4	3	2	1	5	4

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Banana	Avocado	Blackbutt	Spotted gum	Flooded gum	Dunn's white gum	Capsicum (s)	Citrus	Turf
Banana (rainfed)	Capsicum (w)	Caribbean pine	Sugar cane	Persimmon	Sown pastures (rainfed)	Cucurbits (s)		
Cucurbits (w)	Custard apple	Choko	Sugar cane (rainfed)			Ginger (s)		
Papaw	Lychee	Ginger (w)				Maize (forage) – (s) (rainfed)		
Tomato (w)	Macadamia (i) (rainfed)	Gympie messmate				Sorghum (forage) (s) (rainfed)		
	Mango	Strawberry				Soybean		
	Passionfruit	Sweet corn (w)				Sweet corn (s)		
	Pineapple					Sweet potato (s)		
	Stone fruit					Tomato (s)		
	Sweet potato (w)							

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Precipitation (cp)

Effect

Rainfall amount and distribution largely control cropping and grazing productivity, and particularly cropping success in rainfed (dryland) situations. This limitation has limited application on the western catchments because most land uses require supplementary irrigation to ensure adequate production, particularly through the late winter – early spring dry period. As such, the cp limitation only applies to crops that can be grown on a regular basis without supplementary irrigation. These include sugar cane, soybean, maize, sorghum and commercial forestry (Blackbutt, Dunn's white gum, Flooded gum, Gympie messmate and Spotted gum).

Assessment

The amount of rainfall, rainfall distribution between years, seasonal distribution of rainfall within years and losses from evaporation are often used to determine if climatic conditions provide adequate rainfall opportunities for:

- successful planting rain events; and
- sufficient in-crop rainfall for crop establishment and growth to produce some level of product that is economic to harvest.

The ability of soils to store moisture is also important, but available soil water capacity simply extends climatic inputs by influencing the amount of time over which rainfall is made available to plants (see m limitation).

Where 'fresh' watertables occur within or immediately below the root zone of a particular rainfed crop, the water available seasonally from the watertable may modify the cp limitation subclasses.

Limitation class determination

Local experience and QDPI&F/Industry recommendations have been used to determine crop yields and the success of achieving a harvestable product under rainfed conditions.

Crop specific comments

- In the Gold Coast area where annual rainfall is 1200–1500mm, enough effective rainfall is received in approximately 8% of years to grow a harvestable crop of sugar cane (any effects from surface run-on, irrigation or shallow watertables are not considered). Sugar cane can be held-over for a second year if required (ie. two year crop) to achieve a tonnage that is economic to harvest in approximately 50% of years.
- Pineapple can be grown in low rainfall areas but the need for timely rainfall at crucial stages in the crop cycle means that low rainfall areas are high risk.
- Yield of Dunn's white gum decreases in summer dominant high rainfall areas (particularly where high temperatures are associated with high rainfall) due to disease problems.
- Group 6 crops are all irrigated.

Code	Attribute level	Suitability subclasses for various crops						
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
cp 11	Mean annual rainfall > 1800mm, fresh watertable not present within 1.5m of the surface	1	1	1	1	3	1	1
cp 12	Mean annual rainfall > 1800mm, fresh watertable present within 1.0–1.5m of the surface	1	1	1	1	3	1	1
cp 13	Mean annual rainfall > 1800mm, fresh watertable present within 0.5–1.0m of the surface	1	1	1	1	3	1	1
cp 14	Mean annual rainfall > 1800mm, fresh watertable present within 0.5m of the surface	1	1	1	1	3	1	1
cp 21	Mean annual rainfall 1500 to 1800mm, fresh watertable not present within 1.5m of the surface	1	2	1	1	3	1	1
cp 22	Mean annual rainfall 1500 to 1800mm, fresh watertable present within 1.0–1.5m of the surface	1	1	1	1	3	1	1
cp 23	Mean annual rainfall 1500 to 1800mm, fresh watertable present within 0.5–1.0m of the surface	1	1	1	1	3	1	1
cp 24	Mean annual rainfall 1500 to 1800mm, fresh watertable present within 0.5m of the surface	1	1	1	1	3	1	1
cp 31	Mean annual rainfall 1200 to 1500mm, fresh watertable not present within 1.5m of the surface	2	3	2	1	2	3	1
cp 32	Mean annual rainfall 1200 to 1500mm, fresh watertable present within 1.0–1.5m of the surface	1	2	1	1	1	2	1
cp 33	Mean annual rainfall 1200 to 1500mm, fresh watertable present within 0.5–1.0m of the surface	1	1	1	1	1	1	1
cp 34	Mean annual rainfall 1200 to 1500mm, fresh watertable present within 0.5m of the surface	1	1	1	1	1	1	1
cp 41	Mean annual rainfall 1000–1200mm, fresh watertable not present within 1.5m of the surface	4	4	3	1	2	5	1
cp 42	Mean annual rainfall 1000–1200mm, fresh watertable present within 1.0–1.5m of the surface	3	3	2	1	1	3	1
cp 43	Mean annual rainfall 1000–1200mm, fresh watertable present within 0.5–1.0m of the surface	1	2	1	1	1	2	1
cp 44	Mean annual rainfall 1000–1200mm, fresh watertable present within 0.5m of the surface	1	1	1	1	1	1	1
cp51	Mean annual rainfall 850–1000mm, fresh watertable not present within 1.5m of the surface	5	5	4	2	3	5	1
cp 52	Mean annual rainfall 850–1000mm, fresh watertable present within 1.0–1.5m of the surface	4	4	3	1	2	4	1
cp 53	Mean annual rainfall 850–1000mm, fresh watertable present within 0.5–1.0m of the surface	3	3	2	1	1	3	1
cp 54	Mean annual rainfall 850–1000mm, fresh watertable present within 0.5m of the surface	1	1	1	1	1	1	1
cp 61	Mean annual rainfall <850, fresh watertable not present within 1.5m of the surface	5	5	5	3	4	5	1
cp 62	Mean annual rainfall <850, fresh watertable present within 1.0–1.5m of the surface	5	5	4	2	3	5	1
cp 63	Mean annual rainfall <850, fresh watertable present within 0.5–1.0m of the surface	4	4	3	1	2	4	1
cp 64	Mean annual rainfall <850, fresh watertable present within 0.5m of the surface	1	1	1	1	1	1	1

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 7 continued
Banana (rainfed)	Sugar cane (rainfed)	Caribbean pine	Maize (forage) – (s) (rainfed)	Dunn's white gum	Blackbutt	Avocado	Papaw
Macadamia (rainfed)		Gympie messmate	Sorghum (forage) (s) (rainfed)		Flooded gum	Banana	Passionfruit
		Pineapple	Sown pastures (rainfed)			Capsicum (w)	Persimmon
			Soybean			Capsicum (s)	Tomato (s)
			Spotted gum			Choko	Tomato (w)
						Citrus	Strawberry
						Cucurbits (w)	Stone fruit
						Cucurbits (s)	Sweet corn (w)
						Custard apple	Sweet corn (s)
						Ginger (w)	Sweet potato (w)
						Ginger (s)	Sweet potato (s)
						Lychee	Sugar cane
						Macadamia	Turf
						Mango	

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Solar radiation (cr)

Effect

Solar radiation affects the growth potential of plants. Extremes of radiation and temperature may cause stress periods for crops and livestock, particularly where temperate species experience continued high temperatures or tropical species are subject to continued periods of low temperature. It is important to note however, that the physical damage and production losses associated with frosting are covered in the Cf limitation, while effects associated with heatwaves are thought to affect the whole landscape uniformly and are not considered important. The Cr limitation assesses the effect differences in aspect and elevation (eg. north vs south facing slopes) have on crop productivity. Such differences are the result of variations in:

- the amount of solar radiation received; and
- associated seasonal temperature effects.

This limitation is not concerned with climatic extremes such as frost or heatwaves.

Assessment

The Cr limitation specifically aims to assess:

- relative differences in the level of solar radiation received due to changes in aspect and elevation; and
- the effect such differences may have on crop productivity.

Limitation class determination

Application of a combined Prescott Index/DEM surface is used to spatially differentiate areas where the relative level of solar radiation varies due to changes in aspect and elevation. Crop tolerance information and local industry experience have been used to assess the effects such variations have on crop productivity.

Code	Attribute level	Suitability subclasses for various crops				
		Group 1	Group 2	Group 3	Group 4	Group 5
cr 1	Sunny north facing slopes (winter solstice at midday)	1	1	1	2	1
cr 2	Shady south facing slopes (winter solstice at midday)	4	3	2	1	1

Group 1	Group 2	Group 3	Group 4	Group 5	Group 5 continued
Banana	Capsicum (w)	Avocado	Ginger (s) (w)	Blackbutt	Sorghum (forage) – (s) (rainfed)
Banana (rainfed)	Cucurbits (w)	Choko		Capsicum (s)	Sown pastures (rainfed)
Papaw	Pineapple	Citrus		Caribbean pine	Soybean
	Strawberry	Custard apple		Cucurbits (s)	Spotted gum
	Sweet corn (w)	Mango		Dunn's white gum	Sweet corn (s)
	Sweet potato (w)	Passionfruit		Flooded gum	Sweet potato (s)
	Tomato (w)	Persimmon		Gympie messmate	Tomato (s)
	Lychee	Sugar cane		Maize (forage) –(s) (rainfed)	
	Macadamia (i) (rainfed)	Sugar cane (rainfed)			
	Stone fruit	Turf			

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Acid drainage water hazard (da and dp)

Effect

Toxic quantities of acid, aluminium, iron and heavy metals may contaminate land and adjacent waterways when ASS are disturbed or drained. Such contamination can affect or kill aquatic flora and fauna, vegetation, crops and accelerate structural failure of pipes, foundations, bridges and road surfaces.

Assessment

An AASS is a soil in which significant existing acidity (pH of 4 or less) is already present due to the oxidation of iron sulfides and/or the presence of jarosite in the field. While pH <4.0 in itself is not a direct measure of the volume of acid present in such soils it does provides a reliable indicator of the spatial extent of such material. Because existing acidity presents a significant hazard to plant growth, depth to pH <4 has been recorded as a polygon based (ie. UMA) attribute by Manders *et al*. (2002).

Potential acid sulfate soils (PASS) contain unoxidised iron sulfide (FeS_2) and usually have elevated pH values (pH 4.0 to >7.0). A combination of field tests and laboratory analysis are used to determine the presence of PASS. Two field pH tests are conducted—pH_F gives the pH of a soil:water mix, while pH_{FOX} involves reaction of the soil material with hydrogen peroxide (H_2O_2) to rapidly oxidise the iron sulfides and generate acidity. A combination of three factors from the field pH tests are routinely used to estimate whether PASS are present: i) reaction with peroxide, ii) a much lower pH_{FOX} than pH_F; and iii) the actual value of the pH_{FOX} test. PASS is often present when the pH_{FOX} is <3, a strong visible reaction with peroxide is observed, and the pH_{FOX} value is at least one unit below the pH_F result. The detection of hydrogen sulfide gas is also a good indicator that PASS may be present.

Quantitative assessment of the hazard posed by ASS is based on the depth to and quantity of oxidisable sulfur (ie. from unoxidised iron sulfides) and net acidity (actual and potential) as determined by laboratory analysis for particular texture categories. The depth to soil layers with oxidisable sulfur levels above the action criteria has been recorded as a polygon based (ie. UMA) attribute by Manders *et al*. (2002).

The level and distribution of iron sulfides (FeS_2) within ASS are usually highly variable within the landscape, within the soil profile and from point to point within sulfidic layers. Elevation (<5 m), geomorphology (coastal marine plains, swamps) and hydrology (poorly drained horizons) may help to indicate the spatial extent of the hazard.

Limitation class determination

Action criteria describing levels of oxidisable sulfur which trigger the need for management are listed below for three broad soil texture categories. These criteria reflect the guidelines defined by Ahern *et al.* (1998), and also agree with those developed nationally. The texture categories provide a useful guide to the clay content and natural pH buffering capacity of the soil. Disturbing soil material with oxidisable sulfur levels above the defined action criteria will potentially cause an acid drainage water hazard.

The depth to:

- PASS (soil material with pH >4 and oxidisable sulfur levels above the action criteria); or
- AASS (soil material with pH <4 and/or jarosite present); and

the depth to which drainage is required for a particular land use determines the potential for acid drainage water hazard. As such, the hazard rating effectively describes the level of management required to control and manage acid drainage water when ASS are cultivated and drained for agricultural production.

Cultivation and drainage works typically cause acid drainage when either PASS or AASS is present at depths shallower than the depth of the proposed soil disturbance. For example, a drainage hazard would exist:

- where PASS is present between 0.5–1.0 m and drains are >1.0 m deep; or
- where AASS (pH <4.0 and/or jarosite present) is present between 0–0.5 m and deep cultivation and shallow surface drains are present.

In general, drainage works should be shallower than the depth to oxidisable sulfur (PASS) or depth to pH <4.0 (AASS) if acid drainage water hazard is to be avoided. For example, moderately deep drains (about 1.0 m) are generally adequate for crops with rooting depths ≤1.0 m. However, where sulfidic sediments are present at depths >1 m, a reasonable buffer (eg. >0.5 m) should exist between the depth of disturbance and the depth to PASS or AASS. Shallow wide drains that do not penetrate the sulfidic layers are preferable to deep narrow drains that do penetrate the sulfides.

Crop specific comments

The drained soil depth requirement before intersecting AASS or PASS layers varies between crops.

Crops requiring a drained soil depth of 1.5 m are restricted to:

- Avocadoes.

Crops requiring a drained soil depth of 1.0 m include :

- Sweet corn, Maize (forage), Sorghum (forage), Choko, Citrus, Custard apple, Macadamia, Papaw, Stone-fruit, Mango, Lychee, Passionfruit, Persimmon, Gympie messmate, Blackbutt, Spotted gum, Flooded gum, Dunn’s white gum and Caribbean pine.

Crops requiring a drained soil depth of 0.5 m include :

- Capsicum, Cucurbits, Sweet potato, Tomato, Turf, Strawberry and improved pasture.

Action criteria for the assessment of PASS and AASS

Texture category		Potential Acid Sulfate Soil (PASS)		Actual Acid Sulfate Soil (AASS)	
McDonald *et al.* (1990)	**Approximate clay %**	**Action Criteria: net acidity (mol H$^+$/tonne) or equivalent percent oxidisable sulfur (%S)**	**PASS Mapping Code**	**Soil pH**	**AASS Mapping Code**
Sands to loamy sands	≤5	18 (0.03% S)	Code: S		
Sandy loam to light clay	5–40	36 (0.06% S)	Code: S		
Light medium to heavy clay	≥40	62c(0.1% S)	Code: S		
Not applicable				pH < 4.0 and/or jarosite present	Code: A

Attribute levels – based on depth (m) to PASS	
Presence of oxidisable sulfur levels greater than the action criteria at or before a depth of 0.5 m	Code: dp0
Presence of oxidisable sulfur levels greater than the action criteria at depths between 0.5 and 1.0 m	Code: dp1
Presence of oxidisable sulfur levels greater than the action criteria at depths between 1.0–2.0 m	Code: dp2
Presence of oxidisable sulfur levels greater than the action criteria at depths between 2.0–3.0 m	Code: dp3
Presence of oxidisable sulfur levels greater than the action criteria at depths between 3.0–4.0 m	Code: dp4
Presence of oxidisable sulfur levels greater than the action criteria at depths between 4.0–5.0 m	Code: dp5
Presence of oxidisable sulfur levels greater than the action criteria at depths greater than 5.0 m	Code: dp6

Attribute levels – based on depth (m) to AASS [1]	
Presence of soil pH values <4 at or before a depth of 0.5 m	Code: da0
Presence of soil pH values <4 at depths between 0.5 and 1.0 m	Code: da1
Presence of soil pH values <4 at depths between 1.0–2.0 m	Code: da2
Presence of soil pH values <4 at depths between 2.0–3.0 m	Code: da3
Presence of soil pH values <4 at depths between 3.0–4.0 m	Code: da4
Presence of soil pH values <4 at depths between 4.0–5.0 m	Code: da5
Presence of soil pH values <4 at depths greater than 5.0 m	Code: da6

[1]**Note** – Codes for attribute levels have come from existing ASS mapping. The different action criteria for different texture categories were assessed for each polygon/UMA during mapping. ASS mapping uses a joint code combining the AASS (A), PASS (S) and depth codes (1–5+) and an individual code is recorded for each separate ASS map polygon (UMA). For example, a mapping code A0S1 would apply to a polygon with AASS from 0–0.5m depth and PASS from 0.5–1.0 m. The joint mapping codes used by QASSIT have been reinterpreted for the purposes of this study to generate individual assessments of depth to PASS and depth to AASS.

Code	**Attribute level**	**Suitability subclasses for various crops**		
		Group 1	**Group 2**	**Group 3**
da 0	AASS (pH</=4) present at depths <0.5 m	5	5	4
da 1	AASS (pH</=4) present at depths 0.5 m–1 m	5	4	3
da 2	AASS (pH</=4) present at depths 1 m – 2 m	4	3	1
da 3	AASS (pH</=4) present at depths 2 m–3 m	1	1	1
da 4	AASS (pH</=4) present at depths 3 m–4 m	1	1	1
da 5	AASS (pH</=4) present at depths 4 m–5 m	1	1	1
da 6	AASS (pH</=4) a present at depths >5 m	1	1	1

Code	**Attribute level**	**Suitability subclasses for various crops**		
		Group 1	**Group 2**	**Group 3**
dp 0	PASS present at depths <0.5 m	5	5	5
dp 1	PASS present at depths 0.5 m–1 m	5	4	3
dp 2	PASS present at depths 1 m–2 m	4	3	1
dp 3	PASS present at depths 2 m–3 m	1	1	1
dp 4	PASS present at depths 3 m–4 m	1	1	1
dp 5	PASS present at depths 4 m–5 m	1	1	1
dp 6	PASS present at depths >5 m	1	1	1

Group 1 (Depth 1.5)	Group 2 (Depth 1.0 m)	Group 3 (Depth 0.5 m)
Avocado	Blackbutt	Banana
	Caribbean pine	Banana (rainfed)
	Choko	Capsicum (s)(w)
	Citrus	Cucurbits (s)(w)
	Custard apple	Ginger (s) (w)
	Dunn's white gum	Pineapple
	Flooded gum	Sown pastures
	Gympie messmate	Soybean
	Lychee	Strawberry
	Macadamia	Sugar cane
	Macadamia (rainfed)	Sugar cane (rainfed)
	Maize (forage) – (s) (rainfed)	Sweet potato (w)(s)
	Mango	Tomato (s)(w)
	Papaw	Turf
	Passionfruit	
	Persimmon	
	Sorghum (forage) (s)	
	Spotted gum	
	Sweet corn (w) (s)	
	Stone fruit	

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Water erosion (e)

Effect

Land degradation and long term productivity decline will occur on unprotected arable land due to excessive soil erosion.

Assessment

Soil loss will depend on soil drainage characteristics, surface and subsoil erodibility, land slope, land use (ie. particular crop) and agronomic management (eg. surface management system). Surface management practices are defined as agronomic options that aim to minimise soil disturbance while maximising the retention of harvest residue as a surface cover. Soil surface condition, infiltration and soil permeability largely determine the potential for runoff from a soil, while rainfall intensity, slope (gradient and length), surface cover and inherent erodibility/soil stability influence the extent and severity of erosion.

For a particular soil type there is a maximum slope above which soil loss cannot be controlled to within acceptable levels (<10 t/ha/yr), either by erosion control measures or surface management practices. Assessment of this limitation (see slope categories and suitability subclasses listed below) assumes standard surface management and erosion control measures are practised (eg. stable sward management under orchards, cover crops and surface residue management in cultivated crops, graded/parallel rows and/or banks etc). Suitable slope categories listed for each land use (subclasses 1–3) are based on soil conservation research, predicted soil loss using the Universal Soil Loss Equation (USLE), calculated soil erodibility for the surface layer (USLE K factor Lu *et al*. 2003) and landholder experience. The categories listed represent the slope limits below which soil loss will be within acceptable limits (<10 t/ha/yr).

While infiltration rate and soil permeability largely determine the potential for runoff from a soil, it is rainfall intensity, slope (gradient and length), surface management and inherent erodibility/soil stability that influence the extent and severity of erosion. Of these factors only permeability and inherent erodibility are soil based. As such, the concept of soil stability has been developed to qualitatively group soil landscapes based on the presence of some common morphological features within the soil that are likely to influence inherent erodibility. These include profile permeability, surface soil condition, surface texture, sand fraction, degree and type of surface structure and organic matter levels. In addition the qualitative features have been linked to K factor ranges generated by USLE for site data from each landscape. Four soil stability categories from very stable to very unstable are recognised.

Very stable soils: K factor <0.05

- Strongly structured surface soils high in free iron (Ferrosols). Profiles are highly permeable throughout.

Stable soils: K factor <0.05

- Friable surface soils with moderate to strong surface structure (granular or blocky); or surface soils with a soft, firm or weakly hard setting, medium to coarse sandy surface (sands, sandy loam, sandy clay loam); or surface soils very high in organic matter. Profiles are moderately to highly permeable throughout.

Unstable soils: K factor 0.05–0.07

- Hard setting surface soils with weak (granular, blocky) to massive surface structure and fine sandy textures (fine sandy clay loam to fine sandy light clay). Surface horizons are moderately to slowly permeable. Slowly permeable, sodic subsoils are often developed within 1.0m of the surface in lower landscape positions.

Very unstable soils: K factor >0.07

- Hard setting surface soils with weak (granular, blocky) to massive surface structure and silty textures (silty loam to silty light clay). Surface horizons are low in organic matter, slowly permeable and typically overlie slowly to very slowly permeable, sodic subsoils within 0.5 m of the surface.

Limitation class determination

Slope limits are determined in consultation with soil conservation extension and research personnel, and extension and research agronomists. The implications of the subclasses are:

- e1 surveyed row direction only required;
- e2 conventional parallel structures required or some surface management practices;
- e3 e2 measures and some surface management practices;
- e4 non-arable land; and
- e5 non-arable land.

Crop specific comments

- Perennial tree and vine orchards typically practice grass/cover crop sward management and represent relatively stable land uses (ie. suitable on slopes between >5–20 % depending on soil type).
- Papaws and bananas, which are replanted every 6–7 years, are not included with the perennial tree and vine crops. Typically, they require irregular cultivation, are planted in spring and are normally mounded on the contour. They are grouped with macadamia and choko because of the predominance of bare surface soil when compared with sward based systems, even in a mature orchard.
- Crops with extended crop cycles, such as sugar cane and pineapples are only cultivated every 2–4 years, and once established, have good levels of crop cover and produce significant crop residues. While the potential for erosion is greater with these land uses than for tree and vine crops, it is considered less critical than for annual field and horticultural small crops. Although pineapples are only planted every 3 years, soils may be prone to significant erosion due to strict weed control practises that expose bare surface soil. Where pineapples are mounded on the contour with run-off control structures in place erosion risk is reduced.
- Turf is regularly stripped back to a completely bare surface but with a significant root mass and without regular tillage. Rilling and deposition following erosion events is a potential problem because uneven surface contours can present problems with harvesting. Standard management practices such as topdressing and levelling would largely overcome such erosion effects.
- Most field crops/horticultural small crops require seedbed preparation on an annual basis. Tillage during late summer to prepare for the winter copping period leaves paddocks exposed and subject to potentially erosive rainfall events through the autumn months. Tillage is usually aggressive, surface soils very loose and paddocks laid out in straight rows. Land uses in this category are considered most at risk from erosion and slope limits are therefore more robust.
- Slope limits described for forestry situations assume land is already cleared and pastured and broad-scale clearing is not required. These limits assume minimal soil disturbance is practised during land preparation for planting. Lower limits would apply were significant soil disturbance involved.

Soil stability	Code	Attribute level	Suitability subclasses for various crops						
			Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Very stable soils: K factor <0.05	**100**	0% slope	1	1	1	1	1	1	1
	101	0–1% slope	1	1	1	1	1	1	1
	102	1–2% slope	1	1	1	1	1	1	1
	103	2–3% slope	1	1	1	1	1	2	1
	104	3–5% slope	1	1	1	1	2	2	1
	105	5–8% slope	1	1	1	2	2	3	2
	106	8–12% slope	1	1	2	3	3	4	3
	107	12–15% slope	1	2	3	4	4	5	3
	108	15–20% slope	2	3	3	4	5	5	4
	109	20–25% slope	3	3	4	5	5	5	5
	110	25–30% slope	3	4	5	5	5	5	5
	111	30–35% slope	4	5	5	5	5	5	5
	112	>35% slope	5	5	5	5	5	5	5
Stable soils: K factor <0.05	**200**	0% slope	1	1	1	1	1	1	1
	201	0–1% slope	1	1	1	1	1	2	1
	202	1–2% slope	1	1	1	1	1	2	1
	203	2–3% slope	1	1	1	2	2	3	2
	204	3–5% slope	1	1	1	2	2	3	2
	205	5–8% slope	1	1	2	3	3	4	3
	206	8–12% slope	1	2	3	4	4	5	4
	207	12–15% slope	2	3	3	5	5	5	5
	208	15–20% slope	3	3	4	5	5	5	5
	209	20–25% slope	3	4	5	5	5	5	5
	210	25–30% slope	4	5	5	5	5	5	5
	211	30–35% slope	5	5	5	5	5	5	5
	212	>35% slope	5	5	5	5	5	5	5
Unstable soils: K factor <0.05–0.07	**300**	0% slope	1	1	1	1	1	1	1
	301	0–1% slope	1	1	1	1	1	2	1
	302	1–2% slope	1	1	1	2	2	3	2
	303	2–3% slope	1	1	1	2	2	3	2
	304	3–5% slope	1	1	2	3	3	4	3
	305	5–8% slope	1	2	3	4	4	5	4
	306	8–12% slope	2	3	3	5	5	5	5
	307	12–15% slope	3	3	4	5	5	5	5
	308	15–20% slope	3	4	5	5	5	5	5
	309	20–25% slope	4	5	5	5	5	5	5
	310	25–30% slope	5	5	5	5	5	5	5
	311	30–35% slope	5	5	5	5	5	5	5
	312	>35% slope	5	5	5	5	5	5	5

Soil stability	Code	Attribute level	Suitability subclasses for various crops						
			Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Very unstable soils: K factor > 0.07	**400**	0% slope	1	1	1	1	1	2	1
	401	0–1% slope	1	1	1	2	2	3	2
	402	1–2% slope	1	1	2	3	3	4	3
	403	2–3% slope	1	1	2	3	3	4	3
	404	3–5% slope	1	2	3	4	4	5	4
	405	5–8% slope	2	3	4	5	5	5	5
	406	8–12% slope	3	4	5	5	5	5	5
	407	12–15% slope	4	5	5	5	5	5	5
	408	15–20% slope	5	5	5	5	5	5	5
	409	20–25% slope	5	5	5	5	5	5	5
	410	25–30% slope	5	5	5	5	5	5	5
	411	30–35% slope	5	5	5	5	5	5	5
	412	>35% slope	5	5	5	5	5	5	5

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Blackbutt	Avocado	Banana	Ginger(s) (w)	Choko	Capsicum (s) (w)	Sugar cane
Dunn's white gum	Caribbean pine	Banana (rainfed)		Pineapple	Cucurbits (s) (w)	Sugar cane (rainfed)
Flooded gum	Citrus	Macadamia		Strawberry	Maize (forage) (s) (rainfed)	
Gympie messmate	Custard apple	Macadamia (rainfed)		Turf	Sorghum (forage) (s) (rainfed)	
Spotted gum	Lychee	Papaw			Soybean	
	Mango				Sweet corn (s) (w)	
	Passionfruit				Sweet potato (s)(w)	
	Persimmon				Tomato (s) (w)	
	Stone fruit					
	Sown pastures (rainfed)					

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Flooding (f)

Effect

Flood events typically involve inundation from overbank stream flows (or associated backup waters) for periods of at least 1–2 days. The effects of flooding include yield reduction or plant death caused by anaerobic conditions and/or high water temperature and/or silt deposition during inundation. Other effects include physical removal of or damage to the crop by flowing water, floodplain erosion and damage to infrastructure such as irrigation equipment. The permanency of the crop (eg. mature tree crop versus short-lived small crops) and the relative difficulty and/or cost of replacement following flood damage also need to be considered.

Assessment

Flood modelling from relevant Local Government Authorities and local knowledge has been used where appropriate.

Average recurrence interval (ARI), which is a measure of flood frequency, is useful in distinguishing between suitable and unsuitable land in situations where either flood frequency is extreme or crops are particularly intolerant. Modelled outputs showing the spatial extent and depth of flooding at differing flood frequencies (eg. 1 in 2 years, 1 in 10 years, 1 in 50 years and 1 in 100 years) are used to assess the effects of flooding across agricultural areas (eg. either on an individual pixel or map polygon basis).

Limitation class determination

Consultation with local authorities, QDPI&F within DEEDI, community groups and local landholders.

Crop specific comments

- Sugar cane and many other crops are commonly grown on low-lying areas, despite regular flooding. In such cases, some degree of crop tolerance means the effects of flooding do not detract from the intrinsic value of the land.
- Flooding is generally not considered a limitation for winter grown horticultural small crops because the growing season is relatively short and can be timed to avoid most seasonal flooding.
- Some tree crops (eg. citrus, lychee, mango) tolerate inundation for periods of about 1 day or so. This assumes low velocity floodwaters, relatively low silt loads, reasonable water temperatures and rapid internal soil drainage once floodwaters recede.
- While loss of trees due to flooding represents a severe financial loss, most orchard enterprises work towards a return on their investment after about 10 years. Floods less frequent than 1 in 10 years (ie. 1:20 to 1:50 years or less frequent) are statistically beyond the productive life of the trees and areas subject to such floods are classed as marginal for production rather than unsuitable.
- Pineapples are very sensitive to flooding and suffer significant fruit damage and financial loss following an event. However, losses in pineapples are less significant than those suffered through tree losses in orchards because planting occurs every 5–6 years and land can be brought back into production relatively quickly. As such flood events less frequent than 1 in 10 years are considered borderline class 3/4 for pineapples.

Code	Attribute level	Suitability subclasses for various crops								
		Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**
f0	No flooding	1	1	1	1	1	1	1	1	1
f1	Flooding less frequent than 1 in 10 years	4	3	2	1	1	1	1	5	1
f2	Flooding frequency between 1 in 2 and 1 in 10 years	5	5	4	3	2	1	1	5	2
f3	Flooding frequency approaches annual occurrence	5	5	5	5	4	3	2	5	3

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Custard apple	Choko	Ginger (s) (w)	Capsicum (s) (w)	Soybean	Turf	Capsicum (w)	Avocado	Maize (forage) – (s) (rainfed)
Macadamia	Citrus		Caribbean pine	Banana		Cucurbits (w)		Sorghum (forage) (s)
Macadamia (rainfed)	Lychee		Cucurbits (s)	Banana (rainfed)		Sown pastures (rainfed)		Sugar cane
Stone fruit	Mango		Strawberry	Blackbutt		Sweet corn (w)		Sugar cane (rainfed)
	Papaw		Sweet corn (s)	Dunn's white gum		Sweet potato (w)		
	Passionfruit		Sweet potato (s)	Flooded gum		Tomato (w)		
	Persimmon		Tomato (s)	Gympie messmate				
				Spotted gum				

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Wetness (w1, w2 and w3)

Effect

Waterlogged soils reduce plant growth and delay effective machinery operations.

Assessment

Internal and external drainage are assessed. Indicator attributes of internal drainage include texture, grade and type of structure, soil colour, mottles, segregations and the presence of impermeable layers. Drainage class and soil permeability (McDonald *et al.,* 1990) are assessed separately for summer and winter land uses to depths of 0.5 m, 1.0 m and 1.5 m. This allows for seasonal variability in soil wetness and better matches assessments of effective rooting depth for various crops. Slope and topographic position are used to determine external drainage.

Drainage class - accounts for all aspects of internal and external drainage in the existing state.		**Permeability** – relates to aeration in the profile and the speed of soil water movement	
1	**Very poorly drained** – wet most of the year	**H**	**Highly permeable** – (Ks >500 mm/day)
2	**Poorly drained** – wet for several months	**M**	**Moderately permeable** – (Ks 50-500 mm/day)
3	**Imperfectly drained** – wet for about 1 month	**S**	**Slowly permeable** – (Ks 5-50 mm/day)
4	**Moderately well drained** – wet for about 1 week	**V**	**Very slowly permeable** – (Ks <5 mm/day)
5	**Well drained** – wet for several days		
6	**Rapidly drained** – wet for <1 day		

Crops requiring a drained soil depth of 1.5 m are restricted to:
- Avocadoes.

Crops requiring a drained soil depth of 1.0 m include:
- Sweet corn (s&w), Maize (forage), Sorghum (forage), Choko, Citrus, Custard apple, Macadamia, Papaw, Stone-fruit, Mango, Lychee, Passionfruit, Persimmon, Gympie messmate, Blackbutt, Spotted gum, Flooded gum, Dunn's white gum and Caribbean pine.

Crops requiring a drained soil depth of 0.5 m include:
- Ginger, Capsicum (s&w), Cucurbits (s&w), Pineapple, Sweet potato (s&w), Tomato (s&w), Turf, Strawberry, Sugar cane, Sown pasture and Banana.

Limitation class determination

Crop tolerance information, consultation with agronomic extension staff and local landholder experience was used in determining the severity of this limitation. The effects of delayed machinery operations have also been considered. For sown pastures, a wide range of species is available to cater for pasture production across a range of soil wetness conditions (with the exception of very poorly drained sites where there is no recognised non-invasive species).

Crop specific comments

- Wetness subclasses for bananas are similar to sugar cane except soil wetness has a greater effect on machinery usage.
- Imperfectly drained soils (3H, 3M, 3S, 3V) significantly affect plant growth for many crops and are usually the soils where mounding is important. Mounding is a standard management practice for tree crops.
- Wetness subclasses for winter small crops (capsicum, cucurbits, sweet potato, tomato) are less stringent than for equivalent summer crops because during the winter period conditions are drier and temporary watertables may disappear or lower significantly allowing drainage class to approach the category above.

WI Wetness to 1.0 m

Code	Attribute level	Suitability subclasses for various crops			
		Group 1	Group 2	Group 3	Group 4
64	Rapidly drained (6), Highly permeable (4)	1	1	1	1
54	Well drained (5), Highly permeable (4)	1	1	1	1
53	Well drained (5), Moderately permeable (3)	2	1	1	1
44	Moderately well drained (4), Highly permeable (4)	2	4	1	1
43	Moderately well drained (4), Moderately permeable (3)	3	4	2	1
42	Moderately well drained (4), Slowly permeable (2)	4	4	3	2
41	Moderately well drained (4), Very slowly permeable (1)	4	4	3	2
34	Imperfectly drained (3), Highly permeable (4)	4	5	3	2
33	Imperfectly drained (3), Moderately permeable (3)	4	5	4	3
32	Imperfectly drained (3), Slowly permeable (2)	5	5	4	3
31	Imperfectly drained (3), Very slowly permeable (1)	5	5	4	4
24	Poorly drained (2), Highly permeable (4)	5	5	5	4
23	Poorly drained (2), Moderately permeable (3)	5	5	5	4
22	Poorly drained (2), Slowly permeable (2)	5	5	5	5
21	Poorly drained (2), Very slowly permeable (1)	5	5	5	5
14	Very poorly drained (1), Highly permeable (4)	5	5	5	5
13	Very poorly drained (1), Moderately permeable (3)	5	5	5	5
12	Very poorly drained (1), Slowly permeable (2)	5	5	5	5
11	Very poorly drained (1), Very slowly permeable (1)	5	5	5	5

Group 1	Group 2	Group 3	Group 4
Choko	Blackbutt	Citrus	Caribbean pine
Custard apple	Gympie messmate	Dunn's white gum	Mango
Macadamia		Flooded gum	Sorghum (forage) (s) (rainfed)
Macadamia (rainfed)		Lychee	Sweet corn (s) (w)
Papaw		Maize (forage) (s) (rainfed)	
Passionfruit		Persimmon	
Stone fruit		Spotted gum	
		Sweet corn s	

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

W2 Wetness to 0.5 m

Code	Attribute level	Suitability subclasses for various crops						
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
64	Rapidly drained (6), Highly permeable (4)	1	1	1	1	1	1	1
54	Well drained (5), Highly permeable (4)	1	1	1	1	1	1	1
53	Well drained (5), Moderately permeable (3)	2	1	1	1	1	1	1
44	Moderately well drained (4), Highly permeable (4)	2	1	1	1	1	1	1
43	Moderately well drained (4), Moderately permeable (3)	3	1	2	1	1	1	2
42	Moderately well drained (4), Slowly permeable (2)	4	2	3	2	1	2	3
41	Moderately well drained (4), Very slowly permeable (1)	4	2	3	2	1	2	3
34	Imperfectly drained (3), Highly permeable (4)	4	2	3	2	1	2	2
33	Imperfectly drained (3), Moderately permeable (3)	4	2	4	2	1	2	3
32	Imperfectly drained (3), Slowly permeable (2)	5	3	4	3	2	3	4
31	Imperfectly drained (3), Very slowly permeable (1)	5	3	4	3	2	3	4
24	Poorly drained (2), Highly permeable (4)	5	4	5	3	3	3	5
23	Poorly drained (2), Moderately permeable (3)	5	4	5	3	3	3	5
22	Poorly drained (2), Slowly permeable (2)	5	5	5	4	4	4	5
21	Poorly drained (2), Very slowly permeable (1)	5	5	5	4	4	4	5
14	Very poorly drained (1), Highly permeable (4)	5	5	5	5	5	5	5
13	Very poorly drained (1), Moderately permeable (3)	5	5	5	4	5	5	5
12	Very poorly drained (1), Slowly permeable (2)	5	5	5	4	5	5	5
11	Very poorly drained (1), Very slowly permeable (1)	5	5	5	5	5	5	5

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Ginger (s) (w)	Banana	Capsicum (s)	Sugar cane	Sown pastures (rainfed)	Turf	Soybean
	Banana (rainfed)	Cucurbits (s)	Sugar cane (rainfed)			
	Capsicum (w)	Pineapple				
	Cucurbits (w)	Strawberry				
	Sweet potato (w)	Sweet potato (s)				
	Tomato (w)	Tomato (s)				

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

W3 Wetness to 1.5 m

Code	Attribute level	Suitability subclasses for various crops
		Avocado
64	Rapidly drained (6), Highly permeable (4)	1
54	Well drained (5), Highly permeable (4)	2
53	Well drained (5), Moderately permeable (3)	3
44	Moderately well drained (4), Highly permeable (4)	3
43	Moderately well drained (4), Moderately permeable (3)	4
42	Moderately well drained (4), Slowly permeable (2)	5
41	Moderately well drained (4), Very slowly permeable (1)	5
34	Imperfectly drained (3), Highly permeable (4)	4
33	Imperfectly drained (3), Moderately permeable (3)	5
32	Imperfectly drained (3), Slowly permeable (2)	5
31	Imperfectly drained (3), Very slowly permeable (1)	5
24	Poorly drained (2), Highly permeable (4)	5
23	Poorly drained (2), Moderately permeable (3)	5
22	Poorly drained (2), Slowly permeable (2)	5
21	Poorly drained (2), Very slowly permeable (1)	5
14	Very poorly drained (1), Highly permeable (4)	5
13	Very poorly drained (1), Moderately permeable (3)	5
12	Very poorly drained (1), Slowly permeable (2)	5
11	Very poorly drained (1), Very slowly permeable (1)	1

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Microrelief (tm)

Effect

Microrelief such as melon holes, swamp hummock, rills and small gullies cause irregular and reduced crop productivity. This is mainly as a result of uneven water distribution (eg. water ponding in depressions), irregular cultivation and impeded trafficability. Effects associated with the presence of microrelief such as temporary waterlogging and poor surface condition are covered in the wetness (w) and soil physical (ps) limitations respectively.

Assessment

In most cropping situations, levelling of uneven surface relief across a paddock is normally required:

- to improve access for cultivation and other agronomic activities (eg. planting, spraying, harvesting etc); and
- to improve irrigation efficiency and surface drainage.

The vertical interval (VI) of the microrelief typically dictates the amount of levelling required and/or the potential for reduced productivity.

Limitation class determination

Consultation with agronomic extension staff and local landholder experience.

Crop specific comments

Code	Attribute level	Suitability subclasses for various crops		
		Group 1	Group 2	Group 3
tm1	Microrelief, rill or gully features with a vertical interval <0.1 m	1	1	1
tm2	Microrelief, rill or gully features with a vertical interval 0.1 to 0.3 m	1	2	3
tm3	Microrelief, rill or gully features with a vertical interval 0.3 to 0.6 m	2	3	4
tm4	Microrelief, rill or gully features with a vertical interval >0.6 m	3	4	5

Group 1	Group 2	Group 3	Group 3 continued	Group 3 continued
Blackbutt	Maize (forage) (s) (rainfed)	Avocado	Ginger (s) (w)	Pineapple
Caribbean pine	Sorghum (forage) (s) (rainfed)	Banana	Lychee	Soybean
Dunn's white gum	Sugar cane	Banana (rainfed)	Macadamia	Strawberry
Flooded gum	Sugar cane (rainfed)	Capsicum (s) (w)	Macadamia (rainfed)	Sweet corn (s) (w)
Gympie messmate	Turf	Choko	Mango	Sweet potato (s) (w)
Sown pastures (rainfed)		Citrus	Papaw	Stone fruit
Spotted gum		Cucurbits (s) (w)	Passionfruit	Tomato (s) (w)
		Custard apple	Persimmon	

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Topography (ts)

Effect

The safety and/or efficiency of farm vehicle operation is affected by:

- steep gradients in relation to roll stability and side-slip; and
- erosion control layouts on land with significant variability in the degree and direction of slopes (eg. complex slopes). It is particularly important with row crops where final layouts on such lands will involve short rows and sharp curves.

Assessment

Assessment is based on:

- steepness of slope in relation to safety and efficiency;
- variation in slope causing short rows in erosion control layouts; and
- variation in slope direction causing excessive row curvature in erosion control layouts.

Limitation class determination

Consultation with Workplace, Health and Safety guidelines and local landholder experience was used to determine the upper slope limit for safe machinery operation for a range of land uses. Farmer tolerance to short row length and the inability of trailing implements to effectively negotiate curves with less than 30 m radius is also important.

Crop specific comments

- Where tillage forms part of normal management within the crop cycle, a slope limit of 15% is recognised as the upper limit for acceptable machinery use.
- However, where contour based or cross slope sward management is practised in horticultural situations (eg. tree and vine orchards) slopes of 20% are considered manageable.
- In commercial hardwood timber production, where specialised machinery is used in most planting and harvesting operations steeper slope limits up to 35–40% are considered workable.
- Where spraying and harvesting operations in horticultural tree and vine crops can be carried out directly up and down slopes, a maximum slope limit of 25% is considered manageable for safe machinery operation.
- The exception to this is macadamias where the need for ground harvest operations reduces the safe working slope limit to 20%. This relates to the nature of the ground harvesting equipment and a requirement for more turning and side-slope movement than occurs with on-tree harvesting operations.

Code	Attribute level	Suitability subclasses for various crops					
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
ts1	Slope range 0–8%	1	1	1	1	1	1
ts2	Slope range 8–12%	2	1	1	1	1	3
ts3	Slope range 12–15%	3	2	1	1	1	4
ts4	Slope range 15-20%	4	3	2	1	1	5
ts5	Slope range 20–25%	5	4	3	2	1	5
ts6	Slope range 25-30%	5	5	4	3	2	5
ts7	Slope range 30–35%	5	5	5	4	3	5
ts8	Slope range 35–40%	5	5	5	5	4	5
ts9	Slope range >40%	5	5	5	5	5	5

Group 1	Group 1 continued	Group 2	Group 3	Group 4	Group 5	Group 6
Capsicum (s) (w)	Strawberry	Banana	Avocado	Sown pastures (rainfed)	Blackbutt	Soybean
Cucurbits (s) (w)	Sugar cane	Banana (rainfed)	Caribbean pine		Dunn's white gum	
Ginger (s) (w)	Sugar cane (rainfed)	Choko	Citrus		Flooded gum	
Maize (forage) (s) (rainfed)	Sweet corn (s) (w)	Lychee	Custard apple		Gympie messmate	
Pineapple	Sweet potato (s) (w)	Macadamia	Mango		Spotted gum	
Sorghum (forage) (s) (rainfed)	Tomato (s) (w)	Macadamia (rainfed)	Passionfruit			
	Turf	Papaw	Persimmon			
			Stone fruit			

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Landscape complexity (x)

Effect

This limitation assesses the effect soil complexity and/or topographic dissection may have on the size or shape of an area of suitable land. Where soil patterns are complex or land is very dissected, production areas for a particular land use may become small or fragmented. This results in decreased production efficiency and reduced viability in the long term. A 'minimum production area' is defined as the minimum area of land that is practicable to utilise for a particular land use. It may be based on implicit economic criteria, but is not related to an 'economic production unit' or so called 'living area'.

Assessment

After the limitation subclasses for all other limitations have been determined for a particular parcel of land (ie. UMA), one or more of the following are assessed:

- the area of contiguous suitable soil and whether it is less than the minimum production area for a particular land use; and
- the extent and severity of dissected topography.

When the area of contiguous suitable soil in a UMA is less than the minimum production area, the amount of contiguous suitable soil in adjacent UMAs is also included in the assessment. For land uses requiring infrastructure for sustainable production, the distance to adjoining irrigation and/or other infrastructure is also important. In most situations, final suitability class is downgraded if the distance to irrigation and/or necessary infrastructure is greater than 0.5 km.

Limitation class determination

The minimum production area for each land use was determined by consultation with agronomic extension staff and from local landholder experience. The suitability may be modified according to the proximity and extent of non-contiguous suitable land.

Crop specific comments

- Landscape complexity has most effect on broadacre crops that require large paddock sizes for efficiency (eg. sugar cane, forage crops, commercial timber). Lot size is not considered.

Code	Attribute level	Suitability subclasses for various crops						
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
x1	Minimum practical production area >10 ha	1	1	1	1	1	1	1
x2	Minimum practical production area 5-10 ha	1	1	1	1	1	1	1
x3	Minimum practical production area 2.5-5 ha	1	1	3	1	1	4	1
x4	Minimum practical production area 1.5-2.5 ha	1	2	4	3	1	5	1
x5	Minimum practical production area <1.5 ha	4	3	5	4	1	5	2

Group 1	Group 2	Group 2 continued	Group 3	Group 4	Group 5	Group 6	Group 7
Capsicum (s) (w)	Avocado	Papaw	Maize (forage) (s) (rainfed)	Lychee	Sown pastures (rainfed)	Blackbutt	Choko
Cucurbits (s) (w)	Banana	Passionfruit	Sorghum (forage) (s) (rainfed)	Macadamia		Caribbean pine	Turf
Pineapple	Banana (rainfed)	Strawberry		Macadamia (rainfed)		Dunn's white gum	
Sweet corn (s) (w)	Citrus	Sugar cane		Persimmon		Flooded gum	
Sweet potato (s) (w)	Custard apple	Sugar cane (rainfed)		Stone fruit		Gympie messmate	
Tomato (s) (w)	Ginger (s) (w)					Soybean	
	Mango					Spotted gum	

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Water availability (m)

Effect

Plant yield can be severely affected by periods of water stress, particularly during critical growth periods.

Assessment

Plant available water capacity (PAWC) is used as a measure of the amount of soil water available to plants within the effective rooting depth (see pd limitation). PAWC is based on predicted values (Littleboy 1997, Shaw and Yule 1978) modelled using inputs that include particle size analysis (clay, silt and sand %), 15 bar measurements and the % of coarse fragments in the profile. Generally, soil texture, structure, clay content and clay mineralogy have the largest influence on PAWC. The influence of watertables on PAWC is based on the depth at which the watertable resides during most of the year (particularly through the drier months) and the corresponding length of time this occurs within the root zone.

Limitation class determination

PAWC determines a crops capacity to withstand dry periods between rainfall events. Plant growth models are used to predict yields. PAWC is less critical for irrigated crops than for rainfed crops and in irrigated situations is used largely to estimate irrigation frequency. Typical irrigation frequencies during summer months corresponding to differing levels of PAWC include:

- >100 mm = 15 days;
- 75 to 100 mm = 12 to 15 days;
- 50 to 75 mm = 8 to 12 days; and
- <50 mm = <8 days.

Irrigation frequency considers crop rooting depth, seasonal evaporation rates (6 mm/day in summer) and the amount of labour and equipment required. For example, shallow rooted crops require more frequent irrigation compared with deep-rooted crops, while winter crops require less frequent irrigation compared to summer crops. More frequent irrigation requires a greater amount of labour and/or more equipment. Negligible limitations apply to micro-sprinkler or drip irrigation systems where only small amounts of water are added frequently. Long-term watertables within the root zone may over ride soil moisture deficits normally experienced by crops and therefore reduce or eliminate the need for irrigation.

Crop specific comments

Code	Attribute level	Suitability subclasses for various crops						
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
11	Watertable not present within 1.5 m of the surface, very high PAWC (>=125 mm)	2	1	1	1	1	1	1
12	Watertable not present within 1.5 m of the surface, high PAWC (100–<125 mm)	2	1	1	2	2	1	1
13	Watertable not present within 1.5 m of the surface, moderate PAWC (75–<100 mm	2	1	1	3	3	2	2
14	Watertable not present within 1.5 m of the surface, low PAWC (50–<75 mm)	2	1	1	5	4	3	3
15	Watertable not present within 1.5 m of the surface, very low PAWC (<50 mm)	3	2	1	5	5	4	5
21	Watertable not present within 1.0–1.5 m of the surface, very high PAWC (>=125 mm)	2	1	1	1	1	1	1
22	Watertable not present within 1.0–1.5 m of the surface, high PAWC (100–<125 mm)	2	1	1	1	1	1	1
23	Watertable not present within 1.0–1.5 m of the surface, moderate PAWC (75–<100 mm	2	1	1	2	2	1	1

Code	Attribute level	Suitability subclasses for various crops						
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
24	Watertable not present within 1.0–1.5 m of the surface, low PAWC (50–<75 mm)	2	1	1	4	3	2	2
25	Watertable not present within 1.0–1.5 m of the surface, very low PAWC (<50 mm)	3	2	1	4	4	3	3
31	Watertable not present within 0.5–1.0 m of the surface, very high PAWC (>=125 mm)	2	1	1	1	1	1	1
32	Watertable not present within 0.5–1.0 m of the surface, high PAWC (100–<125 mm)	2	1	1	1	1	1	1
33	Watertable not present within 0.5–1.0 m of the surface, moderate PAWC (75–<100 mm	2	1	1	1	1	1	1
34	Watertable not present within 0.5–1.0 m of the surface, low PAWC (50–<75 mm)	2	1	1	3	2	1	1
35	Watertable not present within 0.5–1.0 m of the surface, very low PAWC (<50 mm)	3	2	1	3	3	2	2
41	Watertable not present within 0.5 m of the surface, very high PAWC (>=125 mm)	1	1	1	1	1	1	1
42	Watertable not present within 0.5 m of the surface, high PAWC (100–<125 mm)	1	1	1	1	1	1	1
43	Watertable not present within 0.5m of the surface, moderate PAWC (75–<100 mm	1	1	1	1	1	1	1
44	Watertable not present within 0.5 m of the surface, low PAWC (50–<75 mm)	1	1	1	1	1	1	1
45	Watertable not present within 0.5 m of the surface, very low PAWC (<50 mm)	1	1	1	1	1	1	1

Group 1	Group 2	Group 3	Group 3 continued	Group 4	Group 5	Group 6
Choko	Cucurbits (w)	Avocado	Mango	Banana (rainfed)	Maize (forage) (s) (rainfed)	Pineapple
Cucurbits (s)	Ginger (w)	Banana	Papaw	Macadamia (rainfed)	Blackbutt	Sorghum (forage) summer (rainfed)
Ginger (s)	Sweet corn (w)	Capsicum (s) (w)	Passionfruit	Soybean	Dunn's white gum	Sown pastures (rainfed)
Sweet corn (s)	Sweet potato (w)	Citrus	Persimmon	Sugar cane	Flooded gum	Sugar cane (Irrigated)
Sweet potato (s)		Custard apple	Stone fruit		Gympie messmate	Caribbean pine
Turf		Lychee	Strawberry			Spotted gum
		Macadamia	Tomato (s) (w)			

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Note 1 – Soil drainage may modify PAWC for a particular soil. For example, a shallow watertable within the effective rooting depth for 2–3 months or longer (see w limitation) can provide water to plants for extended periods.

Note 2 – In areas receiving >1200 mm of annual rainfall, macadamias and bananas may be grown without supplementary irrigation but only on soils with a high PAWC (see cp limitation).

Note 3 – Irrigated shallow rooted crops (Cucurbits, Ginger, Sweet corn, Sweet potato, Turf) are usually irrigated using overhead methods, therefore requiring more frequent irrigation and higher management inputs than micro-irrigation/drip systems.

Note 4– PAWC has been predicted to the effective rooting depth (ERD). This is the depth to any impenetrable or impermeable layers (as defined for the pd limitation). Native hardwood eucalypt species however have the ability to penetrate weathered/fractured rock and many impermeable layers and the PAWC boundary between suitable and marginal/unsuitable classes has been relaxed accordingly (when compared with cropping).

Soil depth (pd)

Effect

Shallow soils limit root proliferation and anchorage. Plants may lodge or become uprooted during strong winds.

Assessment

Effective rooting depth within a soil is defined as the depth to which optimal water extraction by roots occurs. As such, it represents the zone of maximum root development. Any soil feature that restricts root exploration will restrict effective rooting depth, limiting water availability (see m limitation) and reducing the potential for adequate anchorage and physical support. Criteria used to determine effective rooting depth within soil landscapes of the Sunshine Coast and Gold Coast region include;

- depth to hard rock, decomposing rock (C horizon), hard pan or any other impermeable layer (as defined for very slow permeability in McDonald *et al.* 1990); or
- depth to high salt concentrations (EC1:5 >0.8 dS/m - often associated with strongly alkaline (pH >8.5) and/or strongly sodic (ESP >15%) subsoil material); or
- depth to extremely acidic subsoil material (pH <4.0).

Limitation class determination

Consultation with agronomic extension staff and local landholder experience.

Code	Attribute level	Suitability subclasses for various crops				
		Group 1	Group 2	Group 3	Group 4	Group 5
pd1	Deep soil (>1 m)	1	1	1	1	1
pd2	Moderately deep soil (0.5 to < 1 m)	2	1	1	1	2
pd3	Shallow soil (0.25 to < 0.5 m)	4	2	1	1	5
pd4	Very shallow soil (<0.25 m)	5	5	4	3	5

Group 1	Group 1 continued	Group 2	Group 3	Group 3 continued	Group 4	Group 5
Banana	Gympie messmate	Maize (forage) – (s) (rainfed)	Capsicum (s) (w)	Strawberry	Sown pastures	Avocado
Banana (rainfed)	Papaw	Sorghum (forage) (s) (rainfed)	Choko	Sweet potato (s) (w)		Custard apple
Blackbutt	Persimmon	Sugar cane	Cucurbits (s) (w)	Tomato (s) (w)		Lychee
Caribbean pine	Spotted gum	Sugar cane (rainfed)	Ginger (s) (w)	Turf		Macadamia
Citrus	Stone fruit	Sweet corn (s) (w)	Passionfruit			Macadamia (rainfed)
Dunn's white gum			Pineapple			Mango
Flooded gum			Soybean			

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Note 1 – Native hardwood eucalypt species have a rooting depth requirement >0.6 m, but have the ability to penetrate weathered/fractured rock and many impermeable layers. Therefore, the 'suitable' soil depth limit to impermeable layers has been decreased from 0.6 m to 0.4 m.

Note 2 – Vine crops (choko, passionfruit) and some small crops (tomatoes) are normally trellised and lodging due to shallow soil depth is not considered an issue. As such, these crops have been treated in the same way as shallow rooted, small crops of low height.

Rockiness (r)

Effect

Coarse fragments (eg. pebbles, gravel, cobbles, stones and boulders) and rock in the plough zone can damage and/or interfere with the efficient use of agricultural machinery. Surface gravel, stone and rock are particularly important and can interfere significantly with planting, cultivation and harvesting machinery used for root crops, macadamias, small crops, annual forage crops and sugar cane. Typically gravel, stone and rock only affect tree crops during ground preparation and planting. Macadamias are an exception however, because gravel can interfere significantly with harvest operations.

Assessment

Assessment is based on the size, abundance and distribution of coarse fragments in the plough layer (McDonald *et al.* 1990). Machinery tolerance to damage caused by rock and stone and farmer tolerance to stone or rock size and content are also important.

Limitation class determination

Consultation with landholders and machinery operators to establish farmer tolerances that relate to profitability and technological capability.

Code	Attribute level	Suitability subclasses for various crops						
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
0	No rocks	1	1	1	1	1	1	1
21	Medium gravel (6–20 mm), <2%		1	1	1	2	3	
22	Medium gravel (6–20 mm), 2–10%	1	1					
23	Medium gravel (6–20 mm), 10–20%	1	1	1	2	1	3	4
24	Medium gravel (6– 20mm), 20–50%	1	1	2	3	2	4	5
25	Medium gravel (6–20 mm), >50%	1	2	3	4	3	5	5
31	Coarse gravel (20–60 mm), <2%	2	3	4	5	4	5	5
32	Coarse gravel (20–60 mm), 2–10%	1	1	1	2	3	3	4
33	Coarse gravel (20–60 mm), 10–20%	1	1	2	3	4	4	5
34	Coarse gravel (20–60 mm), 20–50%	1	2	3	4	5	5	5
35	Coarse gravel (20–60 mm), >50%	2	3	4	5	5	5	5
41	Cobble (60–200 mm), <2%	3	4	5	5	5	5	5
42	Cobble (60– 200 mm), 2–10%	1	1	2	3	2	4	5
43	Cobble (60–200 mm), 10–20%	1	2	3	4	2	5	5
44	Cobble (60–200 mm), 20–50%	2	3	4	5	3	5	5
45	Cobble (60–200 mm), >50%	3	4	5	5	4	5	5
51	Stone (200–600 mm), <2%	4	5	5	5	5	5	5
52	Stone (200–600 mm), 2–10%	1	2	3	4	2	5	5
53	Stone (200–600 mm), 10–20%	2	3	4	5	3	5	5
54	Stone (200–600 mm), >50%	3	4	5	5	4	5	5
55	Stone (200–600 mm), 20–50%	4	5	5	5	5	5	5
61	Boulders (600 mm–2 m), <2%	5	5	5	5	5	5	5

Code	Attribute level	Suitability subclasses for various crops						
62	Boulders (600 mm–2 m), 10–20%	2	3	4	5	3	5	5
63	Boulders (600 mm–2 m), 2– 10%	3	4	5	5	4	5	5
64	Boulders (600 mm–2 m), >50%	4	5	5	5	5	5	5
65	Boulders (600 mm–2 m), 20–50%	5	5	5	5	5	5	5
71	Large boulders (>2 m), 2–10%	5	5	5	5	5	5	5
72	Large boulders (>2 m), <2%	2	3	4	5	3	5	5
73	Large boulders (>2 m), 10–20%	3	4	5	5	4	5	5
74	Large boulders (>2 m), 20–50%	4	5	5	5	5	5	5
75	Large boulders (>2 m), >50%	5	5	5	5	5	5	5
81	Rock outcrop, <2%	5	5	5	5	5	5	5
82	Rock outcrop, 2–10%	2	3	4	5	3	5	5
83	Rock outcrop, 10–20%	3	4	5	5	4	5	5
84	Rock outcrop, 20–50%	5	5	5	5	5	5	5
85	Rock outcrop, >50%	5	5	5	5	5	5	5

Group 1	Group 1 continued	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Avocado	Lychee	Banana	Maize (forage) (s) (rainfed)	Cucurbits (s) (w)	Macadamia	Capsicum (s) (w)	Turf
Blackbutt	Mango	Banana (rainfed)	Sorghum (forage) (s) (rainfed)	Ginger (s) (w)	Macadamia (rainfed)	Strawberry	
Citrus	Passionfruit	Caribbean pine	Sugar cane	Soybean (rainfed)		Sweet potato (s) (w)	
Custard apple	Persimmon	Choko	Sugar cane (rainfed)			Tomato (s) (w)	
Dunn's white gum	Sown pastures (rainfed)	Papaw	Sweet corn (s) (w)				
Flooded gum	Spotted gum	Pineapple					
Gympie messmate	Stone fruit						

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Note 1 – Coarse fragments are particles greater than 2 mm that are not continuous with the underlying bedrock. Rock is defined as being continuous with the bedrock (McDonald *et al.* 1990).

Note 2 – Gravel and rock create serious problems for subsurface crops (ginger, sweet potato). These crops are subject to significant soil disturbance during harvest and face serious post harvest issues if gravel and rock need to be separated from the crop. Severe problems also apply to turf, particularly the effect gravel or rock may have on subsurface cutting equipment. Gravel sized coarse fragments <60mm also create significant issues for macadamia crops during harvest. Problems arise because of the similarity in size between surface gravels and nuts on the ground following shaking. Larger stones and rock also make the ground surface uneven for harvesting equipment and for routine activities such as slashing. As such, the presence of significant surface coarse fragments in macadamias represents a similar limitation to that experienced by most root crops.

Note 3 – Strawberries and other horticultural small crops have low harvest heights and require numerous machinery passes (eg. green manure, seedbed prep, fumigation, bedding up, plastic application, picking etc). While they are severely affected by significant stone or rock, it is less critical than for root crops or macadamias.

Note 4 – Pineapples require intensive but infrequent (only every 3 years) bed preparation prior to planting. Significant stone or rock can severely restrict this and cause excessive damage to machinery. However, fruit is hand picked.

Note 5 – Ground preparation for sugar cane is less intensive than for pineapples and crop cycles are normally 4 years. Significant stone or rock can severely impede low harvest height however.

Note 6 – Bananas require extensive land preparation for a medium term crop (every 6 – 7 years) and stone or rock can represent a significant limitation during cultivation and planting. As such, bananas are more sensitive to the presence of stone or rock than most tree crops, but less sensitive than sugarcane or pineapples.

Salinity (sa)

Effect

High soluble salts within the root zone can affect plants through:

- osmotic effects that limit water uptake;
- toxicity effects associated with specific ions (principally sodium chloride); and
- restrictions on root development down the profile.

Because of these effects, profile salinity within the root zone also forms important criteria in the assessment of effective rooting depth (ERD).

Assessment

Yield decreases are associated with increasing concentrations of salt in the profile. Because plant response and effects on crop yield are species specific, comparisons of average weighted root zone salinity values with yield reduction data (Salcon 1997, House *et al.* 1998, Sun and Dickinson 1993) have been considered for this limitation. The average weighted root zone salinity value (ECse dS/m) was calculated from all 0.1 m depth increments to a depth of 0.9 m from site analytical data ($EC_{1:5}$) and converted to ECse using soil texture and conversion factors (Salcon 1997).

Limitation class determination

Subclass determination is based on average weighted root zone salinity (ESse dS/m) using the approach of Shaw *et al.* (1986).
Class 1 – 0 to 10% yield reduction
Class 2 – 10 to 20% yield reduction
Class 3 – 20 to 35% yield reduction
Class 4 – 35 to 50% yield reduction
Class 5 – >50% yield reduction

Crop Specific Comments

Code	Attribute level	Suitability subclasses for various crops										
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11
sa 0	<1 dS/m weighted profile mean to 0.9 m	1	1	1	1	1	1	1	1	1	1	1
sa 1	1–2 dS/m weighted profile mean to 0.9 m	2	1	1	1	1	1	1	1	1	1	2
sa 2	2–3 dS/m weighted profile mean to 0.9 m	3	2	2	1	2	1	1	1	1	1	3
sa 3	3–4 dS/m weighted profile mean to 0.9 m	4	3	3	2	3	2	2	2	1	1	4
sa 4	4–5 dS/m weighted profile mean to 0.9 m	5	3	3	2	4	2	3	2	1	1	4
sa 5	5–6 dS/m weighted profile mean to 0.9 m	5	4	3	2	5	3	4	3	2	1	5
sa 6	6–7 dS/m weighted profile mean to 0.9 m	5	5	4	3	5	3	5	4	3	2	5
sa 7	7–8 dS/m weighted profile mean to 0.9 m	5	5	4	3	5	4	5	5	4	3	5
sa 8	8–9 dS/m weighted profile mean to 0.9 m	5	5	4	3	5	4	5	5	5	4	5
sa 9	>9 dS/m weighted profile mean to 0.9 m	5	5	5	4	5	5	5	5	5	5	5

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11
Avocado	Blackbutt	Sugar cane	Flooded gum	Capsicum (s) (w)	Custard apple	Stone fruit	Mango	Soybean (rainfed)	Sorghum (forage) - (s) (rainfed)	Caribbean pine
Banana	Maize (forage) - (s) (rainfed)	Sugar cane (rainfed)	Sown pastures	Choko	Macadamia		Persimmon			Dunn's white gum
Banana (rainfed)	Sweet corn (s) (w)	Turf		Cucurbits (s) (w)	Macadamia (rainfed)					Gympie messmate
Citrus	Sweet potato (s) (w)			Ginger (s) (w)	Spotted gum					
Lyche				Tomato (s) (w)						
Papaw										
Passionfrui										
Pineapple										
Strawberry										

Note: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Soil adhesiveness (pa)

Effect

Soil adhesiveness can cause harvest difficulties with underground root and stem crops and can affect the quality and post harvest treatment of harvest material (pa). In addition, adhesive soils are prone to significant levels of soil disturbance during harvest and may be subject to increased compaction and declining structural stability. This limitation applies only to ginger and sweet potato within the Sunshine Coast–Gold Coast region.

Assessment

Indicative soil morphological properties such as texture, structure, sand fraction, clay mineralogy and sub-surface cation chemistry (eg. sodicity to 0.3 m) are used to group soils on the basis of inherent adhesiveness. These inherent characteristics of the soil are evaluated in terms of local landholder/industry experience and typical harvest techniques.

Inherent soil adhesiveness categories used in the assessment of this limitation are defined as follows:

Soil adhesiveness categories		Inherent soil morphological properties affecting adhesiveness	
		Structure and texture characteristics	**Surface condition**
pa1	No restrictions	• Strongly structured (granular, polyhedral) surface soils high in free iron (Ferrosols)	soft or firm
		• Sandy textured surface soils (<SL) low in organic matter	loose, soft or firm
		• Humic surface soils very high in organic matter	soft or firm
pa2	Slightly adhesive soils	Moderately to strongly structured (granular, blocky) surface soils (>SL)	weakly hard setting
pa3	Moderately adhesive soils	Massive to weakly structured (granular, blocky), silty or fine sandy textured surface soils	moderately to strongly hard setting
pa4	Strongly adhesive soils	Sticky and/or sodic clay within 0.3 m of the surface (within the plough zone) (Vertosols, thin surfaced Sodosols)	firm to hard setting or self mulching

Limitation class determination

Plant tolerance limits (particularly plant characteristics eg. rhizome mass versus individual tubers etc) and requirements in relation to harvesting methods are matched against inherent soil adhesiveness and supported by local experience.

Crop specific comments

Code	Attribute level	Suitability subclasses for various crops		
		Group 1	**Group 2**	**Group 3**
pa1	No restrictions	1	1	1
pa2	Slightly adhesive soils	1	1	1
pa3	Moderately adhesive soils	2	1	1
pa4	Strongly adhesive soils	3	1	2

Group 1	Group 2	Group 2 continued	Group2 continued	Group2 continued	Group 3
Ginger (s) (w)	Avocado	Cucurbits (s) (w)	Mango	Soybean (rainfed)	Strawberry
Sweet potato (s) (w)	Banana	Custard apple	Maize (forage) - (s) (rainfed)	Tomato (s) (w)	
Turf	Banana (rainfed)	Dunn's white gum	Papaw	Spotted gum	
	Blackbutt	Flooded gum	Passionfruit	Stone fruit	
	Caribbean pine	Gympie messmate	Persimmon	Sugar cane	
	Capsicum (s) (w)	Lychee	Pineapple (rainfed)	Sugar cane (rainfed)	
	Choko	Macadamia	Sorghum (forage) -(s) (rainfed)	Sweet corn (s) (w)	
	Citrus	Macadamia (rainfed)	Sown pastures (rainfed)		

Narrow moisture range/workability (pm)

Effect

The workability limitation relates to the ease and timeliness with which a soil may be cultivated. Successful soil tillage depends largely on the inherent characteristics of the surface soil as it dries following a wetting cycle and the length of time during which the moisture range of the surface material is appropriate for mechanical disturbance. The time period following rainfall or irrigation during which a soil is capable of being successfully cultivated to achieve favourable seedbed conditions (ie. adequate depth of ploughed layer and favourable tilth) is known as the tillage window.

Some soils have only a narrow tillage window while other soils may be cultivated at any time. Such differences relate directly to the inherent morphological properties of the surface soil particularly texture, structure, sand fraction, clay mineralogy and sub-surface cation chemistry (eg sodicity to 0.3 m). How easily a soil works up and the width of the tillage window become particularly important for crops where land preparation is required to fit a distinct cropping cycle, particularly strictly defined planting times. Typically, workability is only an issue for crops that require cultivation on a regular basis (ie. annually). As such, it is largely irrelevant for perennial tree and vine crops.

Assessment

Local landholder or industry experience is a valuable guide to problems associated with certain soils in a particular district or for particular land uses. Assessment of this limitation attempts to identify soils where only a narrow timeframe exists between when soils are too wet and then too dry to undertake tillage. Assessment is land use specific due to the different tillage requirements different crops may have.

Moisture range/workability categories		**Inherent soil morphological properties affecting workability**	
		Structure and texture characteristics	**Surface condition**
pm1	No restrictions	• Strongly structured (granular, polyhedral) surface soils high in free iron (Ferrosols)	soft or firm
		• Sandy textured surface soils (<SL) low in organic matter	loose, soft or firm
		• Humic surface soils very high in organic matter	soft or firm
		• Moderately to strongly structured (granular, blocky) surface soils (>SL) (friable Dermosols).	soft, firm or weakly hard setting
pm2	Moderate moisture range	Massive to weakly structured (granular, blocky), silty or fine sandy textured surface soils	moderately to strongly hard setting
pm3	Narrow moisture range	Sticky and/or sodic clay within 0.3 m of the surface (within the plough zone) (Dermosols, Vertosols, thin surfaced Sodosols)	firm to hard setting or self mulching

Limitation class determination

Local opinion and industry experience from within the district and also from other areas was used to assess the severity of workability problems associated with differing tillage windows (ie., moisture range) across a range of different soils.

Crop specific comments

Code	**Attribute level**	**Suitability subclasses for various crops**		
		Group 1	**Group 2**	**Group 3**
pm1	No restrictions	1	1	1
pm2	Moderate moisture range	2	1	1
pm3	Narrow moisture range	3	1	2

Group 1	Group1 continued	Group2	Group2 continued	Group 3
Capsicum (s) (w)	Strawberry	Avocado	Lychee	Banana
Cucurbits (s) (w)	Sugar cane	Blackbutt	Macadamia	Banana (rainfed)
Ginger (s) (w)	Sugar cane (rainfed)	Caribbean pine	Macadamia (rainfed)	Choko
Maize (forage) (s) (rainfed)	Sweet corn (s) (w)	Citrus	Mango	Papaw
Pineapple (rainfed)	Sweet potato (s) (w)	Custard apple	Persimmon	Passionfruit
Sorghum (forage) (s) (rainfed)	Tomato (s) (w)	Dunn's white gum	Stone fruit	Sown pastures
Soybean (rainfed)	Turf	Flooded gum	Spotted gum	
		Gympie messmate		

Note 1: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Note 2 – Typically, bananas have a very narrow planting season. As such, narrow moisture range is more critical than for most other tree crops. It is less critical when compared with horticultural field crops however, because planting only occurs every 6–7 years.

Soil surface condition (ps)

Effect

Problems with germination and seedling development during crop establishment are typically associated with adverse physical conditions in the surface soil, such as hard setting behaviour, coarse aggregates and crusting.

Assessment

Soils with indicative morphological properties are evaluated in the context of local landholder or industry experience, particularly planting techniques and planting material (eg. seed vs vegetative planting, seed size, length of crop cycle between plantings etc). Typically, local experience provides a useful guide to problem soils and their characteristics within a particular district. This will vary from district to district due to changes in geology, soil type and dominant land use, as well as local differences in agronomic management.

Surface condition categories		Inherent soil morphological properties affecting surface condition
ps1	No restrictions	No restriction to seedling emergence and/or establishment (ie. surface soils that are not hard setting or crusting and have aggregates <20 mm in size)
ps2	Hard setting low strength surface soils	Hard setting massive soils with sandy loam to clay loam surface textures with dry moderately firm consistency - medium to coarse sand fraction
ps3	Hard setting moderate strength surface soils	Hard setting massive soils with fine sandy loam to clay loam fine sandy or silty clay loam surface textures with dry very firm consistency
ps4	Hard setting high strength surface soils	Hard setting massive soils with dry strong consistency including soils with sodic material within 0.3m of the surface (ie. within the plough zone)
ps5	Coarse surfaced soils with poor seed soil contact	Large aggregate size >20 mm in the surface soil with either coarsely self mulching clays or soils with very coarse blocky surface structure

Limitation class determination

Plant tolerance limits and requirements in relation to germination are matched with soil properties and supported by local experience.

Crop specific comments

Code	Attribute level	Suitability subclasses for various crops				
		Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
ps1	No restrictions	1	1	1	1	1
ps2	Hard setting low strength surface soils	2	1	1	1	2
ps3	Hard setting moderate strength surface soils	3	2	2	1	3
ps4	Hard setting high strength surface soils	3	2	2	1	3
ps5	Coarse surfaced soils with poor seed soil contact	5	3	2	1	4

Group 1	Group 2	Group 3	Group4	Group 4 continued	Group 5
Sorghum (forage) (s) (rainfed)	Capsicum (s) (w)	Ginger (s) (w)	Avocado	Gympie messmate	Soybean (rainfed)
Sown pastures	Cucurbits (s) (w)	Pineapple (rainfed)	Banana	Lychee	
	Maize (forage) – (s) (rainfed)	Sugar cane	Banana (rainfed)	Macadamia	
	Strawberry	Sugar cane (rainfed)	Blackbutt	Macadamia (rainfed)	
	Sweet corn (s) (w)	Sweet potato (s) (w)	Caribbean pine	Mango	
	Tomato (s) (w)		Choko	Papaw	
	Turf		Citrus	Passionfruit	
			Custard apple	Persimmon	
			Dunn's white gum	Spotted gum	
			Flooded gum	Stone fruit	

Note 1 – All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Note 2 – Crops planted from seed (particularly small seeded grasses or pasture species) are most affected by this limitation. Horticultural small crops such as tomatoes, capsicum and cucurbits, which are planted as seedlings, are less affected. Tree and vine crops, which are planted as large tree seedlings, and also crops planted using vegetative material (eg. ginger, pineapple, sugar cane) are least affected.

Soil nutrient deficiency (nd)

Effects

Reduced crop growth may be associated with nutrient deficiencies (ie. restricted levels of one or more available soil nutrients), in many soils. Livestock production may also be affected under such conditions as a result of reduced pasture yield and/or pasture quality and/or lowered nutrient intake in animals.

Assessment

Soil nutrient supply assesses the need for additional fertiliser treatment in excess of standard application rates and practices used during normal crop management. Undeveloped soils low in mineral nutrients, particularly P and K, will require additional fertiliser initially (or the addition of aglime or sulfate fertilisers to correct low P availability associated with low pH <4.5 or high pH 7.0–8.5 respectively) for cultivated crops and sown pastures. Minor elements can be added at low cost. Production of native eucalypt species is dependant on natural soil nutrient levels and nutrient availability. Assessment is based on the nutrient levels within the surface soil (0 to 0.3 m).

For soils deficient in P and K (nd limitation), specific problems assessed include:

- reduced P availability associated with low pH (ie. very strongly acid – pH <4.5) – corrected with additional applications of P or lime applications if 'unavailable' P reserves in the soil are relatively high. Reduced nutrient availability due to low pH may also be associated with nutrient toxicity of other elements such as manganese or aluminium (see nt limitation).
- reduced P availability due to P sorption by organic matter in humic/organic soils or high levels of free iron (Ferrosols). This is corrected with additional applications if not previously fertilised.
- reduced P availability due to slightly alkaline conditions (pH 7.0–8.5) is best corrected with additional applications of P, as slightly alkaline pH is beneficial for the availability of most other nutrients. Very strongly alkaline conditions (pH > 8.5) have not been considered as these are uncommon within the Sunshine Coast–Gold Coast region (ie. restricted to fresh basalt landscapes, particularly lower slopes and associated alluvium, and typically at depths greater than the effective rooting depth (see pd limitation)).

Limitation class determination

Nutrient deficient soils require additional fertiliser applications over and above standard management practices.

Crop specific comments

Code	Attribute level		Suitability subclasses for various crops				
	Available P and K levels		Group 1	Group 2	Group 3	Group 4	Group 5
nd1	P>40 ppm	K >0.6 meq	1	1	1	1	1
nd2	P>40 ppm	K 0.2–0.6 meq	1	1	1	1	1
nd3	P>40 ppm	K <0.2 meq	1	2	2	2	2
nd4	P 20–40 ppm	K >0.6 meq	1	1	1	1	1
nd5	P 20–40 ppm	K 0.2–0.6 meq	1	1	1	1	1
nd6	P 20–40 ppm	K <0.2 meq	2	2	2	2	2

Code	Attribute level		Suitability subclasses for various crops				
nd7	P 10–20 ppm	K >0.6 meq	2	2	1	2	2
nd8	P 10–20 ppm	K 0.2–0.6 meq	2	2	1	2	2
nd9	P 10–20 ppm	K <0.2 meq	3	3	2	2	3
nd10	P 5–10 ppm	K >0.6 meq	3	3	2	2	2
nd11	P 5–10 ppm	K 0.2-0.6 meq	3	3	2	2	2
nd12	P 5–10 ppm	K <0.2 meq	4	4	2	2	3
nd13	P <5 ppm	K >0.6 meq	4	4	2	2	3
nd14	P <5 ppm	K 0.2–0.6 meq	4	4	2	2	3
nd15	P <5 ppm	K <0.2 meq	4	4	2	2	3

Group 1	Group 2	Group 3	Group 4	Group 4 continued	Group4 continued	Group 5
Sown pastures	Blackbutt	Caribbean pine	Avocado	Maize (forage) (s)(rainfed)	Sorghum(forage) (s) (rainfed)	Soybean
	Dunn's white gum	Spotted Gum	Banana	Lychee	Stone fruit	Sugar cane
	Flooded gum		Banana (rainfed)	Macadamia	Strawberry	Sugar cane (rainfed)
	Gympie messmate		Capsicum (s) (w)	Macadamia (rainfed)	Sweet corn (s) (w)	
			Choko	Mango	Sweet potato (s) (w)	
			Citrus	Papaw	Tomato (s) (w)	
			Cucurbit (s) (w)	Passionfruit	Turf	
			Custard apple	Persimmon		
			Ginger (s) (w)	Pineapple (rainfed)		

Note 1 – All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Note 2 – Crops extract the bulk of their soil water requirements (45–70% depending on the particular crop) from the immediate surface soil to a depth of about 0.3 m (Salcon 1997). Therefore, nutrient levels have only been assessed to this depth. Subsoil nutrient supply has not been assessed due to complex interactions between crop type, soil wetness, rooting depth and water availability.

Note 3 – Because fertiliser use is considered a standard management practice associated with intensive cropping systems, nutrient deficiency is only recognised as a minor limitation. It is restricted to soils with P levels <20 ppm and/or K levels <0.2 meq.

Soil nutrient fixation (nf)

Effects

Reduced crop growth may be associated with nutrient deficiencies (ie. restricted levels of one or more of the available soil nutrients) caused by the fixation of mineral nutrients in certain soils. Livestock production may also be affected under such conditions as a result of reduced pasture yield and/or pasture quality and/or lowered nutrient intake in animals.

Assessment

Soil nutrient supply assesses the need for additional fertiliser treatment in excess of standard application rates and practices. Humose and/or organic horizons (Isbell 1996) within some soils have the potential to adsorb nutrients such as P and limit its supply for crop use. Soils high in free iron (such as Krasnozems/Ferrosols) suffer similar problems with P fixation and P availability.

For soils subject to nutrient fixation (nf limitation), specific problems assessed include:

- sorption of P in humose/organic soils (eg. Hydrosols); and
- sorption of P in soils high in free iron and/or aluminium oxides (eg. Ferrosols).

Limitation class determination

Nutrient fixation becomes important when the level of P sorption within a soil requires additional P applications in the order of 50 to 100% in excess of standard P application rates.

Crop specific comments

Code	Attribute level	Suitability subclasses for various crops		
		Group 1	Group 2	Group 3
nf1	Soils that are not humic/organic or high in free iron/aluminium oxides	1	1	1
nf2	Humic/organic soils	1	2	2
nf3	Soils high in free iron and/or aluminium oxides	1	1	2

Group 1	Group 2	Group 3	Group3 continued	Group 3 continued	Group3 continued
Sown pastures	Blackbutt	Avocado	Ginger (s) (w)	Persimmon	Sugar cane (rainfed)
	Caribbean pine	Banana	Maize (forage) (s)(rainfed)	Pineapple (rainfed)	Sweet corn (s) (w)
	Dunn's white gum	Banana (rainfed)	Lychee	Sorghum(forage) (s) (rainfed	Sweet potato (s) (w)
	Flooded gum	Capsicum (s) (w)	Macadamia	Soybean	Tomato (s) (w)
	Gympie messmate	Choko	Macadamia (rainfed)	Stone fruit	Turf
	Spotted gum	Citrus	Mango	Strawberry	
		Cucurbit (s) (w)	Papaw	Sugar cane	
		Custard apple	Passionfruit		

Note 1 – All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Note 2 – Crops extract the bulk of their soil water requirements (45–70% depending on crop) from the surface 0–0.3 m depth (Salcon 1997). Therefore, nutrient levels have only been assessed within the surface soil (0–0.3 m). Subsoil nutrient supply has not been assessed due to complex interactions between crop type, soil wetness, rooting depth and water availability.

Soil nutrient leaching (nl)

Effects

Reduced crop growth may be associated with nutrient deficiencies (ie. restricted levels of one or more of the available soil nutrients) caused by the severe leaching of mineral nutrients in certain soils. Livestock production may also be affected under such conditions as a result of reduced pasture yield and/or pasture quality and/or lowered nutrient intake in animals.

Assessment

Soil nutrient supply assesses the need for additional fertiliser treatment in excess of standard application rates and practices. Soils that are highly permeable (coarse sandy soils, strongly structured soils high in free iron) to depths greater than the effective rooting depth have a high leaching potential. Loss of applied nutrients from the root zone often occurs in such soils. In some situations, improved soil drainage may modify the leaching potential for a particular soil (eg. a shallow watertable within the effective rooting depth can provide leached nutrients to plants for extended periods).

For soils subject to nutrient leaching (nl limitation), specific problems assessed include:

- low nutrient retention capacity associated with high leaching rates.

Limitation class determination

Soils with a low nutrient retention capacity require high fertiliser inputs and/or increased management (eg. very high application rates and/or split dressings).

Crop specific comments

Code	Attribute level	Suitability subclasses for various crops	
		Group 1	**Group 2**
nl1	All very slowly permeable to moderately permeable soils. Also any soils that are subject to watertable fluctuations within 1.5 m of the surface (ie. poorly drained or worse). Includes all soils with a wetness attribute of 5M, 4M, 4S, 4V, 3M, 3S, 3V, 2H, 2M, 2S, 2V, 1H, 1M, 1S, or 1V at 1 m..	1	1
nl2	Any highly permeable soils that are not subject to watertable fluctuations within 1.5 m of the surface. . Includes any soil with a wetness attribute of 3H, 4H, 5H or 6H to a depth of 1.5 m (ie. highly permeable and imperfectly drained or better to 1.5 m)	1	2

Group 1	Group 2	Group2 continued	Group2 continued	Group2 continued	Group2 continued
Sown pastures	Avocado	Citrus	Maize (forage) (s)(rainfed)	Persimmon	Sugar cane
	Banana	Cucurbit (s) (w)	Lychee	Pineapple (rainfed)	Sugar cane (rainfed)
	Banana (rainfed)	Custard apple	Macadamia	Sorghum (forage) (s) (rainfed	Sweet corn (s) (w)
	Blackbutt	Dunn's white gum	Macadamia (rainfed)	Soybean	Sweet potato (s) (w)
	Capsicum (s) (w)	Flooded gum	Mango	Spotted gum	Tomato (s) (w)
	Caribbean pine	Ginger (s) (w)	Papaw	Stone fruit	Turf
	Choko	Gympie messmate	Passionfruit	Strawberry	

Note 1: All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Element toxicity (nt)

Effects

Reduced crop growth may be associated with the oversupply or toxicity (ie. excessive levels) of some mineral nutrients, particularly where soil pH is very low. Livestock production may be also be affected under such conditions as a result of reduced pasture yield and/or pasture quality and/or lowered nutrient intake in animals.

Assessment

Soil nutrient supply assesses the need for additional fertiliser treatment in excess of standard application rates and practices. Low pH affects nutrient availability and some elements such as aluminium (Al) and manganese (Mn) become toxic at very low pH levels. Applications of lime to correct toxicity problems in the surface soil (0–0.3 m) can be undertaken at relatively low cost in most cropping situations. Due to the relatively low returns per unit area for sown pastures however, aglime is unlikely to be a cost effective option and species selection needs to consider adaptation to low pH conditions (especially in the case of legume species).

For soils subject to element toxicity (nt), specific problems assessed include:

- low pH <5.5 in the surface soil (ie. very strongly acidic surface soil to 0. m) as an indicator of possible element toxicity (particularly Al or Mn).

Limitation class determination

Field or laboratory pH data are assessed against published research relating low pH to element toxicity.

Crop specific comments

Code	Attribute level	Suitability subclasses for various crops			
		Group 1	Group 2	Group 3	Group 4
nt1	Surface soil (0–0.3 m) pH >6.0	1	1	1	1
nt2	Surface soil (0–0.3 m) pH 5.0–6.0	1	2	1	2
nt3	Surface soil (0–0.3 m) pH 4.0–5.0	1	3	2	4
nt4	Surface soil (0–0.3 m) pH <4.0	2	4	3	5

Group 1	Group 2	Group 3	Group3 continued	Group 3 continued	Group4
Blackbutt	Sorghum (forage) (s) (rainfed)	Avocado	Maize (forage) (s)(rainfed)	Soybean	Sown pastures (rainfed)
Caribbean pine		Banana (i) (rainfed)	Lychee	Stone fruit	
Dunn's white gum		Capsicum (s) (w)	Macadamia (i) (rainfed)	Strawberry	
Flooded gum		Choko	Mango	Sweet corn (s) (w)	
Gympie messmate		Citrus	Papaw	Sweet potato (s) (w)	
Spotted gum		Cucurbit (s) (w)	Passionfruit	Tomato (s) (w)	
Sugar cane		Custard apple	Persimmon	Turf	
Sugar cane (rainfed)		Ginger (s) (w)	Pineapple (rainfed)		

Note 1 – All crops are irrigated except where indicated as rainfed. Forestry species and sown pastures are rainfed.

Note 1 – Crops extract the bulk of their soil water requirements (45–70% depending on crop) from the surface 0–0.3 m depth (Salcon 1997). Therefore, nutrient levels have only been assessed within the surface soil (0–0.3 m). Subsoil nutrient availability has not been assessed due to complex interactions between crop type, soil wetness, rooting depth and water availability.

Appendix 3
Reinterpretation of existing site data

The following rules were adapted from methodology used in the Maroochy catchment (Sunshine Coast) assessment (Chamberlain and Wilson 2007).

Depth to watertable

Depth to watertable was calculated for each site using site descriptions, soil morphological descriptions and interpreted ASS site data (Manders *et al.* 2002). Depth to watertable was taken as the minimum depth to one of the following:

- Depth of observed watertable
- Upper depth of PASS
- Upper depth of first horizon with a colour 10YR8/1 (where soil is not a Podosol)

And where all three of these criteria are absent,

- Upper depth of first horizon with pale or gley colours

Rooting depth

Rooting depth was inferred for each site using ASS soil morphological descriptions, field tests and laboratory analysis (Manders *et al.* 2002). The rooting depth was taken as the minimum depth to one of the following:

- Upper depth of horizon where field pH <=4 (minimum depth of 0.24 m)
- Depth to watertable [*] (refer to watertable rules below) (minimum depth of 0.24 m)
- Upper depth of a pan horizon (minimum depth of 0.24 m)
- Upper depth of a massive clay horizon (minimum depth of 0.24 m)
- Upper depth of sample where lab electrical conductivity (EC) >= 0.8dS/m
- Depth to weathered rock
- Depth of the lowest recorded horizon

A minimum rooting depth of 0.24 m was applied unless high electrical conductivity values were recorded at the surface. For example, if the minimum rooting depth was 0.05 m due to a low pH and low EC values were recorded in the top 0.3 m, rooting depth was adjusted to 0.24 m. This rule was introduced as some management practices can overcome limitations to rooting depth at the surface plough layer (such as the application of aglime to increase pH).

The following assumptions were use to model rooting depth:

Attribute	**Query where assumption introduced**	**Assumption**
ALL	-	All recorded data is complete and correct
Rooting Depth	rd_ph4_mindepth	Plant roots cannot tolerate a pH less than 4, but can tolerate anything greater than a pH of 4, regardless of the depth (eg. a acid surface is no more or less limiting than an acid subsoil; an acid surface is limiting if over a non-acid subsoil)

[*] Rule was not in original Maroochy catchment methodology (Chamberlain and Wilson 2007)

Attribute	Query where assumption introduced	Assumption
Rooting Depth	rd_ph4_mindepth_2	A low pH can be overridden by management practices (such as the application of aglime) in the plough layer (first 0.24 m), therefore pH is only a limiting factor for rooting depth below 0.24 m.
Rooting Depth	rd_massive clay 1	Roots cannot penetrate massive clay (ZCL or greater) soils that are saturated (below the watertable or below PASS)
Rooting Depth	-	Roots are not limited by structure when the soil is not saturated
Rooting Depth	rd_ec08_mindepth	Roots cannot tolerate an EC greater or equal to 0.8dS/m (1:5 soil water), and therefore cannot grow deeper than soil with this EC.
Rooting Depth	rd_pans_mindepth	Roots cannot penetrate a pan of any type (coffee rock pans in the Rocky Point area are usually thick and strongly cemented).
Rooting Depth	rd_max_depth	Roots cannot be deeper that the depth of the samples (eg. if an auger or push tube uncounted weathered rock or did not go deeper than 1 m, then the roots also cannot penetrate deeper than rock or 1 m)
Rooting Depth	rd_union2	Roots will not grow in a saturated zone (watertable)
Rooting Depth	rd_Rooting_Depth	Roots will not penetrate deeper than the first limiting factor
Rooting Depth	rd_Rooting_Depth_2	Rooting depth assumed to be at least 24 cm where watertable, iron sulfides or low pH is recorded. Rooting depth values of <0.24 m are valid due to factors such as EC >0.8dS/m at surface.
Rooting Depth	-	Roots do not have any other limiting factors other than watertable, pH, lab EC, structure and texture when wet, the presence of pans, and depth of sample.

Plant available water capacity

Plant available water capacity (PAWC) was estimated for each site using PAWCER, a visual basic script run in a Microsoft Access environment. PAWC was calculated using rooting depth (as determined using the above rules) and soil texture.

Permeability

Permeability was inferred for each site using site descriptions, soil morphology, field tests and laboratory analysis. Permeability was calculated at depths of 0.5 m, 1.0 m and 1.5 m. Permeability was taken as the lowest rating up to (and including) the depth being calculated, using the following rules:

Criteria	Permeability Rating	Permeability Description
High EC (>=0.8 dS/m) in the subsoil (B horizons)	1	Very slowly permeable
Pan (coffee rock)	1	Very slowly permeable
Saturated massive clay horizons	1	Very slowly permeable
Unsaturated massive clay	2	Slowly permeable

Criteria	Permeability Rating	Permeability Description
horizons		
Unsaturated weakly structured clay horizons	2	Slowly permeable
Non-acidic (pH>4.5) soils with an angular blocky or prismatic structure	2	Slowly permeable
Acidic (pH <=4.5) soils with an angular blocky or prismatic structure	3	Moderately permeable
Moderate or strong granular and sub-blocky soils which are not sandy	3	Moderately permeable
All horizons with a texture between a loam and a silty clay loam	3	Moderately permeable
Sandy soils (sandy loam or lighter)	4	Highly permeable

The following assumptions were use to model permeability:

Attribute	**Query where assumption introduced**	**Assumption**
ALL	-	All recorded data is complete and correct
Permeability	p_ec08subs	EC alone can indicate permeability
Permeability	p_ec08subs	High EC (>= 0.8 dS/m 1:5 soil water) in the subsoil (B horizons) indicates very slow permeability (1)
Permeability	p_MS_GRSB p_vclay_abovewtpass	Structure with texture can indicate permeability
Permeability	p_MS_GRSB	Strong and moderate granular and sub-blocky soils which are not sandy have a moderate permeability (3)
Permeability	p_notclayorsand p_sandy	Texture alone can indicate permeability
Permeability	p_notclayorsand	All horizons with a texture between a loam and a silty clay loam (not sandy or clayish) have a moderate permeability (3)
Permeability	p_pans	Pans are very slowly permeable regardless of the attributes of that pan (such as pan type, cementation, etc)
Permeability	p_phgt45_ABPR p_phlt45_ABPR	A combination of pH and structure type can indicate permeability
Permeability	p_phgt45_ABPR	Horizons with angular blocky and prismatic structure where pH is not acidic (>4.5) are slowly permeable

Attribute	Query where assumption introduced	Assumption
Permeability	p_phlt45_ABPR	horizons with angular blocky and prismatic structure where pH is acidic (<=4.5) are moderately permeable
Permeability	p_vclay_abovewtpass	All clay horizons with massive structure that are not saturated are slowly permeable
Permeability	p_vclay_belowwtpass	All clay horizons with massive structure that are saturated are very slowly permeable
Permeability	p_wclay_abovewtpass	All weakly structured clay horizons above the watertable and PASS are slowly permeable
Permeability	p_sandy	All sandy soils (up to and including a sandy loam) are highly permeable (4), regardless of any other attributes
Permeability	p_perm_05 p_perm_10 p_perm_15	Permeability at any depth (0.5, 1, 1.5 m) is determined by the horizon with lowest permeability above that depth. For example a permeability of 1 at the surface will give a permeability of 1 at 0.5, 1 and 1.5 m

Drainage

Drainage was inferred for each site using site descriptions of soil morphology, field tests and laboratory analysis. Soil colours together with texture were the main attributes used to infer drainage at depths to 0.5 m, 1.0 m and 1.5 m. Drainage was taken as the lowest rating up to (and including) the depth being calculated, using the following rules:

Criteria	Drainage rating	Drainage description
Measured watertable	1	Very poorly drained
PASS	1	Very poorly drained
Pan (coffee rock)	2	Poorly drained
Organic accumulation (suffix of h, s or hs)	2	Poorly drained
Presence of jarosite mottling above the watertable and above PASS	2	Poorly drained
Pale or gley colours (paler than 7.5 YR and 10YR 5/1 to 8/1 or paler) indicating poorly drained to very poorly drained horizons (mainly Hydrosols)	2	Poorly drained
Pale colours indicating horizons that are not poorly drained to very poorly drained (Tenosols, Dermosols, Kandosols, Vertosols, Chromosols or Podosols).	3	Imperfectly drained

Criteria	Drainage rating	Drainage description
Soil colour neither dull nor bright	3	Imperfectly drained
Bright soil colour	4	Moderately well drained

The following assumptions were used to model drainage:

Attribute	**Query where assumption introduced**	**Assumption**
ALL	-	All recorded data is complete and correct
Drainage	d_10YR81_PO d_otherascs_3 d_bright_colours d_HY_and_OR_2 d_other_colours	Colour (together with soil type) can indicate drainage of a soil
Drainage	d_hs_suffix	The suffix of the horizon name can indicate drainage (accumulation of organic material with iron and or aluminium)
Drainage	d_jaros	The composition of a soil, particularly the presence of jarosite mottles, can indicate the drainage of a soil (above the watertable or PASS)
Drainage	d_10YR81_PO	Podosols A & B horizons with a colour of 10YR81 are poorly drained
Drainage	d_hs_suffix	Horizons with a suffix of h, s, or hs, and therefore the presence of organic matter and aluminium and or iron, are poorly drained (all coffee rock pans in the Rocky Point area are associated with watertables)
Drainage	d_jaros	The presence of jarosite as a mottle in the soil is an indication of poor drainage where it is above the watertable or PASS
Drainage	d_otherascs_3	Dull colours in some soil types indicate imperfectly drained soils
Drainage	d_HY_and_OR_2	Dull colours in some soil types indicate poorly drained soils
Drainage	d_7.5Y51_2	Some colours, regardless of soil type or position in profile, indicate poorly drained soils
Drainage	d_bright_colours	Bright colours indicate moderate drainage, regardless of soil type
Drainage	d_other_colours	Soil with colours that are neither dull not bright are imperfectly drained, regardless of soil type
Drainage	d_pans	Pans are poorly drained (2) regardless of the attributes of that pan (such as pan type, cementation, etc)

Drainage	d_pass_05 d_wt_05 d_pass_10 d_wt_10 d_pass_15 d_wt_15	The presence of PASS or a watertable indicates very poor drainage (1)
Drainage	d_05_qry d_10_qry d_15_qry	Drainage at any depth (0.5, 1.0, 1.5 m) is determined by the horizon with lowest drainage above that depth. For example a drainage of 1 at the surface will give a drainage of 1 at 0.5, 1 and 1.5 m