A LAND CAPABILITY STUDY OF THE CITY OF GREATER BENDIGO, HUNTLY DISTRICT

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Further Information

This report has been prepared to assist broad scale planning in the Huntly District. The information in the report has been derived from air photo interpretation and a limited number of representative field sites. The scale of mapping adopted has necessitated some generalisations from the site information collected. While the ratings indicate the likely performance of the various types of land for a specific use, site specific information may be required for on-site planning. The precision of mapped boundaries is affected by the scale of the map. Any enlargement of the map will distort information and is unlikely to improve its accuracy.

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USER GUIDE

The user guide is designed to assist document users in finding and cross referencing information contained within this report. Each section of the report is listed below with a brief description of the contents and the relationship to other sections.

Summary: The Summary contains a listing of the land capability classes determined for specific types of land use, in each map unit within the project area. A brief discussion of the project area and important land management issues is also provided. Refer to section 4 and Appendix B for a detailed description of map units and capability classes.

Section 1: The Introduction highlights the location of the Huntly District and the specific objectives of this study.

Section 2: The Land Capability Assessment section describes the DCNR methodology for land capability assessment. Table 2.1 and 2.2 highlight the limitations to development and management guidelines for each land capability class. The land use rating tables are contained in Tables 2.3 to 2.8; they are used to determine the capability classes for each map unit. Refer to section 3 and Appendix A for a further description of the parameters that influence each form of land use, and Appendix B for the capability class assigned to each parameter in each map unit.

Section 3: The Land Management Guidelines section describes important landform and soil characteristics which place limitations on land use, and explains how improved land management may reduce or overcome the perceived limitations. Refer to Appendix A for a further description of the parameters that influence land use.

Section 4: The Map Unit Descriptions section contains a broad review of related map units and discusses the common limitations to land use. This is the core section of the report and contains specific map unit descriptions and land capability assessments for each map unit. A dual page format provides general and specific landform and soil information, including susceptibility to land degradation.

Appendixes: There are six appendixes contained in the report. Appendix A describes the parameters that influence land use and outlines the methods used to determine the capability class. Appendix B contains the land capability classes for each land use and each map unit. Appendix C describes the methodologies used for the land capability assessment. Appendix D lists the physical and chemical results of major soil types in each map unit. Appendix E provides a method of establishing recharge (soil permeability) values for various soil types. Appendix F describes the relationship between land system mapping and land capability assessment.

SUMMARY

The Huntly District (previously the Shire of Huntly) was recently annexed into the new City of Greater Bendigo municipality in April 1994.

It is approximately 880 km2 in size and is located north-east of the City of Bendigo. Much residential development has occurred close to the City of Bendigo. The remaining rural areas within easy commuting distance to Bendigo are under pressure from rural residential and rural farmlet development. In recent decades, the population has increased considerably due to the close proximity to Bendigo (Figure 1.1.). This trend is expected to continue as the Department of Planning and Development predicts significant population increases in the Bendigo district.

Table i.i - Huntly district population trends.

Huntly district population trends	
1981	3800
1986	4200
1991	4800

Residential development is centred in the townships of Epsom, Ascot, Huntly, and Elmore, while there are several small residential centres located in the rural areas including North Huntly and Goornong. Rural farmlet development is widespread within the south and east of the district and there is increasing demand for further development.

It is well established that indiscriminate development of land for residential and rural farmlet development may result in extensive land and water degradation, loss of good agricultural land and unnecessarily high development and maintenance costs. Much of the district consists of Land Systems (refer to Appendix F) containing Ordovician sediments with gentle to moderate slopes, 2.1Gs4-3 and 2.1Gs4-6 (refer to Table i ii). These areas are highly susceptible to all forms of water erosion particularly sheet and gully erosion and can contribute significantly to salting in the lower parts of the landscape. Development of these areas for residential and rural farmlet purposes can result in environmental degradation due to complications with roading, building foundations and effluent disposal.

Table i.ii - Susceptibility of land systems to land degradation.

Land system	2.1Gs4-3	2.1Gs4-6	4.2Pf4-2
Water erosion	3	3	1
Wind erosion	1	1	2
Salinity	3	3	2
Area (ha)	15,906	8,369	44,760
Total shire area = 87,538 ha			

1: nil/low susceptibility
2: moderate susceptibility
3: high susceptibility

The area recognised as having high agricultural value, the alluvial plains, cover much of the District. At present, these areas are under some pressure for future subdivision. The alluvial plains land system 4.2Pf4-2 is moderately susceptible to salting and wind erosion.

There is concern over the Coliban Water Authority proposal for disposal of treated effluent onto the alluvial plains. Previous development of the Campaspe West Irrigation District on the alluvial plains at Rochester has led to the formation of high water tables and saline discharge areas. As both developments are linked to the alluvial plains and groundwater system of the Campaspe River, the potential risk of salinity occurring on the Huntly alluvial plain is high.

A Strategy for the development of major urban areas has been prepared for the District, a similar Strategy is now required for the development of rural areas. A detailed land capability assessment will provide valuable supportive information for the preparation of a Rural Strategy, and will enable new development proposals to be readily assessed.

A previous study of part of the Shire of Huntly: ‘A study of the land in the Campaspe River Catchment’ by M.S. Lorimer and

N.R. Schoknecht conducted at 1:100,000 has provided background information on soils and geomorphology across part of the Shire.

Table i.iii - Summary of land capability classes.

MAP UNIT		LAND CAPABILITY RATING					
Symbol	**Description**	**Agriculture**	**Effluent disposal**	**Farm dams**	**Secondary roads**	**Building foundations**	**Rural farmlets**
Qa1	Quaternary alluvium, floodplain	3	5	3	5	5	5
Qa2	Quaternary alluvium, floodplain	3	5	3	5	5	5
Qap	Quaternary alluvium, alluvial plain	3	4	3	4	4	3
Qbe	Quaternary basalt, gentle crest	3	4	3	4	3	4
Tse1	Tertiary alluvial sediments, gentle crest	4	4	5	5	3	5
Tsf1	Tertiary alluvial sediments, gentle slope	4	4	5	5	3	5
Tse2	Tertiary marine sediments, gentle crest	4	5	4	4	3	4
Tsf2	Tertiary marine sediments, gentle slope	3	5	4	4	3	4
Tsg2	Tertiary marine sediments, very gentle slope	3	5	4	3	3	4
Tsh2	Tertiary marine sediments, drainage depression	3	5	4	3	3	4
Ose	Devonian sediments, gentle crest	4	5	5	4	3	5
Osf	Devonian sediments, gentle slope	4	5	4	4	3	4
Osg	Devonian sediments, very gentle slope	3	5	4	3	3	4
Osh	Devonian sediments, drainage depression	3	4	3	3	3	3

Note: Please refer to section 4 (Detailed Map Unit Descriptions and Capability Ratings) for further information.

PREFACE

The Department of Conservation and Natural Resources has been involved in formal land capability assessment studies since the early 1970s. The Land Capability Section of the (then) Soil Conservation Authority established the framework for the conduct of formal land capability studies upon which this more recent work is based. This framework included rating tables for some thirty activities. Ratings for various activities were presented as thematic maps, or combined into ratings for various land uses, depending upon the needs and abilities of the client.

A survey by Lorimer (1991) of the awareness, needs and willingness of Victorian rural municipalities to use land resource information has indicated a general appreciation of the value of sound land resource information for the preparation or revision of long-term planning strategies. Subsequently, a submission seeking funds from the National Soil Conservation Program was prepared. It was proposed to undertake detailed land capability studies in municipalities with significant pressures for change in land use to more intensive uses, where there was significant existing or potential land degradation issues, or where better quality agricultural land was under threat of development for residential purposes.

The Huntly District is one of three districts in the City of Greater Bendigo to be studied in the current series of investigations. The primary objective has been to provide the municipality with detailed land resource information, consisting of base data on the nature of the land, and assessment of the likely performance of the land under various activities. This information can underpin many land use and management decisions by the municipal authority, both now and in the future. In doing so, many of the problems and unexpected costs incurred through inappropriate land use can be avoided.

1. INTRODUCTION

1.1 Introduction

Land varies considerably in its basic characteristics and its response to the demands made upon it. Such demands include the production of food, fibre, water, and development for residential, industrial and recreational purposes.

Planners need to match the requirements of land use with the capability of the land to sustain that use and avoid land degradation. Prior knowledge of soil and land limitations can prevent unnecessary and costly mistakes. Information obtained through land capability assessments can provide the necessary data to assist local government with planning decisions and the preparation of planning strategies for the future.

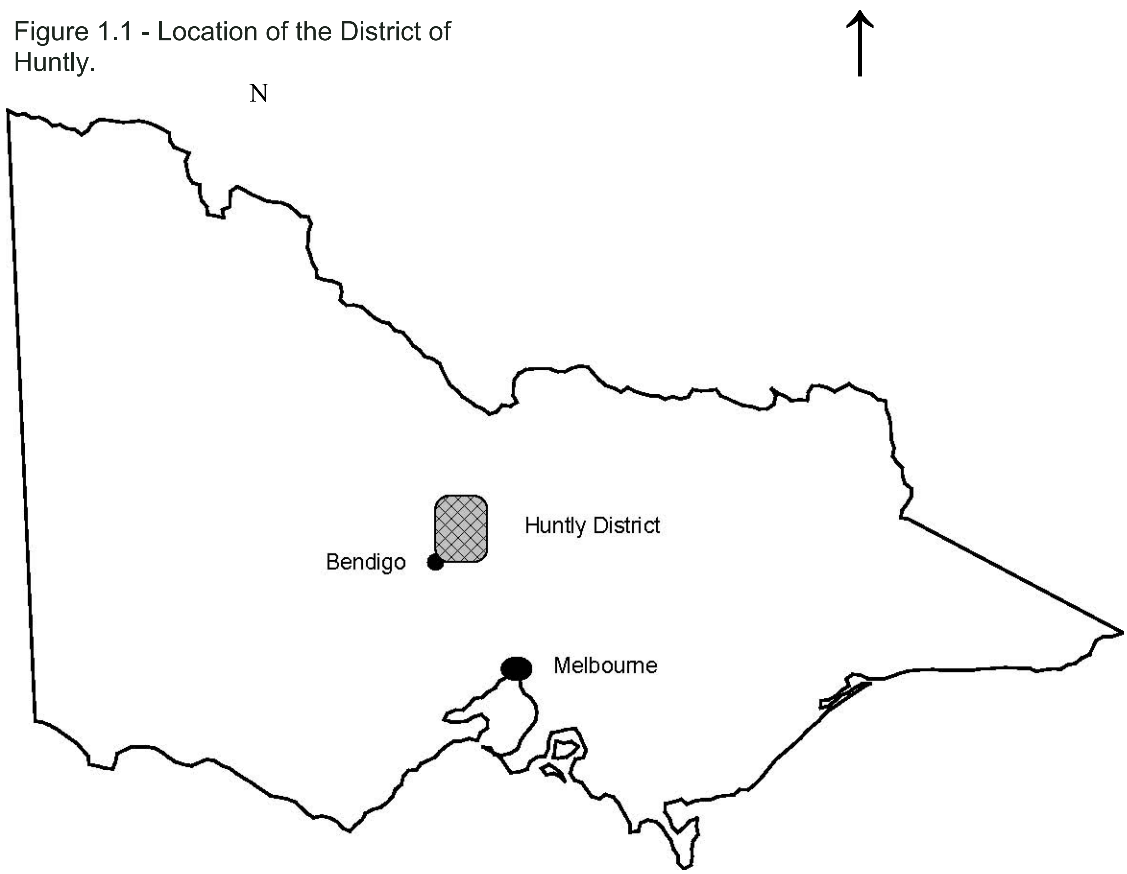
Planning schemes developed and implemented by local government provide an effective means of managing changes in land use. A planning scheme may prohibit or place conditions on land use not well suited to a land type.

This report provides land resource information for broad-scale planning within the Huntly District. It does not provide recommendations for land use and no allowance has been made for social or economic considerations which may influence planning proposals. It is primarily an examination of potential consequences and levels of management required for a range of land uses.

1.2 Location

The Huntly District is located immediately to the north-east of the City of Bendigo, as shown in Figure 1.1. It has an area of approximately 880 km^2.

Figure 1.1 - Location of the District of Huntly.



1.3 Purpose of study

To provide land resource information to the City of Greater Bendigo that will facilitate future land use planning and assessment in the Huntly District.

More specifically:

1. To map and describe the freehold land of the Huntly District at a scale of 1:25,000 (excluding existing urban areas and public land) identifying dominant land types, climatic zones and other features relevant to the assessment of the capabilities of the land.

2. To prepare land capability analyses based on standardised rating tables for:
   * agriculture
   * effluent disposal (septic tanks)
   * earthen dams
   * secondary roads
   * building foundations
   * rural farmlets

3. To provide maps at 1:25,000 scale of:
   * topographic base map, including tree cover and map units
   * thematic land use maps with land capability classes

4. To assist the City of Greater Bendigo in the incorporation of this land resource information into its planning strategies for the district of Huntly.

2. LAND CAPABILITY ASSESSMENT

2.1 Philosophy and principles

Land capability assessment is a rational and systematic method of determining the ability of land to sustain a specific use and level of management, without causing significant long-term degradation.

The objectives of land capability assessments are:

i) to assist land managers and land use planners to identify areas of land with physical constraints for a range of nominated land uses;

ii) to identify management requirements that will ensure a particular land use can be sustained without causing significant on-site or off-site degradation to land, or to water quality.

To achieve these objectives, it is necessary to know the natural characteristics of the land, and understand the effects that a proposed land use may have on the land and the water derived from it.

Land capability assessments analyse basic landform and soils information to determine the ability of the land to sustain a desired land use. A strength of the methodology lies in its association with land systems since the results can be extrapolated, with care, to similar land components and land systems in other areas (Refer to Appendix F).

The ratings provided by a land capability assessment are not intended to restrict development of land, but rather to identify the principal constraints of that land for a specified land use. It is a matter for the land manager or land-use planner to decide if the cost of overcoming the constraints is justified. Where particularly severe physical constraints exist, the planning authority has the option of excluding that land from that use, or permitting the use only under strict conditions. The placement of conditions on development permits is quite a proper exercise of planning responsibility.

2.2 Land resource mapping - methodology and constraints

The main objective of land resource mapping is to identify areas of land that are uniform with respect to the characteristics which affect land use. These areas of land will have a similar land use capability for a nominated use and are likely to respond in a similar way to management. By identifying areas of land with a limited range of variability, the resultant map provides the basis for land capability assessment (for specific methodologies, refer Appendix C).

Mapping an area of land can be a complex task as many differences arise due to interactions between climate, geology and topography. While it is possible to measure and determine some of the land characteristics such as slope, rock outcrop, and soil type, other characteristics such as site drainage, and permeability are less easily determined.

The following procedure has been adopted for this study:

i) The geological boundaries are obtained from existing maps and verified in the field at the appropriate mapping scale.

ii) The broad landform pattern and the landform elements are identified from air-photos using a binocular stereoscope. The map units are derived from this information.

iii) Extensive field verification of map units ensure that map units are consistent with respect to parent material, slope, position in the landscape, soil type, drainage and native vegetation.

iv) A representative site for each map unit is selected, to record general landform and site information. The incidence of any land degradation in each map unit is also recorded.

v) A soil pit or large exposure of the soil profile is prepared at each selected site. Detailed soil profile information is recorded. Colour photographs are taken and soil samples collected for physical and chemical analyses (see Appendix D and the corresponding tables for each Land Unit in Section 4.2 for details).

vi) The permeability of the soil profile is measured when the soils are near field capacity (see Appendix C).

vii) The map unit boundaries are entered into a Geographic Information System where the data is combined with base-map information on roads, contours and streams to produce a final base map of the study area with appropriate headings and legend.

viii) Land capability ratings for those land uses relevant to the study are derived from the climatic, land and soil data available for each map unit based on standardised rating tables. Separate land capability assessment maps are prepared for the specified land uses.

ix) A report is prepared to provide accompanying land resource information and methodology for the land capability maps.

2.3 Assessment procedure

A land capability rating table lists key land characteristics such as slope, site drainage or soil depth, which may affect the ability of the land to support a specified land use. These land characteristics are quantified and graded into classes for the land use being assessed. Each map unit within the study area is given a capability class according to the tables shown in Section 2.4.

It is the most limiting factor that determines the Capability Class for the map unit. This is related to the degree of limitation for that land use and the general level of management that will be required to minimise degradation.

A Capability Class of one represents essentially no physical limitations to the proposed land use whilst a Class of five indicates a very low capability to sustain the land use. Limitations in Class five generally exceed the current level of management skills and technology available. Severe deterioration of the environment is likely to occur if development is attempted. A Class of two, three or four will require increasing levels of management to sustain the particular land use, otherwise the environment will deteriorate.

Separate class descriptions are prepared for agriculture (Table 2.1) and other land uses (Table 2.2). Due to the scale of mapping adopted (1:25000), the inherent variability within some landscapes may result in the presence of small unrepresentative areas within map units. In some cases, these areas will have a capability class exceeding that of the overall map unit. An opportunity may therefore exist to utilize land with less constraints for the chosen development.

2.4 Land capability rating tables

Each land capability rating table (refer Tables 2.3, 2.4, 2.5, 2.6, 2.7 and 2.8) contains criteria which will strongly influence the ability of the land to sustain the desired land use. The limitations distinguishing each land capability class from one to five are also presented for comparison.

There has been no attempt to rank the criteria in order of importance. The objective of having classes is to identify the kind of limitation and its severity. It is recognised that criteria may interact, but an underlying objective of this study is to provide the information in a usable form, rather than have a convoluted series of alternative pathways that would be too complex for the intended user to follow.

Where there are known interactions between different criteria, it is the responsibility of the planner or land manager to assess the importance of the limiting factor(s) and to determine the need for management or additional financial input to overcome the limitation.

Theoretically a single diagnostic land quality could be found and used to rate land performance, but there is the risk of such a feature masking the true parameters that affect the land use, thus preventing a change to a more appropriate land use or level of management. Land use and land management practices will continue to change and if the community is concerned about long-term sustainability of specific land uses, then the limitations of the soil, the various processes of land degradation, and the possibility of off-site effects, must be recognised. Once a limitation to land use is identified, steps can be taken to overcome or minimise the long-term effect of land degradation that would result if the land use was continued.

Table 2.1 - Land capability classes for agriculture.

CLASS	CAPABILITY	DEGREE OF LIMITATION
Class 1	Very good	Can sustain a wide range of uses including an intensive cropping regime. Very high levels of production possible with standard management levels.
Class 2	Good	Moderate limitations to agricultural productivity, overcome by readily available management practices.
Class 3	Fair	Can sustain agricultural uses with low to moderate levels of land disturbance such as broadacre cultivation in rotation with improved pastures. Moderate to high levels of production possible with specialist management practices such as minimum tillage.
Class 4	Poor	Low capacity to resist land disturbance such as cultivation. Moderate production levels possible with specialist management such as improved pasture establishment with minimum tillage techniques. Recommended for low disturbance agriculture such as grazing or perennial horticulture.
Class 5	Very poor	Very low capability to resist disturbance. Areas of low productive capacity. Minimal grazing levels or non-agricultural uses recommended.

Note: Land is assessed for agricultural production on the basis of climate, topography, and the inherent characteristics of the soil. Climate differs from topography and soil features in that it is a regional parameter rather than site specific. The capability table identifies the versatility and potential productivity of an area for a range of agricultural uses, and highlights the necessary level of management required to sustain the land use.

These agricultural ratings are for comparative purposes only and should not be used as a basis for detailed property planning.

Table 2.2 - Land capability classes for effluent disposal, farm dams, secondary roads, building foundations and rural residential and rural farmlet development.

CLASS	CAPABILITY	DEGREE OF LIMITATION TO DEVELOPMENT	GENERAL DESCRIPTIONS AND MANAGEMENT GUIDELINES
Class 1	Very good	The limitation of long term instability, engineering difficulties or erosion hazards do not occur or they are very slight.	Areas with high capability for the proposed use. Standard designs and installation techniques, normal site preparation and management should be satisfactory to minimise the impact on the environment.
Class 2	Good	Slight limitations are present in the form of engineering difficulties and/or erosion hazard.	Areas capable of being used for the proposed use. Careful planning and the use of standard specifications for site preparation, construction and follow up management are necessary to minimise the impact of the development on the environment.
Class 3	Fair	Moderate engineering difficulties and/or moderately high erosion hazard exist during construction.	Areas with a fair capability for the proposed use. Specialised designs and techniques are required to minimise the impact of the development on the environment.
Class 4	Poor	Considerable engineering difficulties during development and/or a high erosion hazard exists during and after construction.	Areas with poor capability for the proposed use. Extensively modified design and installation techniques, exceptionally careful site preparation and management are necessary to minimise the impact of the development on the environment.
Class 5	Very poor	Long term severe instability, erosion hazards or engineering difficulties which cannot be practically overcome with current technology.	Performance of the land for the proposed use is likely to be unsatisfactory. Severe deterioration of the environment will occur if development is attempted in these areas.

Table 2.3 - Land capability assessment for agriculture.

PARAMETERS INFLUENCING AGRICULTURAL PRODUCTION		LAND CAPABILITY RATINGS				
		Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
C: Climate	Length of growing season (months)	12 - 11	10 - 8	7 - 5	4 - 2	< 2
T: Topography	Slope (%)	< 1	1 - 3	4 - 10	11 - 32	> 32
S: Soil	Condition of topsoil *	25 - 21	20 - 16	15 - 11	10 - 6	5 - 1
	Depth of topsoil (mm)	> 300	300 - 160	150 - 110	100 - 50	< 50
	Depth to rock/hardpan (m)	> 2.0	2.0 - 1.5	1.5 - 1.0	1.0 - 0.5	< 0.5
	Depth to seasonal watertable (m)	> 5.0	5.0 - 2.0	2.0 - 1.5	1.5 - 1.0	< 1.0
	Total amount of water (mm) available to plants *	> 200	200 - 151	150 - 101	100 - 51	50 - 0
	Index of permeability/rainfall *	Very high	High	Moderate	Low	Very low
	Dispersibility of top soil (Emerson) *	E6, E7, E8	E3(1), E3(2), E4, E5	E3(3), E3(4)	E2	E1
	Gravel/stone/boulder content (v/v %) *	0	1 - 10	11 - 25	26 - 50	> 50
	Electrical conductivity(μs/cm) *	< 300	300 - 600	600 - 1400	1400 - 3500	> 3500
	Susceptibility to sheet/rill erosion *	Very low	Low	Moderate	High	Very high
	Susceptibility to gully erosion *	Very low	Low	Moderate	High	Very high
	Susceptibility to wind erosion *	Very low	Low	Moderate	High	Very high

Note: The potential agricultural productivity land of is generally classified by the CTS criteria (Climate, Topography and Soil) e.g. the 'ideal' prime agricultural areas would be denoted by C_1 T_1 S_1 compared with another area that had, for example, a 5 - 7 month growing season, slopes of 3% and a depth to rock/hardpan of only 0.7 m, denoted by C_3T_2 S_4. The overall Land Capability Class of this latter land would be 4; with soil factors being the major limiting features.

* See Appendix A

Table 2.4 - Land capability assessment for on-site effluent disposal.

PARAMETERS INFLUENCING EFFLUENT DISPOSAL	LAND CAPABILITY RATINGS				
	Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Slope (%) *	< 3	3 - 10	11 - 20	21 - 32	> 32
Flooding risk *	Nil	Low	Moderate	High	Very high
Drainage *	Rapidly drained	Well drained	Moderately drained	Imperfectly drained	Poorly/very poorly drained
Depth to seasonal watertable (m)	> 2.0	2.0 - 1.5	1.5 - 1.0	1.0 - 0.5	< 0.5
Depth to hard rock/impermeable layer (m)	> 1.5	1.0 - 1.5	1.0 - 0.75	0.75 - 0.5	< 0.5
Number of months/year when average daily rainfall > Ksat *	0	1	2	3	> 3
Permeability (Ksat mm/day) *	> 500 **	500 - 100	100 - 50	50 - 10	< 10

Note: Areas capable of absorbing effluent from a standard anaerobic, all-waste, septic tank connected to a single family dwelling (approximate output of 1000 litres per day).

10 mm/day is equivalent to disposing of 1000 l/day along a 0.5 x 200 m trench

* See Appendix A

** Permeabilities > 1000 mm/day could pollute groundwater

Table 2.5 - Land capability assessment for earthen dams.

PARAMETERS INFLUENCING THE CONSTRUCTION OF EARTHEN DAMS	LAND CAPABILITY RATINGS				
	Class 1	Class 2	Class 3	Class 4	Class 5
Slope (%) *	3 - 7	0 - 3	7 - 10	10 - 20	> 20
Linear shrinkage (%) *	0 - 5	6 - 12	13 - 17	18 - 22	> 22
Suitability of subsoil *	Very high	High	Moderate	Low	Very low
Depth to seasonal watertable (m)	> 5		5 - 2		< 2
Depth to hard rock (m)	> 5	5 - 3	3 - 2	2 - 1	< 1
Permeability (Ksat mm/day) *	< 1	1 - 10	11 - 100	101 - 1000	> 1000
Dispersibility of subsoil (Emerson)	E3(2), E3(3)	E3(1), E3(4)	E2(1), E2(2), E5(A), E5(B)	E2(3), E2(4), E5(C), E5(D)	E1, E6, E7, E8
Susceptibility to slope failure	Very low	Low	Moderate	High	Very high

Note: This table should only be considered for small farm dams to 1000 m^3 in capacity, that have a top water level less than 3 m above the original ground surface at the upstream side of the wall.

Rock outcrop, depth of topsoil and flooding risk were also considered but have not been included for reasons given in Appendix A.

* See Appendix A

Table 2.6 - Land capability assessment for secondary roads.

PARAMETERS INFLUENCING SECONDARY ROADS	LAND CAPABILITY RATINGS				
	Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Slope (%)	0 - 1	2 - 5	6 - 10	11 - 30	> 30
Drainage *	Rapidly	Well	Moderately	Imperfectly	Poorly
Depth of seasonal watertable (m)	> 5	5 - 2	2 - 1	1 - 0.5	< 0.5
Proportion of stones and boulders (v/v %) *	0	1 - 10	11 - 20	21 - 50	> 50
Depth to hard rock (m)	> 1.5	1.5 - 0.75	0.75 - 0.51	0.5 - 0.25	< 0.25
Susceptibility to slope failure *	Very low	Low	Moderate	High	Very high
Linear shrinkage (%) *	< 6	7 - 12	13 - 17	18 - 22	> 22
Bearing capacity (kPa) *	> 50		< 50		
Flooding risk*	Nil	Low	Moderate	High	Very high
Dispersibility of subsoil Emerson (> 4% slope) *	E6, E7, E8	E4, E5, E3(1), E3(2)	E3(3), E3(4)	E2	E1
Unified Soil Group	GW, GC, SC	SM, SW, GM	SP, CL, CH,MH, GP	ML	Pt, OH, OL

Note: Areas capable of being used for the construction of earthen roads for light vehicles without sealed surfaces or concrete drainage and kerbing.

* See Appendix A

Table 2.7 - Land capability assessment for building foundations.

PARAMETERS INFLUENCING BUILDING FOUNDATIONS	LAND CAPABILITY RATINGS				
	Class 1	Class 2	Class 3	Class 4	Class 5
Slope (%) i) Slab ii) Stumps/footings	0 - 1 0 - 5	2 - 5 6 - 10	6 - 10 11 - 30	11 - 30 30 - 45	> 30 > 45
Drainage *	Rapidly drained	Well drained	Moderately well drained	Imperfectly drained	Poorly drained
Depth to seasonal watertable (m)	> 5	5 - 2	2 - 1	1 - 0.5	< 0.5
Proportion of stones and boulders (v/v %)	0	1 - 10	11 - 20	21 - 50	> 50
Depth to hardrock (m)	> 1.5	1.5 - 0.75	0.75 - 0.51	0.5 - 0.25	< 0.25
Susceptibility to slope failure *	Very low	Low	Moderate	High	Very high
Linear shrinkage (%) * i) Slab ii) Stumps/footings	< 12 < 6	13 - 17 7 - 12	18 - 22 13 - 17	22 - 30 18 - 22	> 30 > 22
Flood risk	Nil	Low	Moderate	Moderate/high	High

Note: Areas capable of being used for the construction of buildings of one or two stories. It is assumed that any excavation will be less than 1.5 m and can be completed by a tractor-backhoe or equipment of similar capacity. Two methods of construction are considered:

i) Concrete slab - 100 mm thick and reinforced
ii) Stumps or strip footings

* See Appendix A

Rural residential and rural farmlet development involve a range of land uses. There is a need to consider the capability of each individual land use in assessing the overall capability of a map unit to sustain rural residential and small farm development. More intensive use of the land will require an improved level of management to reduce the likelihood of land degradation.

The land and soil within certain map units can vary substantially in the Huntly District. It is recognised that in areas greater than 5 ha, detailed site inspection may highlight areas with a higher capability to support a given land use. For example, dam construction may be restricted by shallow soil depth on a small allotment, however on a large allotment a minor drainage line may be found to contain sufficient soil depth to enable a dam to be constructed. Larger allotments also allow for greater flexibility in management and design, however an allotment size of 1/4 - 1 acre will place absolute limits on options for development.

In the District, rural residential development occurs on allotments of 0.8 -2 ha while rural farmlet development occurs on allotments greater than 10 ha. In assessing the overall capability class for rural residential and small farm development, the capability of building foundations, secondary roads, effluent disposal and farm dams are combined to arrive at a final capability class (refer to appendix B). In the case of rural farmlets, the potential for variation in land and soil has been recognised, and the map unit classes have been modified according to Table 2.8 below.

Table 2.8 - Land capability assessment for rural residential and rural farmlet development.

RURAL RESIDENTIAL (0.8 - 2.0 ha)		RURAL FARMLETS (> 10 ha)	
Building foundations	No change to capability classes.	Building foundations	*Upgrade by 1 capability class* if major limitation is due to slope, proportion of stones and boulders, drainage and depth to hard rock. No change to capability class if another criteria is the major limitation present.
Secondary roads	No change to capability classes.	Secondary roads	*Upgrade by 1 capability class* if major limitation is due to slope, proportion of stones and boulders, drainage and depth to hard rock. No change to capability class if another criteria is the major limitation present.
Effluent disposal	No change to capability classes.	Effluent disposal	*Upgrade by 1 capability class* if major limitation is due to permeability, drainage, no. of months/year average rainfall > Ksat, and depth to hard rock. No change to capability class if another criteria is the major limitation present.
Farm dams	No change to capability classes.	Farm dams	*Upgrade by 1 capability* class if major limitation is due to depth to hard rock No change to capability class if another criteria is the major limitation present.

3. LAND MANAGEMENT GUIDELINES

3.1 Management of land characteristics that influence land use

The criteria used in land capability rating tables have been selected because of the limitations they impose on the use of the land. This section explains why these features are important and how an improved level of management can reduce or even overcome the limitation. The information has been extracted from Rowe *et al.* (1988) and Charman and Murphy (1991).

3.1.1 Soil texture

Soil texture is largely determined by the proportions of different-sized soil particles which make up the soil. Top soils with well-graded textures have a relatively even distribution of particle sizes from clay through to sand, and tend to be better able to support agricultural and pastoral activities than either very sandy or very clayey soils. They are better able to withstand cultivation and compaction and are more resistant to soil erosion.

Soil texture is closely related to available water-holding capacity. The fine sandy loam - silty clay loam soils have more available water than sands or clays, and so can maintain plant growth for longer periods after wetting. Texture is also an important determinant in soil infiltration and internal drainage, with sandier soils tending to have greater infiltration rates and better internal drainage. Clay soils are generally more suitable for grazing than for agriculture. Well-structured or self-mulching clays may be very difficult to cultivate in either the wet or dry states. On the other hand, soils with coarse or sandy texture are very unstable and easily eroded, and may need the protection of a vegetative cover over the dry season.

Some of the limitations imposed by soil texture can be reduced or overcome by special treatments such as the addition of stabilising chemicals and incorporating organic matter.

3.1.2 Boulders and rock outcrop

Boulders and rock outcrop provide physical obstacles to excavation, cultivation and plant growth, and so inhibit land uses involving these activities. It may be possible to remove isolated rock outcrops by blasting, but for extensive uses, such as cropping and grazing, boulders and rock outcrop are a permanent limitation. Additional costs may be involved with the increased management required to maintain pasture growth or reduce storm water run-off from rocky areas.

3.1.3 Depth to hard rock

The presence of shallow hard rock (<0.5m) causes problems for engineering and agricultural land use. Shallow hard rock may need frequent removal for engineering activities such as road works, building foundations and other shallow excavation work.

Shallow hard rock may be overcome with heavy machinery and blasting. Agricultural land use including cropping and farm dams are permanently restricted where shallow hard rock is present.

Very shallow soils are inherently more susceptible to erosion and require the protection of a permanent undisturbed cover of vegetation.

3.1.4 Depth of top soil

Top soil is not favoured as a construction material because of its low bearing capacity. The greater the depth of top soil, the greater the cost of removing and stockpiling it. Many excavation permits now require the top soil to be re-spread on construction sites to facilitate revegetation and this can be done successfully provided the compacted surface is broken up prior to the top soil being returned.

3.1.5 Depth to seasonal, perched or permanent watertable

The presence of a watertable close to the surface causes problems for both agricultural and engineering land uses. Saturated soils have a low bearing capacity so, for uses dependent on a stable foundation (e.g. building foundations, roads), a high watertable is undesirable.

High watertables restrict the percolation of additional water from rainfall, irrigation or the effluent from septic tanks through the soil profile, whereas a fluctuating watertable is likely to cause leaching of the more mobile plant nutrients, or the concentration of iron compounds which immobilise nutrients such as phosphorus. Poor aeration in the zone of saturation will restrict root growth. Trafficability can be adversely affected, and in the case of effluent disposal, public health aspects may be of concern. High watertables may also restrict the depth of excavation for farm dams and quarries, even shallow excavations for sand and gravel deposits.

Watertables can be lowered by pumping or constructing artificial drains, however if the water is saline, disposal options are limited.

3.1.6 Dispersible clays

Dispersion is the spontaneous deflocculation of the clay fraction of a soil in water. Slaking is the breakdown of an aggregate into smaller aggregates. Dispersion and slaking are important characteristics of a soil because of their influence on the stability of the soil structure. Soils with a high degree of slaking or dispersion have a high erosion potential and any activity that exposes the top soil or sub-soil to rainfall or running water increases the risk of erosion.

Dispersible top soils usually have poor physical characteristics, such as surface crusting, cloddiness, poor aeration and low emergence of plant seedlings. Maintenance of an effective pasture cover or litter layer reduces raindrop splash, dispersion and the associated surface sealing of top soils.

Dispersible subsoils predispose a site to tunnel or gully erosion. The risk may be minimised by careful pasture management such as ensuring that the slopes and drainage depressions are well vegetated with plant species that have deep root systems and high water requirements. Road batters may be subject to slumping and erosion, with subsequent turbidity of run-off water and sedimentation in nearby water storages. As the dispersibility of the subsoil increases, so does the need to reduce batter slopes and establish a protective vegetative cover on the exposed soil.

3.1.7 Flooding

Flooding can be a problem on land with very low gradients and within confined drainage ways. Precise data is difficult to obtain on the frequency of flood events and the classes have been determined by observations of land form, catchment geometry and soil types which reflect recent sediment deposition. A distinction should be made between fast flowing flood waters (flash floods) and flooding caused by a rise in water levels with little flow (inundation). The type and severity of impact caused by these two forms of flooding differ and therefore different types of management may be required to reduce the hazard.

Floods are a threat to human safety, causing damage to property and livestock. Thus, flood-prone land should not be used for intensive development, but should be retained for land use such as grazing, where stock can be moved to higher ground in times of increased hazard. In some areas the problem may be overcome by building levee banks or retarding basins, however there may be severe environmental problems caused by this form of management. Some modification of flooding characteristics may be possible by special management aimed at delaying surface run-off. When dealing with large catchments, the problem is a long-term hazard and a permanent limitation.

3.1.8 Organic matter

Where soil materials are to be used as road fill or for earthen dams, the presence of organic matter reduces soil quality for these purposes. Soils containing even moderate amounts of organic matter are more compressible and less stable than inorganic soils. The presence of organic material in sand for concrete is also undesirable.

When used as a medium for plant growth, a high level of organic matter is most desirable as it improves soil structure and chemical fertility. Soils high in organic matter are good for intensive cropping, however cultivation promotes rapid oxidation of organic matter and the condition of the top soil will deteriorate if the organic matter is not replaced. Organic matter levels can be increased by sowing improved pastures, ploughing in green manure crops and stubble retention.

3.1.9 Permeability

Soils of low permeability have poor drainage through the profile. On sloping land, lateral flow may occur above an impervious layer thereby draining the water away from the site, but on relatively flat areas such soils can become waterlogged and inhibit plant growth or become too boggy for the use of agricultural machinery. Low permeability in soils also reduces the efficiency of effluent disposal systems. This limitation can be overcome if sufficient area is available to increase the length of absorption trench or utilize plants to transpire water from the effluent disposal area. For earthen dams, low permeability in the floor, the sides and the walls of the dam is most desirable. An extremely permeable soil may have excessive leaching of plant nutrients or an inability to retain moisture for plant growth. Such a soil may drain too rapidly to purify the effluent from septic tanks, thereby increasing the risk of polluting groundwaters or nearby streams.

3.1.10 Plasticity index

The plasticity index is a measure of the range of moisture content over which the soil is in the plastic state. A soil is most easily worked or is most readily deformed when in the plastic state. A low index indicates that the range is narrow, which is desirable where the stability of the material is important, such as in a road subgrade. However where the soil is to be cultivated, a higher plasticity index is desirable to enable working over a wider range of moisture contents.

3.1.11 Linear shrinkage (shrink-swell potential)

This relates to the capacity of clayey soil material to change in volume with changes in moisture content, and is dependant on the quantity and nature of the clay minerals present. The shrink-swell characteristics of a soil influence the capability of land for uses such as roads or buildings which require a stable substrate. Buildings and roads shift or crack in soils which undergo large changes in volume during periodic wetting and drying. Construction on soils with a high shrink-swell potential requires special techniques such as laying deeper-than-usual foundations for roads or using a reinforced concrete slab rather than stumps or strip footings for buildings.

3.1.12 Site drainage

Site drainage is influenced by soil type, soil permeability, steepness of slope, slope shape, rainfall and position in the landscape. For most land uses it is important that water flows freely from the site, since poor site drainage can result in the land becoming waterlogged and boggy, inhibiting plant growth, damaging roads and buildings through subsidence, and reducing the capacity of the area to dispose of effluent. Special works or higher levels of management may be necessary to overcome poor site drainage and this will add to the cost of development and production.

3.1.13 Slope

As the angle and length of slope increases so too does the erosion hazard. The loss of adequate ground cover during the construction of dams, roads and buildings, or on land that is cultivated or overgrazed, increases the risk of erosion. Steeper slopes are more difficult and costly to use for agricultural, forestry or road-making activities, and impose limitations on the type of machinery which can be used.

Certain soil types become unstable in wet conditions. As the slope increases, the risk of mass movement also increases, particularly if large quantities of water are contained in the soil profile. Instability can occur on natural slopes, under trees or pasture, road batters and earthen dam banks.

Effluent from septic tanks contains high levels of nutrients and bacterial organisms. If the absorption beds are situated on sloping land, then during wet periods when the soil profile may be saturated (from excessive rainfall and/or run-off from upslope), there is an increased risk of effluent being washed into the streams and water storages further down the catchment. This may result in adverse consequences for water quality and aquatic ecosystems.

3.1.14 Soil reaction

The pH of the soil is a measure of its acidity or alkalinity. Most plants have a pH range in which optimum growth can be expected. Soil acidification occurs as nitrates that were fixed by pasture legumes are leached from the soil, and by the addition of acids in superphosphate. With the long-term use of superphosphate and Nitrogen fixing legumes, and the constant removal of grain, hay and/or animal products from the land, the top soils in many areas have become more acid ($pH< 5.5$ in H_20) and the potential for aluminium toxicity has increased. Acid soils and aluminium toxicity can result in a decline in plant vigour and growth.

3.1.15 Stones and gravel

The stone and gravel content in a soil can restrict land use and plant growth in the following ways:

i) reducing the available water content and nutrient supply in the profile;

ii) increasing the wear and tear on cultivating and excavating machinery;

iii) increasing the cost of harvesting root and tuber crops, e.g. potatoes.

Little can be done to overcome this limitation, other than the continual removal of stones from an area as they appear on the landsurface

4. DETAILED MAP UNIT DESCRIPTIONS AND CAPABILITY RATINGS

Fourteen map units have been identified within the Huntly District. For each group of map units related by geology, there is a broad review of the common land uses, soil types, forms of land degradation, and major constraints to land use. Each individual map unit is described in a two page format which includes a site description, soil profile description and land capability assessment.

Note:

(i) Because soil observation depth did not exceed 1.5m, the depth to hard rock and depth to seasonal watertable have been generalised where they exceed 1.5m.

(ii) pH recorded in the soil profile descriptions are field pH results. The pH recorded in the interpretation of laboratory analysis are $CaCl_2$ or field pH as indicated.

(iii) Minor drainage lines have not been mapped as separate map units. Soils of minor drainage lines often have similar soils of greater depth and reduced drainage capacity to those of the surrounding map unit. Minor drainage lines are often indicated as watercourses on maps 1A and 1B.

4.1 Quaternary alluvial map units

The Quaternary alluvial areas cover much of the Huntly district. The extensive alluvial plains of the Campaspe River and Bendigo Creek are the dominant map unit. Other alluvial units include the narrow active floodplain and associated terraces present along the Campaspe River, and narrow active floodplains associated with creeks flowing through Ordovician terrain.

Significant disturbance has occurred on these alluvial areas due to agricultural uses such as cropping, grazing and irrigated horticulture. Most soils present are considered to be disturbed soils with frequent mixing of topsoils and subsoils. Soils subjected to frequent cropping often develop clayey topsoils.

The soils present on the alluvial plain are complex. Red duplex soils are most common, with bleached and mottled red duplex soils being the main derivative. Grey cracking clays and yellow uniform clays are also present.

Adjacent to the Campaspe River and bordering the alluvial plain are two terraces and a narrow active floodplain. Due to restrictions of scale, the narrow active floodplain was not sampled. The river terraces are not continuous, and in many cases only one terrace may be present. Uniform clays, often overlaid with a sandy wash are common on both terraces.

The soils present on the narrow active floodplains of Gunyah, Five Mile, Sandy, Yankee, Reedy and Picanniny Creeks are variable. Higher in the catchment area, greater variation in soil type will occur. Soil types were therefore identified lower in the catchment where soils show less variation. In general, bleached and mottled yellow duplex soils are predominant, with an occasional sandy wash present. Uniform clays may become common close to the alluvial plain.

Soils present in the alluvial areas are relatively stable. Soils with light textured topsoils are susceptible to wind erosion, especially when cultivated. The narrow creek floodplains also suffer from minor streambank erosion.

Land management considerations

The major limitations for land use in the alluvial areas include flooding risk and subsoil permeability.

Rural residential development is common in units adjoining the narrow creek floodplains. However flooding is a critical factor in this unit and rural residential development has a very high risk. Effluent disposal will require special consideration due to poor soil drainage characteristics and flooding. Secondary roads may also need careful planning to minimise possible flood damage and overcome dispersible subsoils.

Agriculture is the predominant land use in the alluvial areas. Soil conditions for grazing and broadacre cropping are good, with rainfall being the main limitation for production. Care is required when cropping on the lower floodplains as flooding may cause soil loss and nutrient wash into streams.

4.2 Quaternary volcanic map units

The volcanic landscape is restricted to a narrow flow of olivine basalt north of Goornong, and some eroded outcrops in the Campaspe River near Barnadown. The basalt terrain at Goornong is slightly elevated above the alluvial plain and covers Ordovician sediments below.

Due to the small outcrop, soils show little variation. Cultivation has mixed the topsoil and subsoil leaving a red uniform clay. Minor sheet erosion occurs when topsoils are exposed through cultivation.

Land management considerations

Land use on the basalt terrain is limited by dispersible subsoils, poor drainage and permeability.

These limitations do not adversely effect current broadacre cropping practices in this unit.

If developed for rural residential use, dams, secondary roads and effluent disposal will need careful planning to overcome existing soil limitations.

Plate 1 Map Unit: Qa1
PPF: Uf
Brown Kandosol

Plate 2 Map Unit Qa2
PPF: Dy3.41
Yellow Sodosol

Plate 3 Map Unit: Qap
PPF: Dr3.13
Red Chromosol

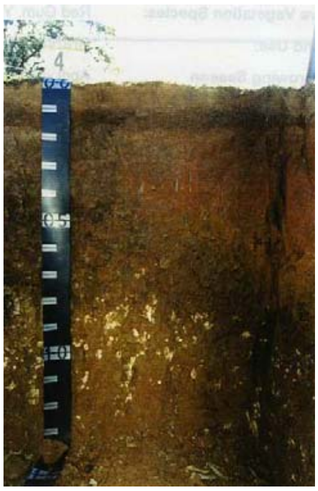
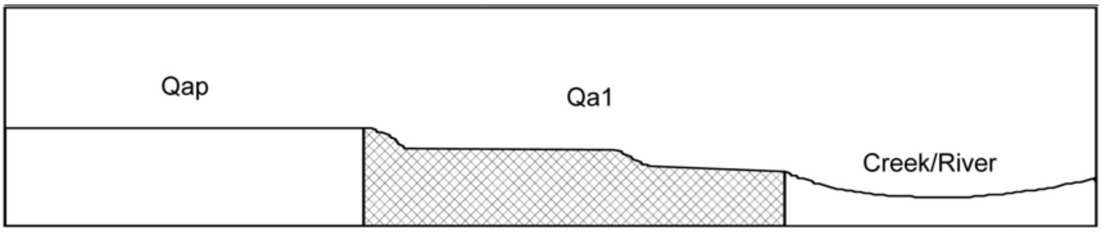


Plate 4 Map Unit: Qbe
PPF: Uf
Red Dermosol

MAP UNIT SYMBOL: Qa1

Area: 2175 ha

MAP UNIT: Quaternary alluvium, floodplain



A. GENERAL DESCRIPTION

This map unit occurs along the Campaspe River from Barnadown and continues past Elmore. The unit usually consists of two non continuous river terraces which comprise the active river floodplain. In some situations only one terrace may be present. The soils are variable depending upon the position of the terrace. A dark uniform clay is the dominant soil type, however dark duplex soils are also common. Sand and gravel lenses may be present within the profile at varying depths. The unit is commonly used for intensive horticulture and broadacre cropping, this has resulted in mixing of topsoils and subsoils. Seasonal flooding occurs in this unit.

SITE CHARACTERISTICS

Parent Material Age:	Quaternary	Depth to Seas. Watertable:	> 1.5 m
Parent Material Lithology:	Alluvium	Flooding Risk:	Very high
Landform Pattern:	Alluvial plain	Drainage:	Well drained
Landform Element:	Channel bench	Rock Outcrop:	Nil
Slope a) common:	0%	Depth to Hard Rock:	> 1.4 m
Slope b) range:	0-1%		

Potential Recharge to Groundwater: Low

Major Native Vegetation Species: Red Gum, Yellow Box

Present Land Use: Grazing, irrigation, cropping

Length of Growing Season April - September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Very low	Low	Very low	Very low	Very low	Low
Incidence	Very low	Very low	Very low	Nil	Nil	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1	0-5 cm	Dark greyish brown (10YR4/2) fine sandy loam, moderate subangular blocky structure, peds 20-50 mm, rough fabric, firm consistence, small subrounded quartz pebbles are common, pH 6.5. Clear transition to:
B1	5-10 cm	Dark greyish brown (10YR4/2) coarse sandy clay, massive structure, earthy fabric, medium subrounded and subangular quartz pebbles are abundant, pH 6.0. Clear transition to:
B21	10-25 cm	Dark greyish brown (10YR4/2) light clay, moderate subangular blocky structure, peds 20-50 mm, rough fabric, firm consistence, small subrounded quartz pebbles are common, pH 6.5. Gradual transition to:
B22	25-55 cm	Dark grey (10YR4/1) light clay, weak subangular blocky structure, peds 20-50 mm, rough fabric, firm consistence, pH 6.5. Gradual transition to:
B23	55-140+ cm	Very dark greyish brown (10YR3/2), light clay, weak subangular blocky structure, peds 20-50 mm, rough fabric, pH 7.0.

CLASSIFICATION

Factual Key:	Uf (major), Dd (minor)
Australian Soil Classification:	Haplic, Mesotrophic, Brown Kandosol, thin, moderately gravelly, loamy, clayey, very deep
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	5.3	18	VL	M	S	S	S	H	VL
B11	5.1	54	VL	L	D	S	S	L	VL
A21	4.9	35	VL	L	D	S	S	L	M
B22	5.7	14	VL	M	D	D	S	L	L
B23	5.7	27	VL	M	D	D	S	L	M

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Slow (average 45 mm/day, range 10-85 mm/day)
Available Water Capacity:	High (180 mm H_2O)
Linear Shrinkage (B horizon):	Very low (4%)

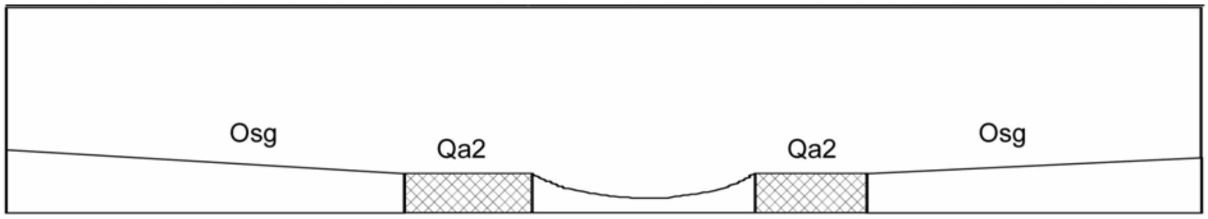
C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature(s)/Land Use
Agriculture	$C_3T_1S_2$	Climate
Effluent Disposal	5	Flooding risk
Farm Dams	3	Permeability
Building Foundations slab stumps/footings	 5 5	Flooding risk Flooding risk
Secondary Roads	5	Flooding risk
Rural Farmlet	5	Effluent disposal, secondary roads, building foundations

MAP UNIT SYMBOL: Qa2

Area: 994 ha

MAP UNIT: Quaternary alluvium, floodplain



A. GENERAL DESCRIPTION

Narrow active floodplains are present along Gunyah, Five Mile, Sandy, Yankee, Reedy and Picanniny Creeks. These creeks flow through the Ordovician sedimentary terrain. Bleached and mottled yellow duplex soils are common, with an occasional sandy wash indicating the occurrence of seasonal flooding. Uniform yellow clays may be present where these creeks enter the alluvial plain. Streambank erosion is common in this unit.

SITE CHARACTERISTICS

Parent Material Age:	Quaternary	Depth to Seas. Watertable:	> 1.5 m
Parent Material Lithology:	Alluvium	Flooding Risk:	Very high
Landform Pattern:	Floodplain	Drainage:	Moderately well drained
Landform Element:	Channel bench	Rock Outcrop:	Nil
Slope a) common:	1%	Depth to Hard Rock:	> 1.4 m
Slope b) range:	0-1%		

Potential Recharge to Groundwater: Low

Major Native Vegetation Species: Red Gum, Yellow Gum

Present Land Use: Grazing, cropping, rural residence

Length of Growing Season: April-September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Low	Low	Low	Low	Low	Low
Incidence	Low	Low	Very low	Nil	Low	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A11 0-15 cm — Dark greyish brown (10YR4/2) sandy clay loam, moderate subangular blocky structure, rough fabric, very weak consistence, few small subrounded quartz and sedimentary pebbles, pH 6.0. Clear transition to:

A12 15-25 cm — Dark greyish brown (10YR4/2) sandy clay loam, moderate subangular blocky structure, rough fabric, very weak consistence, few small subrounded quartz and sedimentary pebbles, pH 5.5. Abrupt transition to:

A2 25-45 cm — Brown (10YR5/3), bleached (10YR8/2) light clay, many fine distinct orange and pale mottles, massive structure, earthy fabric, firm consistence, few small subrounded quartz and sedimentary pebbles, pH 5.5. Gradual transition to:

B2 45-105 cm — Reddish yellow (7.5YR6/8) light medium clay, many medium prominent red, pale and brown mottles, weak subangular blocky structure, peds 20-50 mm, smooth fabric, strong consistence, pH 6.0. Cleat transition to:

2A1 105-125 cm — Reddish yellow (7.5YR6/8) light medium clay, many coarse grey, red and brown mottles, massive structure, earthy fabric, loose consistence, pH 6.0. Clear transition to:

2B2 125-140+ cm — Brown (10YR5/3), light medium clay, moderate subangular blocky structure, smooth fabric, weak consistence, pH 6.0.

CLASSIFICATION

Factual Key:	Dy3.41 (major), Dy3.42 (minor)
Australian Soil Classification:	Dystrophic, Mottled Subnatric, Yellow Sodosol, thick, gravelly, clay loamy, clayey, very deep
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A11	4.3	5	VL	VL	D	S	T	M	VL
A12	4.3	8	VL	VL	D	S	T	M	H
A2	4.5	10	VL	VL	D	D	T	VL	H
B2	4.6	3	VL	VL	D	D	T	VL	L
2A1	4.7	26	VL	VL	D	D	S	VL	H
2B2	4.5	58	VL	L	D	D	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Slow (average 40 mm/day, range 0-145 mm/day)
Available Water Capacity:	Very high (215 mm H_2O)
Linear Shrinkage (B horizon):	Linear Shrinkage (B horizon): Low (7%)

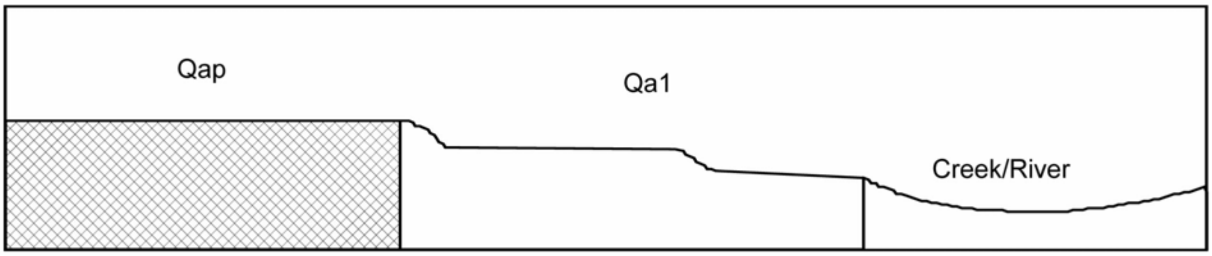
C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature(s)/Land Use
Agriculture	$C_3T_2S_2$	Climate
Effluent Disposal	5	Flooding risk
Farm Dams	3	Depth to seasonal watertable, permeability, dispersibility of subsoil
Building Foundations slab stumps/footings	 5 5	 Flooding risk Flooding risk
Secondary Roads	5	Flooding risk
Rural Farmlet	5	Effluent disposal, secondary roads, building foundations

MAP UNIT SYMBOL: Qap

Area: 38963 ha

MAP UNIT: Quaternary, alluvium plain



A. GENERAL DESCRIPTION

The alluvial plain of the Campaspe River and Bendigo Creek is the most extensive unit in the district. The alluvial plain also has a complex range of soil types present. The dominant soil type is a red duplex soil with mottled subsoils, these soils may often have bleached A_2 horizons. Slight rises on the plain may contain old river channels which have coarse sands and gravels while drainage depressions contain yellow uniform clays. In isolated areas surrounding Bagshot and Mayreef, grey cracking clays represent an older alluvial plain, these may be found overlying gentle Ordovician slopes adjacent to the current alluvial plain. The alluvial plain is an important agricultural area supporting cropping and grazing.

SITE CHARACTERISTICS

Parent Material Age:	Quaternary	Depth to Seas. Watertable:	> 1.5 m
Parent Material Lithology:	Alluvium	Flooding Risk:	High
Landform Pattern:	Alluvial plain	Drainage:	Moderately well drained
Landform Element:	Plain	Rock Outcrop:	Nil
Slope a) common:	0%	Depth to Hard Rock:	> 1.3 m
Slope b) range:	0-1%		

Potential Recharge to Groundwater: Low

Major Native Vegetation Species: Red Gum, Yellow Box

Present Land Use: Broadacre cropping, grazing

Length of Growing Season: April - September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Very low	Moderate	Low	Very low	Low	Low
Incidence	Very low	Low	Low	Nil	Low	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

1A1 0-25 cm — Reddish brown (5YR5/4) clay loam, massive structure, earthy fabric, weak consistence, pH 5.0. Abrupt transition to:

1B2 25-75 cm — Reddish brown (2.5YR4/4) light clay, moderate angular blocky structure, peds 20-50 mm, very firm consistence, pH 6.5. Abrupt transition to:

2A1 75-115 cm — Reddish brown (5YR5/4) clayey coarse sand, many very coarse faint red mottles, massive structure, sandy fabric, weak consistence, pH 7.0. Gradual transition to:

2B2 115-130+ cm — Reddish brown (5YR4/4) light clay, many very coarse faint red and orange mottles, weak structure, rough fabric, firm consistence, pH 8.5.

CLASSIFICATION

Factual Key:	Dr3.13 (major), Dr2.42, Dr2.12 (minor)
Australian Soil Classification:	Haplic, Mesotrophic, Red Chromosol, medium, non gravelly, clay loamy, clayey, very deep
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
1A1	5.1	4	VL	VL	D	S	T	VL	VL
1B2	7.0	36	VL	M	D	S	S	VL	L
2A1	7.4	15	VL	L	D	D	S	VL	H
2B2	8.0	25	VL	L	D	D	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Moderate (average 130 mm/day, range 95-180 mm/day)
Available Water Capacity:	Moderate (155 mm H_2O)
Linear Shrinkage (B horizon):	Low (10%)

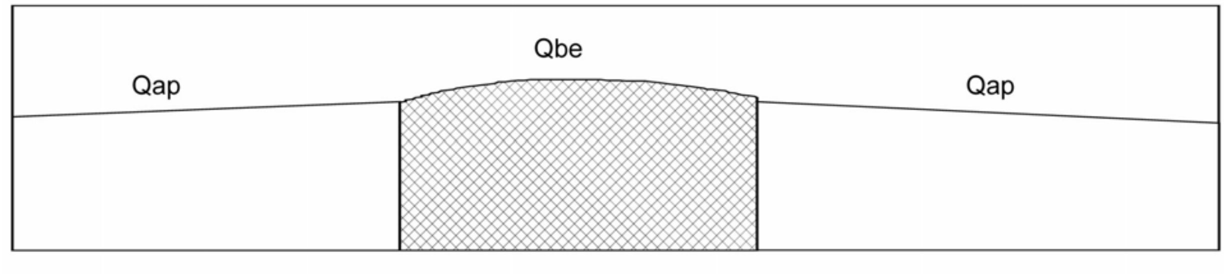
C. LAND CAPABILITY ASSESSMENT

Land Use	**Class**	**Major Limiting Feature(s)/Land Use**
Agriculture	$C_3T_2S_3$	Climate, topsoil condition, susceptibility to gully erosion
Effluent Disposal	4	Flooding risk
Farm Dams	3	Permeability
Building Foundations slab stumps/footings	 4 4	 Flooding risk Flooding risk
Secondary Roads	4	Flooding risk
Rural Farmlet	3	Effluent disposal, farm dams secondary roads, building foundations

MAP UNIT SYMBOL: Qbe

Area: 154 ha

MAP UNIT: Quaternary basalt, gentle crest



A. GENERAL DESCRIPTION

A narrow basalt flow is present north of Goornong on the Midland Highway. The unit is currently cropped and grazed leading to mixing of topsoils and minor sheet erosion. The dominant soil is a mottled red duplex soil with soft carbonate concretions at depth.

SITE CHARACTERISTICS

Parent Material Age:	Quaternary	Depth to Seas. Watertable:	> 1.5 m
Parent Material Lithology:	Basalt	Flooding Risk:	Very low
Landform Pattern:	Lava plain	Drainage:	Moderately well drained
Landform Element:	Crest	Rock Outcrop:	Nil
Slope a) common:	2%	Depth to Hard Rock:	> 1.4 m
Slope b) range:	0-3%		

Potential Recharge to Groundwater: Moderate

Major Native Vegetation Species: Cleared

Present Land Use: Broadacre cropping

Length of Growing Season: April-September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Moderate	Moderate	Very low	Low	Very low	Low
Incidence	Low	Very low	Very low	Very low	Nil	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1	0-15 cm	Dark brown (7.5YR4/2) fine sandy clay, weak subangular blocky structure, peds 20-50 mm, rough fabric, weak consistence, pH 6.0. Clear transition to:
B1	15-40 cm	Reddish brown (5YR5/3) light clay, moderate subangular blocky structure, peds 20-50 mm rough fabric, firm consistence, pH 7.0. Gradual transition to:
B21	40-70 cm	Light yellowish brown (10YR6/4) medium clay, many fine distinct orange and red mottles, moderate subangular structure, peds 20-50 mm smooth fabric, firm consistence, pH 9.5. Gradual transition to:
B31	70-130 cm	Brown (10YR5/3) medium clay, moderate subangular blocky structure, peds 20-50 mm smooth fabric, firm consistence, few small rounded basaltic pebbles, pH 9.5. Gradual transition to:
B32	130-140+ cm	Light yellowish brown (10YR6/4) medium clay, coarse distinct red and orange mottles are common, strong subangular blocky structure, peds 10-20 mm, smooth fabric, firm consistence, pH 9.5.

CLASSIFICATION

Factual Key:	Uf (major), Dr3.13 (minor)
Australian Soil Classification:	Hypocalcic, Red Dermosol, medium, non gravelly, clayey, very deep
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	4.5	7	VL	L	S	S	T	M	VL
B1	6.4	10	VL	M	D	S	S	VL	H
B21	7.3	31	VL	H	D	S	S	VL	H
B31	8.4	51	VL	VH	D	S	S	V	H
B32	8.4	46	VL	VH	D	S	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Slow (average 20 mm/day, range 0-50 mm/day)
Available Water Capacity:	High (180 mm H_2O)
Linear Shrinkage (B horizon):	Moderate (15%)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature(s)/Land Use
Agriculture	$C_3T_3S_3$	Climate, slope, depth of top soil, susceptibility to sheet erosion, susceptibility to gully erosion,
Effluent Disposal	4	Permeability
Farm Dams	3	Linear shrinkage, depth to hard rock, permeability, dispersibility of subsoil
Building Foundations slab stumps/footings	 3 3	 Drainage Drainage, linear shrinkage
Secondary Roads	4	Dispersibility of subsoil
Rural Farmlet	4	Secondary roads

4.3 Tertiary alluvial sedimentary map units

The remnants of an early Tertiary floodplain, the alluvial sediments have been extensively eroded over time. The alluvial sediments are found on gentle crests and slopes overlying Ordovician sediments from Epsom to Barnadown. The alluvial sediments contain course quartz gravels, sands, clays and conglomerate. These hilltop gravel deposits have been extensively strip mined in the district.

Soils of the alluvial sediments vary considerably due to the impact of strip mining. Areas in which strip mining has occurred will require individual assessment to determine varying site conditions.

The soils present in undisturbed areas are bleached, mottled yellow duplex soils. Soil depth is shallow on crests, but increases downslope. Occasional drainage depressions contain similar soils. Conglomerate (cemented rounded gravels) often underlie subsoils.

Soil erosion is not considered a problem, however areas denuded by strip mining will suffer from sheet erosion.

Heathlands containing an unusual abundance of indigenous wildflowers and orchids can be found in undisturbed areas. These areas have high conservation significance and should be protected.

Land management considerations

The Tertiary sediments cover only a small proportion of the district and much of this is now being developed for rural residential land use.

The shallow depth to hard rock and impermeable and dispersible subsoils are the major constraints to land use.

Siting of access tracks and effluent disposal fields will require special consideration, while dam construction will be limited by shallow, dispersible soils and small catchment areas. Alternative effluent disposal systems may be required.

Improved land management is required to protect drought prone crests from overgrazing.

4.4 Tertiary marine sedimentary map units

The Tertiary marine sediments have only recently been identified. The marine sediments have been extensively eroded by action of the ancestral Bendigo Creek. Remnant marine sediments are present on gentle crests and slopes overlying Ordovician sediments from Huntly to Bagshot.

Much of the marine sediments have been subjected to grazing and cultivation. Soils are commonly disturbed with mixing or loss of topsoil common. Surface stone is common on some crests and slopes.

A red uniform clay is common on crests and slopes, however red duplex soils are likely where topsoils are undisturbed. Minor drainage lines can contain a mixture of tertiary and Ordovician parent materials. The soils are therefore variable. Red uniform clays are common while mottled and bleached yellow duplex soils are also present.

Land management considerations

There are considerable limitations associated with the marine sediments, however, with good land management and carefully planned development, land use on the marine sediments can proceed without unnecessary land degradation. The major constraints include depth to hard rock, dispersible subsoils and impermeable subsoils.

Shallow depth to hard rock will require careful siting of effluent disposal fields and farm dams. Effluent disposal is limited by impermeable subsoils and alternative systems of disposal may be needed for rural residential subdivisions. Dispersible subsoils can result in dam failure and erosion of roadside table drains. Suitable construction techniques are needed to ensure dams and table drains are successful.

Cropping of marine sediments may require increased maintenance of equipment where surface stone is common on crests and slopes. Minor sheet erosion may also occur where soils are cultivated.

SOILS OF QUATERNARY ALLUVIAL AND VOLCANIC ORIGIN

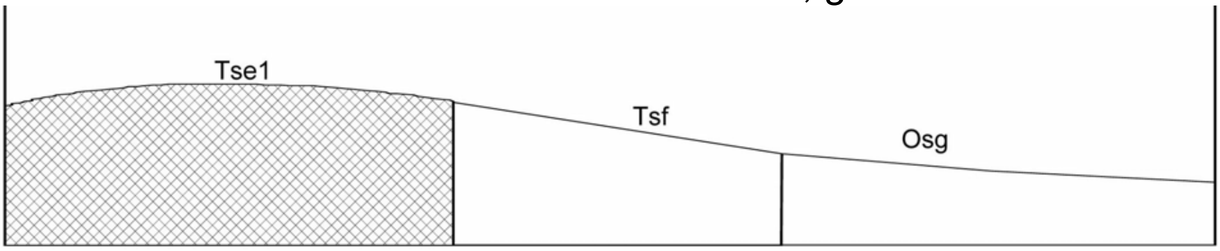
Plate 5 Map Unit: Tse1, Tsf1
PPF: Dy3341
Grey Chromosol

Plate 6 Map Unit Tse2, Tsf2, Tsg2, Tsh2
PPF: Uf
Red Dermosol

MAP UNIT SYMBOL: Tse1

Area: 25 ha

MAP UNIT: Tertiary alluvial sediments, gentle crest



A. GENERAL DESCRIPTION

Isolated tertiary sedimentary crests are found overlying Ordovician sediments in the south of the District. Mining of the alluvial gravel deposits in this unit has left few undisturbed sites, and remnant soils show little resemblance to the original soil. Undisturbed sites contain a bleached and mottled yellow duplex soil, often overlying cemented quartz gravels. Sheet erosion is common on disturbed sites. Site inspections are required when developing areas previously used for gravel extraction.

SITE CHARACTERISTICS

Parent Material Age:	Tertiary	Depth to Seas. Watertable:	> 1.5 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Nil
Landform Pattern:	Rises	Drainage:	Moderately well drained
Landform Element:	Hillcrest	Rock Outcrop:	Nil
Slope a) common:	3%	Depth to Hard Rock:	> 0.8 m
Slope b) range:	3-7%		

Potential Recharge to Groundwater: Moderate

Major Native Vegetation Species: Red Box, Grey Box

Present Land Use: Grazing, gravel extraction

Length of Growing Season: April - September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Moderate	Moderate	Low	Low	Low	Moderate
Incidence	Low	Low	Low	Low	Nil	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1	0-20 cm	Dark brown (7.5YR4/2) sandy loam, single grained sandy, very weak consistence, small, medium and large sedimentary and quartz pebbles of mixed shape are abundant, pH 6.5. Clear transition to:
A2	20-30 cm	Light yellowish brown (10YR6/4) light clay with many coarse prominent red mottles, weak subangular blocky structure, peds 5-10 mm, rough fabric, firm consistence, small, medium and large mixed sedimentary and quartz pebbles are abundant, pH 6.0. Clear transition to:
B21	30-45 cm	Brownish yellow (10YR6/6) light medium clay, many medium prominent red mottles, strong platy structure, peds 2-5 mm, smooth fabric, weak consistence, many small angular sedimentary and quartz pebbles, pH 6.0. Clear transition to:
B22	45-65 cm	Light grey (10YR7/2) light medium clay, many coarse prominent red and pale mottles, strong platy structure, peds 2-5 mm, smooth fabric, weak consistence, many medium sized angular sedimentary and quartz pebbles, pH 6.0. Clear transition to:
	65-80+ cm	Weathered sedimentary rock.

CLASSIFICATION

Factual Key:	Dy3.41 (major)
Australian Soil Classification:	Mottled, Eutrophic, Grey Chromosol, medium, non gravelly, loamy, clayey, moderate
Unified Soil Group:	ML

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	5.4	5	VL	L	D	S	T	H	L
A2	5.4	9	M	L	D	D	T	L	M
B21	5.8	11	L	L	D	S	T	L	VH
B22	8.0	10	M	M	D	S	S	VL	VH

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Slow (average 30 mm/day, range 10-70 mm/day)
Available Water Capacity:	Moderate (115 mm H_2O)
Linear Shrinkage (B horizon):	Low (10%)

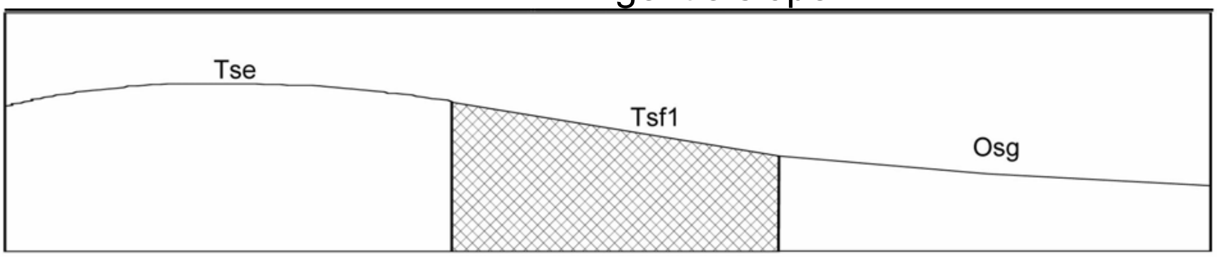
C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature(s)/Land Use
Agriculture	$C_3T_3S_4$	Depth to hard rock/pan
Effluent Disposal	4	Permeability
Farm Dams	5	Depth to hard rock, dispersibility of subsoil
Building Foundations slab stumps/footings	 3 3	 Drainage Drainage
Secondary Roads	5	Dispersibility of subsoil
Rural Farmlet	5	Farm dams, secondary roads

MAP UNIT SYMBOL: Tsf1

Area: 113 ha

MAP UNIT: Tertiary sediments, gentle slope



A. GENERAL DESCRIPTION

Isolated gentle slopes are found overlying Ordovician sediments in the south of the District. Mining of gravel deposits in this unit is less extensive than within the tertiary crests. Undisturbed sites are more common. Undisturbed sites contain a bleached and mottled yellow duplex soil, often overlying cemented quartz gravels. Sheet erosion is common on disturbed sites. Site inspections are required when developing areas previously used for gravel extraction.

SITE CHARACTERISTICS

Parent Material Age:	Tertiary	Depth to Seas. Watertable:	> 1.5 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Nil
Landform Pattern:	Rises	Drainage:	Moderately well drained
Landform Element:	Hillslope	Rock Outcrop:	Nil
Slope a) common:	5%	Depth to Hard Rock:	> 1.0 m
Slope b) range:	4-7%		

Potential Recharge to Groundwater: Low

Major Native Vegetation Species: Red Box, Grey Box

Present Land Use: Grazing, gravel extraction

Length of Growing Season: April - September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Moderate	Moderate	Low	Low	Low	Moderate
Incidence	Low	Low	Low	Low	Nil	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1 0-20 cm — Dark brown (7.5YR4/2) sandy loam, single grained sandy, very weak consistence, small, medium and large sedimentary and quartz pebbles of mixed shape are abundant, pH 6.5. Clear transition to:

A2 20-35 cm — Light yellowish brown (10YR6/4) light clay with coarse sand, many coarse prominent red mottles, weak subangular blocky structure, peds 5-10 mm, rough fabric, firm consistence, small, medium and large mixed sedimentary and quartz pebbles are abundant, pH 6.0. Clear transition to:

B21 35-50 cm — Brownish yellow (10YR6/6) light medium clay, many medium prominent red mottles, strong platy structure, peds 2-5 mm, smooth fabric, weak consistence, many small angular sedimentary and quartz pebbles, pH 6.0. Clear transition to:

B22 50-70 cm — Light grey (10YR7/2) light medium clay, many coarse prominent red and pale mottles, strong platy structure, peds 2-5 mm, smooth fabric, weak consistence, many medium sized angular sedimentary and quartz pebbles, pH 6.0. Clear transition to:

70-80+ cm — Weathered sedimentary rock.

CLASSIFICATION

Factual Key:	Dy 3.41 (major)
Australian Soil Classification:	Mottled, Eutrophic, Grey Chromosol, medium, non gravelly, loamy, clayey, moderate
Unified Soil Group:	ML

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	5.4	5	VL	L	D	S	T	H	L
A2	5.4	9	M	L	D	D	T	L	M
B21	5.8	11	L	L	D	S	T	L	VH
B22	8.0	10	M	M	D	S	S	VL	VH

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Slow (average 30 mm/day, range 10-70 mm/day)
Available Water Capacity:	(115 mm H_2O)
Linear Shrinkage (B horizon):	Low (10%)

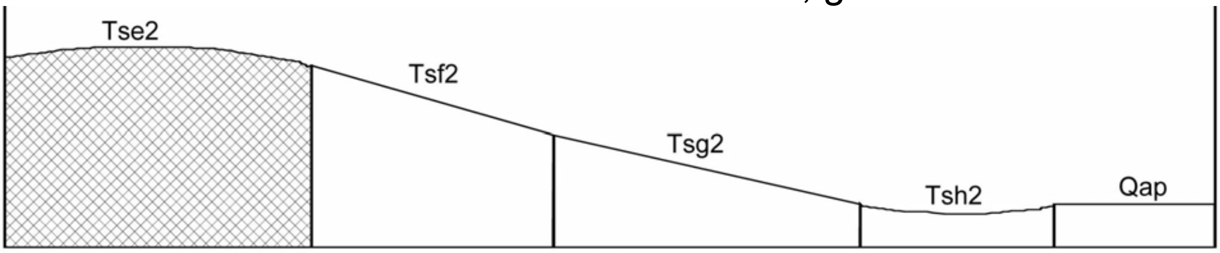
C. LAND CAPABILITY ASSESSMENT

Land Use	**Class**	**Major Limiting Feature(s)/Land Use**
Agriculture	$C_3T_3S_4$	Depth to hard rock
Effluent Disposal	4	Permeability
Farm Dams	5	Depth to hard rock, dispersibility of subsoil
Building Foundations slab stumps/footings	 3 3	 Slope, drainage Drainage
Secondary Roads	5	Dispersibility of subsoil
Rural Farmlet	5	Farm dams, secondary roads

MAP UNIT SYMBOL: Tse2

Area: 102 ha

MAP UNIT: Tertiary marine sediments, gentle crest



A. GENERAL DESCRIPTION

Tertiary marine sedimentary crests are present in the south of the district overlying Ordovician sediments. The soils are red uniform clay soils with characteristic soft carbonate nodules in the subsoil. Minor soil variations include a shallow mottled red duplex. Disturbance of these units is high due to cropping and grazing pressure. Sheet erosion is common on soils disturbed by cropping and grazing.

SITE CHARACTERISTICS

Parent Material Age:	Tertiary	Depth to Seas. Watertable:	> 1.0 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Nil
Landform Pattern:	Rises	Drainage:	Well drained
Landform Element:	Hillcrest	Rock Outcrop:	< 10%
Slope a) common:	2%	Depth to Hard Rock:	0.7 m
Slope b) range:	0-7%		
Potential Recharge to Groundwater: Moderate			
Major Native Vegetation Species: Grey Box, Yellow Gum, Red Box			
Present Land Use: Broadacre cropping, grazing, rural residential			
Length of Growing Season: April-September			

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Low	Moderate	Very low	Very low	Very low	Low
Incidence	Low	Low	Very low	Very low	Nil	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1	0-10 cm	Dark brown (7.4YR4/2) light clay, weak subangular blocky structure, peds 20-50 mm, rough fabric, firm consistence, few small and medium mixed shape quartz and sedimentary pebbles, pH 6.0. Clear transition to:
B2	10-50 cm	Reddish brown, (5YR5/4) medium clay, moderate subangular blocky structure, peds 20-50 mm, smooth fabric, very strong consistence, very few small angular sedimentary pebbles, pH 8.0. Gradual transition to:
B3	50-70 cm	Light reddish brown (7.5YR6/4) medium clay, many medium faint red and grey mottles, strong subangular blocky structure, peds 20-50 mm, smooth fabric, firm consistence, few small angular platy sedimentary pebbles, pH 10.0. Abrupt transition to:
	70-110+ cm	Weathered sedimentary rock.

CLASSIFICATION

Factual Key:	Uf (major), Dr3.13, Dy3.13 (minor)
Australian Soil Classification:	Sodic, Hypocalcic, Red Dermosol, Medium, slightly gravelly, clayey, clayey, moderate
Unified Soil Group:	CH

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	5.1	20	VL	M	S	S	S	H	VL
B2	8.5	61	VL	H	D	S	S	VL	H
B3	8.8	78	VL	VH	D	S	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Very slow (average 2 mm/day, range 0-5 mm/day)
Available Water Capacity:	Moderate (145 mmH_2O)
Linear Shrinkage (B horizon):	Moderate (15%)

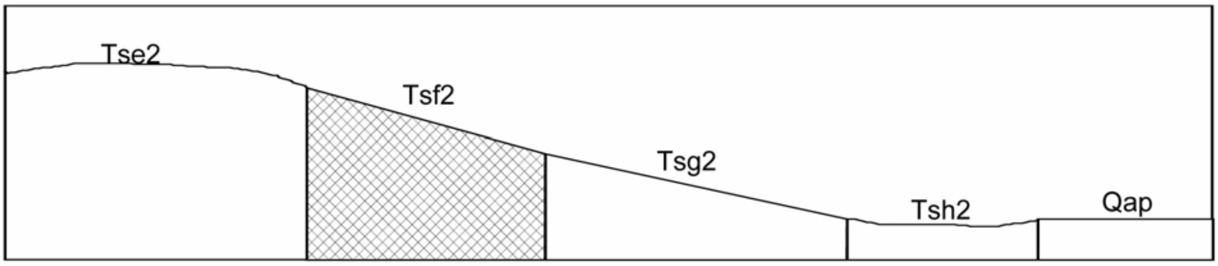
C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature(s)/Land Use
Agriculture	$C_3T_3S_3$	Depth of top soil, depth to hard rock, climate, slope, available water capacity, gravel/stone/boulder content, susceptibility to gully erosion
Effluent Disposal	5	Number of months/year the average daily rainfall >Ksat, permeability
Farm Dams	4	Depth to hard rock
Building Foundations slab stumps/footings	 3 3	Depth to seasonal watertable Linear shrinkage, depth to seasonal watertable
Secondary Roads	4	Dispersibility of subsoil
Rural Farmlet	4	Effluent disposal, farm dams, secondary roads

MAP UNIT SYMBOL: Tsf2

Area: 1610 ha

MAP UNIT: Tertiary marine sediments, gentle slope



A. GENERAL DESCRIPTION

Gentle tertiary marine slopes are frequently cropped and grazed in the south of the District. Soils are predominantly a uniform red clay with soft carbonate nodules at depth. Minor soil variations include shallow red duplex soils. Mixing of topsoils and sheet erosion are common in this unit.

SITE CHARACTERISTICS

Parent Material Age:	Tertiary	Depth to Seas. Watertable:	> 1.0 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Nil
Landform Pattern:	Rises	Drainage:	Well drained
Landform Element:	Hillslope	Rock Outcrop:	Nil
Slope a) common:	5%	Depth to Hard Rock:	0.8 m
Slope b) range:	4-8%		

Potential Recharge to Groundwater: Low

Major Native Vegetation Species: Grey Box, Yellow Gum, Red Box

Present Land Use: Broadacre cropping, grazing, rural residential

Length of Growing Season: Season April-September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Moderate	Moderate	Very low	Very low	Very low	Low
Incidence	Low	Low	Very low	Very low	Very low	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1	0-15 cm	Dark brown (7.4YR4/2) light clay, weak subangular blocky structure, peds 20-50 mm, rough fabric, firm consistence, few small and medium mixed shape quartz and sedimentary pebbles, pH 6.0. Clear transition to:
B2	15-55 cm	Reddish brown, (5YR5/4) medium clay, moderate subangular blocky structure, peds 20-50 mm, smooth fabric, very strong consistence, very few small angular sedimentary pebbles, pH 8.0. Gradual transition to:
B3	55-75 cm	Light reddish brown (7.5YR6/4) medium clay, many medium faint red and grey mottles, strong subangular blocky structure, peds 20-50 mm, smooth fabric, firm consistence, few small angular platy sedimentary pebbles, pH 10.0. Abrupt transition to:
C	75-110+ cm	Weathered sedimentary rock.

CLASSIFICATION

Factual Key:	Uf (major), Dr3.13, Dy3.13 (minor)
Australian Soil Classification:	Sodic, Hypocalcic, Red Dermosol, medium, slightly gravelly, clayey, clayey, moderate
Unified Soil Group:	CH

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	5.1	20	VL	M	S	S	S	H	VL
B2	8.5	61	VL	H	D	S	S	VL	H
B3	8.8	78	VL	VH	D	S	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Very slow (average 2 mm/day, range 0-5 mm/day)
Available Water Capacity:	Moderate (145 mm H_2O)
Linear Shrinkage (B horizon):	Moderate (15%)

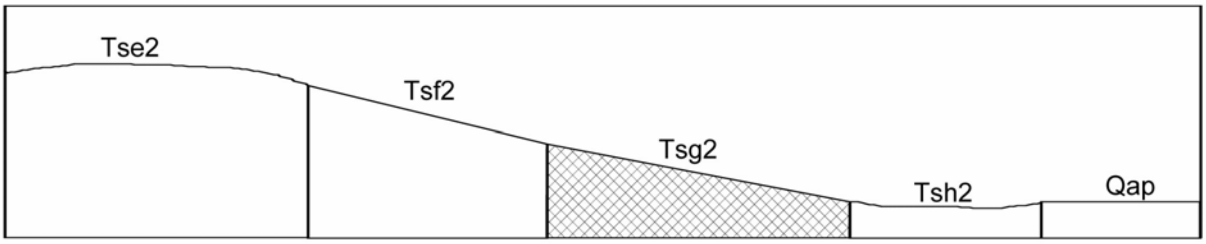
C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature(s)/Land Use
Agriculture	$C_3T_3S_3$	Climate, slope, depth of topsoil, depth to hard rock/pan, available water capacity, susceptibility to sheet and gully erosion
Effluent Disposal	5	Number of months/year when the average daily rainfall >Ksat, permeability
Farm Dams	4	Depth to hard rock
Building Foundations slab stumps/footings	 3 3	 Slope Linear shrinkage
Secondary Roads	4	Dispersibility of subsoil
Rural Farmlet	4	Effluent disposal, secondary roads

MAP UNIT SYMBOL: Tsg2

Area: 662 ha

MAP UNIT: Tertiary marine Sediments, very gentle slope



A. GENERAL DESCRIPTION

Very gentle marine sedimentary slopes are frequently cropped and grazed in the south of the District. Soils are predominantly a uniform red clay with soft carbonate nodules at depth. Minor soil variations include shallow red duplex soils. Mixing of topsoils and sheet erosion are common in this unit.

SITE CHARACTERISTICS

Parent Material Age:	Tertiary	Depth to Seas. Watertable:	> 1.0 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Nil
Landform Pattern:	Rises	Drainage:	Well drained
Landform Element:	Hillslope	Rock Outcrop:	Nil
Slope a) common:	3%	Depth to Hard Rock:	0.8 m
Slope b) range:	1-3%		

Potential Recharge to Groundwater: Low

Major Native Vegetation Species: Grey Box, Yellow Gum, Red Box

Present Land Use: Broadacre cropping, grazing, rural residential

Length of Growing Season: April-September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Low	Moderate	Very low	Very low	Low	Low
Incidence	Low	Low	Very low	Very low	Very low	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1	0-15 cm	Dark brown (7.4YR4/2) light clay, weak subangular blocky structure, peds 20-50 mm, rough fabric, firm consistence, few small and medium mixed shape quartz and sedimentary pebbles, pH 6.0. Clear transition to:
B2	15-55 cm	Reddish brown, (5YR5/4) medium clay, moderate subangular blocky structure, peds 20-50 mm, smooth fabric, very strong consistence, very few small angular sedimentary pebbles, pH 8.0. Gradual transition to:
B3	55-80 cm	Light reddish brown (7.5YR6/4) medium clay, many medium faint red and grey mottles, strong subangular blocky structure, peds 20-50 mm, smooth fabric, firm consistence, few small angular platy sedimentary pebbles, pH 10.0. Abrupt transition to:
C	80-110+ cm	Weathered sedimentary rock.

CLASSIFICATION

Factual Key:	Uf (major), Dr3.13, Dy3.13 (minor)
Australian Soil Classification:	Sodic, Hypocalcic, Red Dermosol, medium, slightly gravelly, clayey, clayey, moderate
Unified Soil Group:	CH

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	5.1	20	VL	M	S	S	S	H	VL
B2	8.5	61	VL	H	D	S	S	VL	H
B3	8.8	78	VL	VH	D	S	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Very slow (average 2 mm/day, range 0-5 mm/day)
Available Water Capacity:	Moderate (145 mmH_2O)
Linear Shrinkage (B horizon):	Moderate (15%)

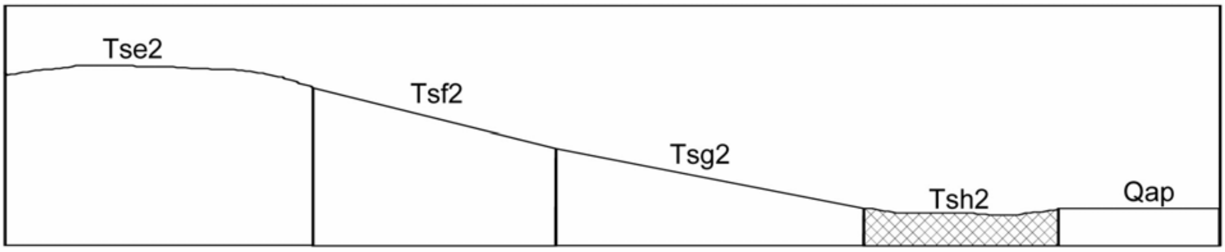
C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature(s)/Land Use
Agriculture	$C_3T_2S_3$	Climate, depth of topsoil, depth to hard rock/pan, available water capacity, susceptibility to gully erosion
Effluent Disposal	5	Number of months/year the average daily rainfall >Ksat, permeability
Farm Dams	4	Depth to hard rock
Building Foundations slab stumps/footings	 2 3	 Nil Linear shrinkage
Secondary Roads	3	Linear shrinkage, USG subsoil
Rural Farmlet	4	Effluent disposal

MAP UNIT SYMBOL: Tsh2

Area: 87 ha

MAP UNIT: Tertiary marine sediments, drainage depression



A. GENERAL DESCRIPTION

Minor drainage depressions are present in the tertiary marine sediments. Drainage depressions often contain material from the marine sediments and the underlying Ordovician sediments. Soils are highly variable with deeper red duplex soils common higher in the landscape and relatively uniform soils present lower in the landscape.

SITE CHARACTERISTICS

Parent Material Age:	Tertiary	Depth to Seas. Watertable:	>1.0 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Very low
Landform Pattern:	Rises	Drainage:	Moderately well drained
Landform Element:	Drainage depression	Rock Outcrop:	Nil
Slope a) common:	2%	Depth to Hard Rock:	1.0 m
Slope b) range:	0-5%		

Potential Recharge to Groundwater: Low

Major Native Vegetation Species: Grey Box, Yellow Gum

Present Land Use: Broadacre cropping, grazing, rural residential

Length of Growing Season: April-September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Low	Moderate	Very low	Very low	Low	Low
Incidence	Low	Low	Very low	Very low	Very low	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1 0-15 cm Dark brown (7.4YR4/2) light clay, weak subangular blocky structure, peds 20-50 mm, rough fabric, firm consistence, few small and medium mixed shape quartz and sedimentary pebbles, pH 6.0. Clear transition to:

B2 15-70 cm Reddish brown, (5YR5/4) medium clay, moderate subangular blocky structure, peds 20-50 mm, smooth fabric, very strong consistence, very few small angular sedimentary pebbles, pH 8.0. Gradual transition to:

B3 70-85 cm Light reddish brown (7.5YR6/4) medium clay, many medium faint red and grey mottles, strong subangular blocky structure, peds 20-50 mm, smooth fabric, firm consistence, few small angular platy sedimentary pebbles, pH 10.0. Abrupt transition to:

85-110+ cm Weathered sedimentary rock.

CLASSIFICATION

Factual Key:	Uf (major), Dy3.42 (minor)
Australian Soil Classification:	Sodic, Hypocalcic, Red Dermosol, medium, slightly gravelly, clayey, clayey, moderate
Unified Soil Group:	CH

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	5.1	20	VL	M	S	S	S	H	VL
B2	8.5	61	VL	H	D	S	S	VL	H
B3	8.8	78	VL	VH	D	S	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Very slow (average 2 mm/day, range 0-5 mm/day)
Available Water Capacity:	Moderate (145 mmH_2O)
Linear Shrinkage (B horizon):	Moderate (15%)

C. LAND CAPABILITY ASSESSMENT

Land Use	**Class**	**Major Limiting Feature(s)/Land Use**
Agriculture	$C_3T_2S_3$	Climate, available water capacity, susceptibility to gully erosion
Effluent Disposal	5	Number of months/year when the average daily rainfall >Ksat, permeability
Farm Dams	4	Depth to hard rock
Building Foundations slab stumps/footings	 3 3	 Drainage, flooding risk Drainage, linear shrinkage, flooding risk
Secondary Roads	3	Drainage, linear shrinkage, flooding risk, USG subsoil
Rural Farmlet	4	Effluent disposal

4.5 *Ordovician sedimentary map units*

Ordovician sediments containing mudstone, siltstone and sandstone are present in the district of Huntly. In the south east, Ordovician sediments are tightly folded and faulted. Narrow, often rocky crests and highly dissected steeps slopes are common surrounding Mt Sugarloaf. Further west, the steeper terrain gives way to the low, undulating hills, gentle crests and broad drainage depressions of the Wellsford State Forest. Low undulating hills, gentle crests and broad drainage depressions are also found to the north-west around the Whipstick State Forest.

Soils vary considerably due to marked changes in land use, topography and climate.

Much of the Ordovician landscape is currently reserved as State Forest. However significant harvesting of timber and clearing of woodland for grazing and cropping has taken place since early white settlement. Loss of vegetation cover, combined with periods of high grazing and cultivation pressure have modified the soils present. In many cases, erosion has removed much or all of the original topsoil, while cultivation has resulted in mixing of topsoils and subsoils. Many soil types present are considered to be modified soils and are likely to differ from undisturbed soils in their natural state.

In general, shallow and stony uniform clay loams are common where rocky crests and steep rocky slopes occur. Weak stony gradational soils and yellow duplex soils predominate where soil depth increases, especially when moderate slopes are encountered. Occasional red duplex and gradational soils occur in areas of good drainage. Surface stone is common on all crests and steep to moderate slopes.

Soils of the low, undulating hills show less variation and soil depth regularly exceeds 1.5m in drainage lines. Soils present on gentle crests are mostly red duplex with uniform or gradational soils present where soils are shallow or rock outcrops. Bleached, mottled red duplex soils are predominant on the gentle slopes, and broad drainage depressions have bleached and mottled yellow duplex soils. The presence of significant surface stone is restricted to isolated rocky crests and areas of rock outcrop.

The Whipstick area with a rainfall of 400 mm is significantly drier than the 550 mm of the Wellsford area. In this area, stony red gradational and duplex soils characteristically do not have bleached A2 or significantly mottled subsoils due to the changed rainfall and drainage pattern.

Various land degradation problems exist within the Ordovician landscape. Sheet erosion and gully erosion are common where vegetation cover is sparse. The presence of highly fractured rock outcrop and shallow stony soils also contributes to local and regional groundwater recharge.

Land management considerations

The low undulating hills are not well suited to a range of land uses. The major concerns include drainage, subsoil permeability and dispersibility. Shallow depth to hard rock may be a problem on gentle crests and slopes.

With rural residential development rapidly increasing in these areas, careful design of effluent disposal fields, farm dams and secondary roading is required. Alternative effluent disposal systems may need investigation for rural residential subdivisions.

Soil conditions, including topsoil depth and gravel, stone and boulder content, do not favour cropping on these units, however limited cropping does occur. Limitations on grazing are less severe and can be overcome with appropriate stocking rates and conservation of summer pasture. Moderate sheet erosion may occur where vegetative cover is lost due to cultivation and grazing.

SOILS OF QUATERNARY ALLUVIAL AND VOLCANIC ORIGIN

Plate 7 Map unit: Ose
PPF: Dr2.12
Red Sodosol

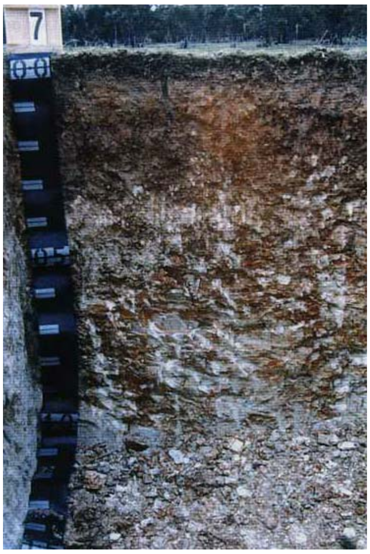


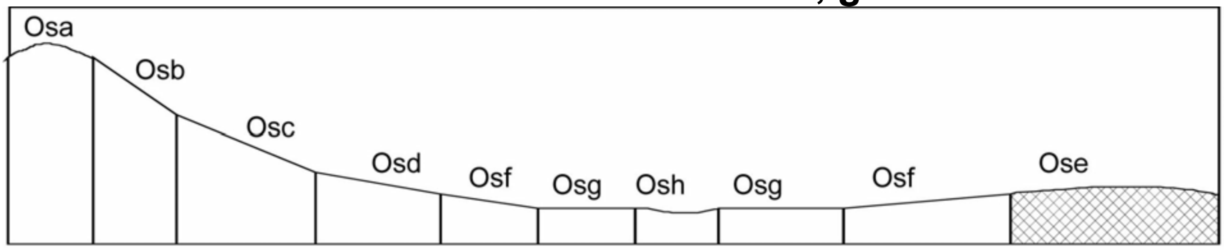
Plate 8 Map unit: Osf, Osg
PPF: Dr3.42
Red Sodosol

Plate 9 Map Unit: Osh
PPF: Dy3.41
Yellow Sodosol

MAP UNIT SYMBOL: Ose

Area: 662 ha

MAP UNIT: Ordovician sediments, gentle crest



A. GENERAL DESCRIPTION

Gentle Ordovician sedimentary crests are common in the south of the District. Much of this unit resides in the Wellsford and Whipstick State Forests. Soils are shallow in this unit with surface rock common in some areas. Stony, red mottled duplex soils are dominant and may occasionally contain a faint to distinct bleached horizon with buckshot gravels.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician	Depth to Seas. Watertable:	> 1.5 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Nil
Landform Pattern:	Rises	Drainage:	Well drained
Landform Element:	Hillcrest	Rock Outcrop:	< 20%
Slope a) common:	3%	Depth to Hard Rock:	0.6 m
Slope b) range:	2-7%		

Potential Recharge to Groundwater: Moderate

Major Native Vegetation Species: Grey Box, Yellow gum, Red Ironbark, Mallee

Present Land Use: Grazing

Length of Growing Season: April-September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Moderate	Moderate	Low	Very Low	Very low	Low
Incidence	Moderate	Low	Low	Very low	Nil	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1	0-10 cm	Dark greyish brown (10YR4/2) clay loam fine sandy, weak subangular blocky structure, peds 510 mm, rough fabric, weak consistence, many small angular quartz and sedimentary pebbles, pH 6.0. Abrupt transition to:
B2	10-30 cm	Yellowish red (5YR5/6) light clay, strong angular blocky structure, peds 2-5 mm, smooth fabric, firm consistence, small angular quartz and sedimentary pebbles are common, pH 6.0. Gradual transition to:
B3	30-55 cm	Reddish brown (5YR5/4) light medium clay, strong angular blocky structure, peds 5-10 mm, smooth fabric, firm consistence, very few subangular quartz and sedimentary pebbles, pH 8.5. Gradual transition to:
R	55-100+ cm	Sedimentary rock.

CLASSIFICATION

Factual Key:	Dr2.12 (major), Gn3.14 (minor)
Australian Soil Classification:	Mesotrophic, Subnatric, Red Sodosol, thin, moderately gravelly, clay loamy, clayey, moderate
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	5.2	45	VL	L	D	S	T	H	VL
B2	6.6	72	VL	L	D	S	S	L	H
B3	8.2	67	L	M	D	S	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Very slow (average 1 mm/day, range 0-2 mm/day)
Available Water Capacity:	Low (75 mm H_2O)
Linear Shrinkage (B horizon):	Low (7%)

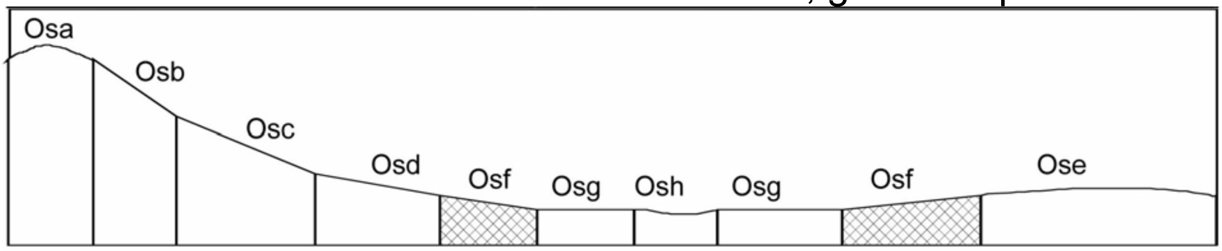
C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature(s)/Land Use
Agriculture	$C_3T_3S_4$	Depth of top soil, depth to hard rock/pan, available water capacity, gravel stone and boulder content
Effluent Disposal	5	Permeability, no of months\year average daily rainfall >Ksat
Farm Dams	5	Depth to hard rock
Building Foundations slab stumps/footings	 3 3	 Depth to seasonal watertable Depth to seasonal watertable
Secondary Roads	4	Dispersibility of subsoil
Rural Farmlet	5	Farm dams

MAP UNIT SYMBOL: Osf

Area: 11130 ha

MAP UNIT: Ordovician sediments, gentle slope



A. GENERAL DESCRIPTION

The gentle sedimentary slopes are common throughout the Wellsford and Whipstick area. The dominant soil type is a bleached and mottled red duplex soil. In the Whipstick area these soils may have whole colored subsoils. Minor variations will include bleached and mottled yellow duplex soils in minor drainage lines. Soils are generally shallow, stony and rarely exceed 70 cm.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician	Depth to Seas. Watertable:	> 1.5 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Very low
Landform Pattern:	Rises	Drainage:	Moderately well drained
Landform Element:	Hillslope	Rock Outcrop:	< 10%
Slope a) common:	5%	Depth to Hard Rock:	< 0.7 m
Slope b) range:	4-10%		

Potential Recharge to Groundwater: Moderate

Major Native Vegetation Species: Grey box, Yellow box, Red box, Mallee

Present Land Use: Grazing, rural residential, broad acre cropping

Length of Growing Season: April-September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Moderate	High	Low	Very low	Low	Low
Incidence	Moderate	Low	Low	Very low	Very low	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1	0-5 cm	Dark grey (10YR4/1) sandy clay loam, moderate subangular blocky structure, peds 2-5 mm, rough fabric, very weak consistence, many small subangular and angular quartz and sedimentary pebbles, pH 6.5. Clear transition to:
A2	5-15 cm	Pink (7.5YR4/1) bleached (7.5YR8/2) coarse sandy clay, many fine distinct orange and pale mottles, weak subangular blocky structure, peds 2-5 mm, rough fabric, firm consistence, many small subangular and angular quartz and sedimentary pebbles, pH 6.5. Clear transition to:
B2	15-25 cm	Light reddish brown (5YR6/4) medium clay, few fine distinct orange and pale mottles, strong subangular blocky structure, peds 5-10 mm, smooth fabric,, firm consistence, few medium angular and subangular quartz and sedimentary pebbles, pH 6.5. Gradual transition to:
B3	25-50 cm	Light reddish brown (5YR6/4) light medium clay, moderate subangular blocky structure, peds 10-20 mm, smooth fabric, firm consistence, pH8.5.
R	50-110+ cm	Sedimentary rock.

CLASSIFICATION

Factual Key:	Dr3.42 (major), Dr2.12, Dr 3.12 (minor)
Australian Soil Classification:	Mesotrophic, Mottled-Mesonatric, Red Sodosol, thin, moderately gravelly clay loamy, clayey, moderate
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	4.5	42	VL	L	D	S	T	H	VL
A2	4.8	31	VL	VL	D	D	S	M	VL
B2	5.9	75	VL	L	D	S	S	VL	H
B3	7.7	66	M	M	D	S	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Very low (average 1 mm/day, range 0-15 mm/day)
Available Water Capacity:	Moderate (145 mm H_2O)
Linear Shrinkage (B horizon):	Very low (6%)

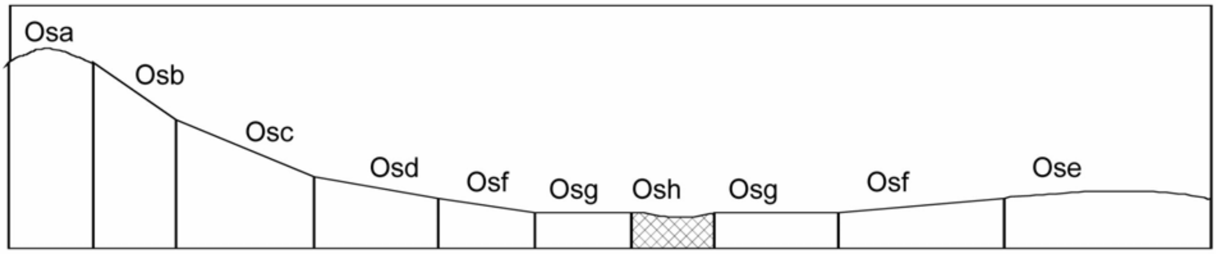
C. LAND CAPABILITY ASSESSMENT

Land Use	**Class**	**Major Limiting Feature(s)/Land Use**
Agriculture	$S_3T_3S_4$	Gravel stone and boulder content, susceptibility to gully erosion
Effluent Disposal	5	No of months/year when average daily rainfall >Ksat, permeability
Farm Dams	4	Depth to hard rock, dispersibility of subsoil
Building Foundations slab stumps/footings	 3 2	 Slope Nil
Secondary Roads	4	Dispersibility of subsoil
Rural Farmlet	4	Effluent disposal, farm dams, secondary roads

MAP UNIT SYMBOL: Osg

Area: 12051

MAP UNIT: Ordovician sediments, very gentle slope



A. GENERAL DESCRIPTION

The very gentle sedimentary slopes contain similar soils to gentle slopes. Bleached and mottled stony red duplex soils are common with occasional bleached and mottled yellow duplex soils in minor drainage lines. Soil depth may occasionally reach 100 cm.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician	Depth to Seas. Watertable:	> 1.5 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Very low
Landform Pattern:	Rises	Drainage:	Moderately well drained
Landform Element:	Hillslope	Rock Outcrop:	Nil
Slope a) common:	2%	Depth to Hard Rock:	< 1.0 m
Slope b) range:	1-3%		

Potential Recharge to Groundwater: Low

Major Native Vegetation Species: Grey Box, Yellow Box, Red Gum, Mallee

Present Land Use: Grazing, broadacre cropping, rural residential

Length of Growing Season: April-September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Moderate	Moderate	Low	Very low	Moderate	Low
Incidence	Low	Low	Low	Very low	Very low	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A1 0-5 cm Dark grey (10YR4/1) sandy clay loam, moderate subangular blocky structure, peds 2-5 mm, rough fabric, very weak consistence, many small subangular and angular quartz and sedimentary pebbles, pH 6.5. Clear transition to:

A2 5-20 cm Pink (7.5YR4/1) bleached (7.5YR8/2) coarse sandy clay, many fine distinct orange and pale mottles, weak subangular blocky structure, peds 2-5 mm, rough fabric, firm consistence, many small subangular and angular quartz and sedimentary pebbles, pH 6.5. Clear transition to:

B2 20-30 cm Light reddish brown (5YR6/4) medium clay, few fine distinct orange and pale mottles, strong subangular blocky structure, peds 5-10 mm, smooth fabric,, firm consistence, few medium angular and subangular quartz and sedimentary pebbles, pH 6.5. Gradual transition to:

B3 30-70 cm Light reddish brown (5YR6/4) light medium clay, moderate subangular blocky structure, peds 10-20 mm, smooth fabric, firm consistence, pH8.5.

R 70-130+ cm Sedimentary rock.

CLASSIFICATION

Factual Key:	Dr3.42 (major), Dy3.42, Uf (minor)
Australian Soil Classification:	Mesotrophic, Mottled-Mesonatric, Red Sodosol, thin, moderately gravelly clay loamy, clayey, moderate
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A1	4.5	42	VL	L	D	S	T	H	VL
A2	4.8	31	VL	VL	D	D	S	M	VL
B2	5.9	75	VL	L	D	S	S	VL	H
B3	7.7	66	M	M	D	S	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Very slow (average 1 mm/day, range 0-15 mm/day)
Available Water Capacity:	Moderate (150 mm H_2O)
Linear Shrinkage (B horizon):	Very low (6%)

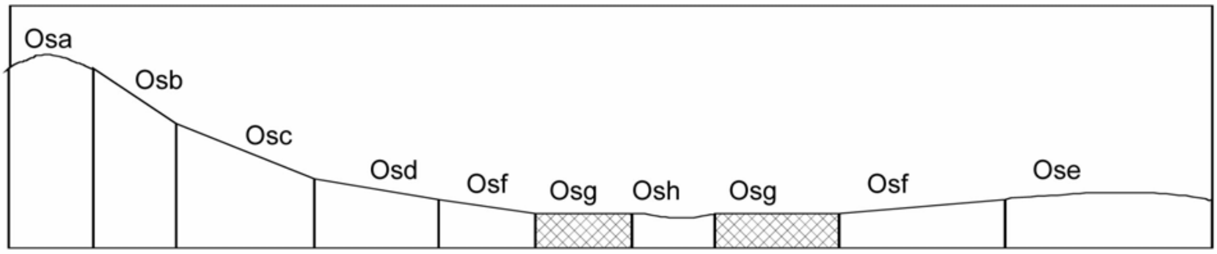
C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature(s)/Land Use
Agriculture	$C_3T_2S_3$	Climate, depth of topsoil, depth to hard rock/pan, available water capacity, gravel stone and boulder content, susceptibility to sheet and gully erosion
Effluent Disposal	5	Number of months/year average daily rainfall >Ksat, permeability
Farm Dams	4	Dispersibility of subsoil
Building Foundations slab stumps/footings	 3 3	 Drainage Drainage
Secondary Roads	3	Drainage, USG subsoil
Rural Farmlet	4	Effluent disposal, farm dams

MAP UNIT SYMBOL: Osh

Area: 1290 ha

MAP UNIT: Ordovician sediments, drainage depression



A. GENERAL DESCRIPTION

Drainage lines that run through the Ordovician sediments are generally wide and contain soil profiles reaching 200 cm in depth. In many situations minor drainage lines may not have been mapped due to restrictions of scale. Bleached and mottled yellow duplex soils are dominant while uniform yellow clays may be found adjacent to floodplain areas. Minor gully erosion is present in this unit.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician	Depth to Seas. Watertable:	1.5 m
Parent Material Lithology:	Sedimentary	Flooding Risk:	Moderate
Landform Pattern:	Rises	Drainage:	Moderately well drained
Landform Element:	Drainage depression	Rock Outcrop:	Nil
Slope a) common:	1%	Depth to Hard Rock:	> 1.5 m
Slope b) range:	0-3%		

Potential Recharge to Groundwater: Low

Major Native Vegetation Species: Red Gum, Yellow Gum, Grey Box, Yellow Box

Present Land Use: Grazing, broadacre cropping, rural residential

Length of Growing Season: April-September

LAND DEGRADATION

Degradation Processes	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	Moderate	Low	Low	Low	Moderate	Low
Incidence	Low	Low	Low	Very low	Very low	Not available

B. SOIL PROFILE

PROFILE DESCRIPTION

A11	0-15 cm	Dark greyish brown (10YR4/2) sandy clay loam, moderate subangular blocky structure, rough fabric, very weak consistence, few small subrounded quartz and sedimentary pebbles, pH 6.0. Clear transition to:
A12	15-25 cm	Dark greyish brown (10YR4/2) sandy clay loam, moderate subangular blocky structure, rough fabric, very weak consistence, few small subrounded quartz and sedimentary pebbles, pH 5.5. Abrupt transition to:
A2	25-45 cm	Brown (10YR5/3), bleached (10YR8/2) light clay, many fine distinct orange and pale mottles, massive, earthy fabric, firm consistence, few small subrounded quartz and sedimentary pebbles, pH 5.5. Gradual transition to:
B2	45-100 cm	Reddish yellow (7.5YR6/8) light medium clay, many medium prominent red, pale and brown mottles, weak subangular blocky structure, peds 20-50 mm, smooth fabric, strong consistence, pH 6.0. Cleat transition to:
2B1	100-125 cm	Reddish yellow (7.5YR6/8) light medium clay, many coarse grey, red and brown mottles, massive structure, earthy fabric, loose consistence, pH 6.0. Clear transition to:

2B2	125-140+ cm	Brown (10YR5/3), light medium clay, moderate subangular blocky structure, smooth fabric, weak consistence, pH 6.0.

CLASSIFICATION

Factual Key:	Dy3.41 (major), Dy3.42, Uf (minor)
Australian Soil Classification:	Dystrophic, Mottled Subnatric, Yellow Sodosol, thick, gravelly, clay loamy, clayey, very deep
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($CaCl_2$)	% Gravel	EC (salts)	Nutrient Status	P	K	Al	Organic Matter	Dispersibility
A11	4.3	5	VL	VL	D	S	T	M	VL
A12	4.3	8	VL	VL	D	S	T	M	H
A2	4.5	10	VL	VL	D	D	T	VL	H
B2	4.6	3	VL	VL	D	D	T	VL	L
2B1	4.7	26	VL	VL	D	D	S	VL	H
2B2	4.5	58	VL	L	D	D	S	VL	H

VL: Very Low L: Low M: Moderate H: High VH: Very High D: Deficient S: Satisfactory
T: Potentially Toxic NA: Not Available * see Appendix D for analytical results ** Strongly Acidic

SOIL PROFILE CHARACTERISTICS:

Permeability:	Slow (average 40 mm/day, range 0-150 mm/day)
Available Water Capacity:	Very high (213 mm H_2O
Linear Shrinkage (B horizon):	Low

C. LAND CAPABILITY ASSESSMENT

Land Use	**Class**	**Major Limiting Feature(s)/Land Use**
Agriculture	$C_3T_2S_3$	Climate, susceptibility to sheet erosion
Effluent Disposal	4	Permeability
Farm Dams	3	Depth to hard rock, depth to seasonal watertable, permeability, dispersibility of subsoil
Building Foundations slab stumps/footings	 3 3	 Drainage, flooding risk Drainage, flooding risk
Secondary Roads	3	Drainage, depth to seasonal watertable, flooding risk, USG subsoil
Rural Farmlet	3	Effluent disposal, farm dams, secondary roads, building foundations

5. ACKNOWLEDGEMENTS

The authors would like to thank David Rees and Nathalie Baxter for their invaluable technical advice and support in the field, and Keith Reynard, who, as well as assisting in the field, patiently entered the information into the GIS. Les Russell supervised the study, and Craig Clifton provided editorial advice.

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Gathering of soils information would not be possible without the support of the landholders in the district, who provided access to their properties. The authors would like to thank those landholders and their families for allowing detailed soils information to be collected on their properties.

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APPENDIX A. NOTES TO ACCOMPANY LAND CAPABILITY RATING TABLES

A.1 Total amount of water available to plants

Available Water Capacity (AWC) is a measure of the amount of usable water in the soil for plant growth. It is determined from the difference between the amount of water retained by the soil after drainage (field capacity) and the moisture content of a soil at wilting (permanent wilting point). There is a reasonable correlation between soil texture and AWC (Salter and Williams 1969) (Table A.1),

Table A.1 Available water capacity of soils.

Range (mm/m)	Average value for calculations (mm/m)	Sands	Sandy loams	Loams	Clay loams	Clays
76 - 100	90	KS				
101 - 125	110	LKS	KSL			
126 - 150	130	S				SC, C
151 - 175	160	CS, LS	SL	L	SCL	
176 - 200	190	FS	FSL	CL, ZL	ZCL	ZC
201 - 225	210	LFS				

Note: The total amount of water available to plants can be calculated by adding the amount of available water in each horizon down to a maximum depth of two metres.

The gravel content of the soil horizons should also be taken into account.

Soil horizon	Texture	Depth of horizon (m)	AWC of horizon (mm/m)	Available water in horizon (mm)
A	SL	0.15	160	24
B2	SC	1.25	130	143

For example, the total amount of water in the worked example above = 167 (Class 2)

A.2 Bearing capacity

Measurements were not taken of bearing capacities.

A.3 Coarse fragment sizes

Gravel: 2 - 60 mm
Cobbles: 60 - 200 mm
Stones: 200 - 600 mm
Boulders: 600 - 2000 mm

A.4 Linear shrinkage

The Linear Shrinkage and depth of solum can replace the value for reactivity of a soil. Reactivity is used in the Australian Standard AS 2870.2 (SAA 1977), and is based on the depth of the clay layer and its shrink-swell capacity. Different areas of Victoria are identified, with 0.6 m depth being a common cut-off mark between two categories.

A.5 Condition of the topsoil

The texture, organic matter content and the size/strength of soil aggregates all influence the general behaviour of soils when subjected to different agricultural land uses and management practices. The lack of knowledge relating the performance of soils to specific attributes does not allow values for the above criteria to be divided into meaningful classes - certainly not the 5class system used in these land capability rating tables. The concept of "Condition of topsoil" combines the score placed on each criteria to give a total score that is then compared to a 5class rating, (Table A.2).

For profiles with more than one A horizon, i.e. A1 and A2, top soil conditions should be determined separately for each horizon and then averaged.

Nutrient status of topsoil: The topsoil is considered the major source of nutrients for plant growth whereas the subsoil is the more reliable source of moisture. Nutrient status of topsoil = sum of exchangeable base cations (Ca, Mg, K) (Lorimer and Schoknecht 1987).

A.6 Depth to hard rock or impermeable layer

This criterion provides a measure of the effectiveness of the soil profile in filtering the nutrient and bacterial content from the effluent. The Septic Tank Code of Practice (Environment Protection Authority *et al.* 1990) requires a depth of at least one metre.

A.7 Depth to seasonal watertable

The Septic Tank Code of Practice (Environment Protection Authority *et al.* 1990) requires a minimum of one m depth of unsaturated soil for the proper functioning of effluent disposal trenches. Ideally the groundwater table should be much lower than one m, thereby reducing the risk of a rising groundwater table influencing the effectiveness of the absorption trenches. The risk of surface salting problems also increases when a saline groundwater table rises to within 1 - 1.5 m of the soil surface.

Table A.2 Rating for topsoil condition.

Criteria	Description	Score
Texture	Sands	1
	Sandy loams	2
	Loams	5
	Clay loams	4
	Clays	3
Structure (grade)	Apedal, massive	1
	Apedal, loose	2
	Weak	3
	Moderate	4
	Strong	5
Structure(size)	Very large (> 200 mm)	1
	Large (50 - 200 mm)	2
	Moderate (10 - 50 mm)	4
	Small (2 - 10 mm)	5
	Very small (< 2 mm)	3
Organic matter content (org.C x 1.72)	Very low (< 1%)	1
	Low (1 - 2%)	2
	Moderate (2 - 3%)	4
	High (> 3%)	5
Nutrient status of topsoil (sum of exch. Ca, Mg, K)	Very low (< 4 meq/100g)	1
	Low (4-8 meq/100g)	2
	Moderate (9-18 meq/100g)	3
	High (19-30 meq/100g)	4
	Very high (> 30 meq\100g)	5
Rating for topsoil condition:	**Class**	**Total score**
	1	21 – 25
	2	16 – 20
	3	11 - 15
	4	6 - 10
	5	5

A.8 Depth of topsoil

Topsoil depth is considered during dam construction and is used when measuring the susceptibility of topsoils to erosion (Table A.10). Depth of topsoil influences the quantity of overburden that needs to be scraped clear and kept for spreading back on a dam embankment to establish a grass cover, once the construction is completed.

A.9 Dispersibility

Sustainable land use requires that the soil be able to withstand the physical forces of cultivation and compaction without adverse structural change. Soil aggregate stability can be measured by the Emerson Aggregate Test (Emerson 1977). In the case of secondary roads, dispersion can significantly effect the condition of the road when slopes are greater than 4%. Because of the close correlation between dispersible soils and high exchangeable sodium percentages in those soils, it is unnecessary to include both criteria in the capability rating table.

A.10 Drainage

This parameter is the combination of several criteria that influence the moisture status of the soil profile, *viz* slope, subsurface and surface flow, water holding capacity, level of groundwater tables, perched or permanent, and permeability. Only because of its general usage, reasonable definition (McDonald *et al*. 1984) and direct relevance to effluent disposal fields, building foundations and secondary roads has this criterion been retained.

A.11 Electrical conductivity

The following correlation in Table A.3 between the electrical conductivity of soil samples taken from the 0 - 50 cm layer of the soil profile and soil salinity has been established.

Table A.3 The effects of soil salting on plant growth.

Class	Severity of salting	E.C. dS/m *	Site characteristics
1	Nil/very low	< 0.3	Plant growth unaffected
2	Low	0.30 - 0.53	Growth of salt-sensitive plants, e.g. cereals and clover is restricted
3	Moderate	0.53 - 1.26	Patchy pasture growth; salt-sensitive plants are replaced with species that are more salt-tolerant
4	High	1.26 - 2.5	Small areas of bare ground; surviving plant species have high salt tolerance
5	Very high/severe	> 2.5	Large areas of bare ground; highly salt-tolerant plants; trees may be dead or dying

* NB: 1000 μS/cm = 1 dS/m

A.12 Flooding risk

Building regulations prohibit building on flood-prone land, therefore land with some risk of flooding must be identified. Flooding is unlikely to cause a septic tank to fail, however the risk of polluting the floodwaters with phosphorus, nitrogen and bacterial organisms increases with the number of effluent disposal fields involved. The dilution factor will be dependent on the quantity of floodwater.

Dams are built to intercept and store run-off water. It is not possible in these tables to distinguish between seasonal run-off and seasonal flooding; the latter poses a threat to the stability of the dam, and the risk of flooding will depend on the intensity and duration of rainfall, the run-off characteristics of the catchment and the land use within the catchment. Flooding risk is rated in Table A.4

Table A.4 Flooding risk.

Risk	Class	Limitation	Condition of flood
Nil	1	No limitation	No flooding
Low	2	Minor	Minor inundation No debris Flood return period: annual
Moderate	3	Significant	Broad, slow moving No debris Flood return period: 1 in 20 to 1 in 50 years
High	4	Major	Broad, slow moving Little debris Flood return period: 1 in 100 years
Severe	5	Prohibitive	Deep channel, fast flowing Debris carrying Flood return period: 1 in 100 years

A.13 Length of the growing season

Agricultural production is governed by moisture, temperature and photoperiod (photoperiod is taken to be consistent throughout Victoria).

Length of Growing Season (months) = 12 - (P + T)

P = Number of months where monthly evapotranspiration > average monthly rainfall

T = Number of months where mean monthly temperature < 6^{o} C

A.14 Number of months per year when average daily rainfall > K_{sat}

This parameter is included (although it is closely aligned to drainage) to provide an indication from climatic, rather than soil and topographic data, of the period of time each year when effluent absorption trenches might cease to function.

Data required:

* Average monthly rainfall figures.
* Average number of wet days for each month.
* K_{sat} values. Assumptions made:

Assumptions made:

* Evapotranspiration <1 for winter months.
* Winter-early spring months are when problems arise.
* The soil profile is at field capacity.
* Where slope is significant, run-off = run-on.

A.15 Permeability of a soil profile (K_{sat})

Permeability is controlled by the least permeable layer of a soil profile and its ability to transmit water. Permeability is independent of climate and surface drainage. The rate at which water moves down through the soil profile is an indicator of the tendency of a soil to saturate, it is an important feature if plant growth is to be maintained in areas where rainfall is spasmodic or unreliable.

Permeability provides a measure of the rate at which a saturated soil profile will conduct water to depth. K_{sat} measurements may over-estimate the value for the disposal of effluent because the soil macropores are transmitting water, whereas the real situation must take into account the clogging effect of effluent on the bottom of effluent disposal trenches, thereby reducing the rate of water movement into the soil.

The measurement of K_{sat} often produces quite variable results even between replicates on the same site, so the setting of class limits is difficult and by necessity must be very broad. Estimates of permeability can be made using the features of the least permeable soil horizon if K_{sat} values are not available, however it should be clearly indicated where estimates have been made (Table A.5).

Table A.5 Permeability characteristics of a soil profile.

Estimated permeability	Ksat range (mm/day)	Time taken for saturated soil to drain to field capacity	Soil features
Very low	< 10	Months	Absence of visible pores
Low	10 - 100	Weeks	Some pores visible
Moderate	100 - 500	Days	Clearly visible pores
High	500 - 1500	Hours	Large, continuous clearly visible pores
Very high	1500 - 3000	Rarely saturated	Abundant large pores
Excessive	> 3000	Never saturated	No restriction to water movement through the soil profile

A.16 Index for permeability/rainfall

This relationship has been included to take into account the situation where a strongly structured soil with very high permeability would be assessed as having a major limitation. In a dry climate, this would be correct as the soil would be drought-prone most of the year, however in a high rainfall area such a soil may be highly productive.

Conversely a soil with low permeability may experience waterlogging for extended periods in a high rainfall area, but store sufficient moisture to extend the average growing season of a low rainfall area. A method of combining permeability and rainfall is shown in Table A.6.

Table A.6 Index for permeability/rainfall.

Permeability		Average annual rainfall (mm/year)				
Estimated	Ksat (mm/day)	< 400	400 - 600	600 - 800	800 - 1000	> 1000
Very low	< 10	High	High	Moderate	Low	Very low
Low	10 - 100	High	Very high	High	Moderate	Low
Moderate	100 - 500	Moderate	High	Very high	High	Moderate
High	500 - 1500	Low	Moderate	High	Very high	High
Very high	> 1500	Very low	Low	Moderate	High	Very high

A.17 Rock outcrop

This estimate has not been included as a parameter that influences the performance of earthen dams because the parameter, depth to hard rock, is inversely correlated to the proportion of rock outcropping at the soil surface, and is a good surrogate.

A.18 Slope

As the slope increases, so too does the chance of run-on water entering effluent disposal trenches and saturating the system. In addition, run-off of unfiltered effluent is more likely to enter minor drainage depressions and water courses. The increasing incidence of algal blooms in water storages emphasises the need to eliminate the entry of unfiltered effluent into watercourses.

The best ratio of earth moved to water stored in dams occurs on land with slopes between 3-7%. Gentler slopes involve greater expense as the above ratio approaches unity, whereas steeper slopes require higher embankments for proportionally less water stored.

A.19 Susceptibility to gully erosion

No single factor can adequately represent the susceptibility of an area to the gully erosion process. A number of factors are involved and each should be scored independently and then the sum of the scores can be related back to a 5 - class rating (Table A.7).

Table A.7 Susceptibility to gully erosion.

Criteria	Description	Score
Slope	< 1%	1
	1 - 3%	2
	4 - 10%	3
	11 - 32%	4
	> 32%	5
Sub-soil dispersibility	E1	5
	E2, E3(3), E3(4)	4
	E3(1), E3(2)	3
	E4, E5	2
	E6, E7, E8	1
Depth to rock/hardpan	0 - 0.5m	1
	0.6 - 1.0m	2
	1.1 - 1.5m	3
	1.6 - 2.0m	4
	> 2.0m	5
Subsoil structure	Apedal, massive Weak	1
	fine < 2 mm	3
	mod. 2 - 10 mm	2
	coarse > 10 mm Moderate	1
	fine < 2 mm	4
	mod. 2 - 10 mm	3
	coarse > 10 mm Strong	2
	fine < 2 mm	5
	mod. 2 - 10 mm	3
	coarse > 10 mm	1
	Apedal, single grained	5
Lithology of substrate	Basalt	1
	Volcanic	2
	Rhyodacite	2
	Granite	4
	Alluvium	3
	Colluvium	5
	Tillite	4
	Ordovician sandstone/mudstone	5
	Silurian sandstone/mudstone	4
Rating for susceptibility to gully erosion:	Class	Total score
	1. Very low	6 – 10
	2. Low	11 – 13
	3. Moderate	14 – 17
	4. High	18 – 20
	5. Very high	21 – 25

A.20 Susceptibility to slope failure

The instability of slopes in a catchment area of a dam poses a threat to the storage capacity of that dam. Additional costs are also involved if the dam requires regular desludging. This assessment considers that land slips are the result of factors such as soil depth, slope, soil texture, volume of water held in the soil, permeability of the solum and the underlying parent material.

Since the quantity of water in a profile is itself a function of soil texture, depth and permeability, the table below is presented as a first attempt to assess the susceptibility of land to slope failure by relating the total amount of water in the soil profile to the slope (Table A.8).

Table A.8 Susceptibility to slope failure.

Slope %	Total amount of water in the soil profile		
	Low (< 70 mm H_20)	Moderate (70-170 mm H_20)	High (> 170 mm H_20)
Gentle < 10	Very low	Very low	Low
Moderate 10-32	Low	Moderate	High
Steep > 33	Moderate	High	Very high

A.21 Suitability of subsoil for earthen dams

In the building of earthen dams, suitability of subsoil is dependent on the nature of the material, which is represented by the Unified Soil Group classification, and depth of the material. Refer to Table A.9

Table A.9 Suitability of subsoil for earthen dams.

DEPTH OF SUBSOIL (m)	Unified soil group of subsoil				
	SP, SW, GP, GW, Pt, OH, OL	ML, MH	GM, CH, SM	CL	GC, SC
< 0.5	Very low	Very low	Very low	Very low	Very low
1.0 - 0.5	Very low	Low	Moderate	Moderate	Moderate
1.5 - 1.0	Very low	Moderate	High	High	High
> 1.5	Very low	Moderate	High	High	Very high

A.22 Susceptibility of soil to sheet and rill erosion by water

The table following (Table A.10) has been adapted from Elliott and Leys (1991). The erodibility index for a range of soil properties closely relates to the susceptibility of soils to erosion by water, and in the tables below, the same soil properties have been used (texture, structure grade, topsoil depth and dispersibility (Emerson aggregate test)) and then related to slope to determine a rating for susceptibility.

The final rating for susceptibility to sheet/rill erosion is read from Table A.11 once the erodibility of the topsoil and the slope of the area have been assessed.

Table A.10 Erodibility of topsoils

Texture group (A1)	Structure grade (A1)	Horizon depth (A1 + A2)	Dispersibility		
			VL - L **E3(1), E3(2), E4, E5, E6, E7, E8**	**M - H** **E3(3) ,E3(4) , E2**	**VH E1**
Sand	apedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	M L L		
Sandy loam	Apedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	M L L	H M	
	Weakly pedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	H M M	E V	
Loam	Apedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	M L L	H M	
	weakly pedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	H M M	E V	
	peds evident	< 0.2 m 0.2 - 0.4 m > 0.4 m	H H H	E	
Clay loam	Apedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	M L L	H M	
	weakly pedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	H M M	E V	
	peds evident	< 0.2 m 0.2 - 0.4 m > 0.4 m	H H M	E E	
Light clay	Weakly pedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	H M M	E V V	E E E
	peds evident	< 0.2 m 0.2 - 0.4 m > 0.4 m	M M M	V H H	E E E
	highly pedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	H M M	E V V	
Medium to heavy clay	Weakly pedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	M M M	H H H	E V V
	peds evident	< 0.2 m 0.2 - 0.4 m > 0.4 m	H M M	E V V	E E E
	highly pedal	< 0.2 m 0.2 - 0.4 m > 0.4 m	H M M V	E V E	E E

L - Low M - Moderate H - High V - Very high E - Extreme

Table A.11 Susceptibility of soil to sheet and rill erosion.*

Slope %	Topsoil erodibility (from Table A.10)				
	Low	Moderate	High	Very high	Extreme
< 1 %	Very low	Very low	Low	Low	Moderate
1 - 3 %	Very low	Low	Moderate	Moderate	High
4 - 10%	Low	Moderate	Moderate	High	Very high
11 - 32%	Moderate	Moderate	High	Very high	Very high
> 32%	Moderate	High	Very high	Very high	Very high

*Note: Topsoil erodibility is determined from the texture, structure, depth and dispersibility of the topsoil (Table A.10). The susceptibility of the topsoil to sheet and rill erosion relates to the combined effect of slope and topsoil erodibility (Table A.11).

A.23 Susceptibility of soil to erosion by wind

The susceptibility of land to wind erosion is a function of soil erodibility, the probability of erosive winds when the soil is dry and the exposure of the land component to wind (Lorimer 1985). Soil erodibility is a very important factor to consider in land capability rating tables (Table A.12).

Table A.12 Soil erodibility

	Soil type	Rating
1.	Surface soil has a strong blocky structure (aggregates > 0.8 mm), or is apedal and cohesive or has a dense layer of stones, rock or gravel	Very low
	Surface soil has strong fine structure (aggregates < 0.8 mm)	Moderate
	Surface soil has a weak-moderate structure or is apedal and loose	Go to 2
2.	Surface soils with organic matter > 20%	High
	Surface soils with organic matter 7 - 20%	Moderate
	Surface soils with organic matter < 7%	Go to 3
3.	Surface soils with the following textures:	
	Fine-medium sands	Very high
	Loamy sands	High
	Sandy loams, silty loams	High
	Loams, coarse sands	Moderate
	Clay loams	Low
	Clays	Very low

A.24 Susceptibility to acidification

Soil acidification is usually observed over time as a decrease in soil pH. It may take place in the topsoil or subsoil. Soil acidification will cause contrasting effects depending upon the initial pH of the soil. In general, soil pH below 4.5 ($CaCl_2$) will cause toxic aluminium and manganese to be released. This causes retarded root growth in plants and may increase leaching of soluble salts and nutrients into groundwater, rivers and streams. Measurement of susceptibility to acidification for this report is based upon the following table (Table A.13) and analysis of topsoils from each map unit.

Table A.13 Susceptibility of soil to acidification

Susceptibility	Texture	pH ($CaCl_2$)	Annual rainfall
Low	Medium Heavy	< 4.5 All	> 450mm > 450 mm
Moderate	Medium Light	> 4.5 < 4.5	> 450 mm > 450 mm
High	Light	> 4.5	> 450 mm

Note: Land management, such as pasture species and stocking rates can contribute to acidification. Organic matter is not used as an indicator for susceptibility as its effects are complex.

APPENDIX B. WORKING TABLES FOR LAND CAPABILITY CLASSES

B.1 Agriculture

MAP UNITS	Qa1	Qa2	Qap	Qbe	Tse1	Tsf1	Tse2	Tsf2	Tsg2	Tsh2	Ose	Osf	Osg	Osh
climate	3	3	3	3	3	3	3	3	3	3	3	3	3	3
topography	1	2	2	3	3	3	3	3	2	2	3	3	2	2
topsoil conditions A1,A2	2	2:5	3	2	2:4	2;4	2	2	2	2	2	2:2	2:2	2:5
depth of topsoil	2	1	2	3	2	2	3	3	3	2	4	3	3	1
depth to hard rock/pan	1	1	1	1	4	4	3	3	3	2	4	3	3	2
depth to seasonal watertable	1	2	1	1	1	1	1	1	1	2	1	1	1	2
available water capacity	2	1	2	2	3	3	3	3	3	3	4	3	3	1
permeability-rainfall index	1	2	1	1	1	1	1	1	1	1	1	1	1	2
dispersibility of topsoil	1	1	1	1	2	2	1	1	1	1	1	1	1	1
gravel/stone/boulder content	2	2	1	1	2	2	3	2	2	2	4	4	3	1
electrical conductivity	1	1	1	1	2	2	1	1	1	1	1	1	1	1
susceptibility to sheet erosion	1	2	1	3	3	3	2	3	2	2	3	3	3	3
susceptibility to gully erosion	2	2	3	3	3	3	3	3	3	3	3	4	3	2
susceptibility to wind erosion	1	2	2	1	2	2	1	1	1	1	2	2	2	2

B.2 Effluent disposal

MAP UNITS	Qa1	Qa2	Qap	Qbe	Tse1	Tsf1	Tse2	Tsf2	Tsg2	Tsh2	Ose	Osf	Osg	Osh
Slope	1	1	1	2	2	2	2	2	1	2	2	2	1	1
Flooding risk	5	5	4	1	1	1	1	1	1	3	1	1	1	3
Drainage	2	3	3	3	3	3	2	2	2	3	2	2	3	3
Depth to seasonal watertable	1	1	1	1	2	2	1	1	1	1	1	1	1	1
Depth to hard rock/impermeable layer	1	1	1	2	3	3	3	2	2	2	4	4	4	2
No. of month/year av rainfall >Ksat	1	1	1	1	1	1	5	5	5	5	5	5	5	1
Permeability	4	4	2	4	4	4	5	5	5	5	5	5	5	4

B.3 Farm dams

MAP UNITS	Qa1	Qa2	Qap	Qbe	Tse1	Tsf1	Tse2	Tsf2	Tsg2	Tsh2	Ose	Osf	Osg	Osh
Slope	2	2	2	1	1	1	2	1	2	2	2	1	2	2
Linear shrinkage	1	2	2	3	2	2	3	3	3	3	2	2	2	2
Suitability of subsoil	2	2	2	2	4	4	3	2	2	2	4	3	3	2
Depth to seasonal watertable	1	3	1	1	1	1	1	1	1	1	1	1	1	3
Depth to hard rock	1	1	1	3	5	5	4	4	4	4	5	4	3	3
Permeability	3	3	3	3	3	3	2	2	2	2	2	2	2	3
Dispersibility of subsoil	2	3	2	3	5	5	3	3	3	3	3	4	4	3
Susceptibility to slope failure	1	2	1	2	1	1	1	1	1	1	1	1	1	2

B.4 Secondary roads

MAP UNITS	Qa1	Qa2	Qap	Qbe	Tse1	Tsf1	Tse2	Tsf2	Tsg2	Tsh2	Ose	Osf	Osg	Osh
Slope	1	1	1	2	2	3	2	3	2	2	2	2	2	2
Drainage	2	3	3	3	3	3	2	2	2	3	2	2	3	3
Depth to seasonal watertable	1	3	1	1	1	1	1	1	1	2	1	1	1	3
Proportion of stone and boulder	1	1	1	1	1	1	3	1	1	1	3	2	2	1
Depth to hard rock	1	1	1	1	2	2	2	2	2	2	3	2	2	2
Susceptibility to slope failure	1	2	1	2	1	1	1	1	1	1	1	1	1	2
Linear shrinkage	1	2	2	3	2	2	3	3	3	3	2	1	1	2
Flooding risk	5	5	4	1	1	1	1	1	1	3	1	1	1	3
Dispersibility of subsoil (>4% slope)	-	-	-	4	5	5	4	4	-	-	4	4	-	-
USG subsoil	3	3	3	3	4	4	3	3	3	3	3	3	3	3

B.5 Building foundations, i) slab ii) stumps

MAP UNITS	Qa1	Qa2	Qap	Qbe	Tse1	Tsf1	Tse2	Tsf2	Tsg2	Tsh2	Ose	Osf	Osg	Osh
Slope i); ii)	1:1	1:1	1:1	2:1	2:1	3:2	2:1	3:2	2:1	2:1	2:1	3:2	2:1	2:1
Drainage	2	3	3	3	3	3	2	2	2	3	2	2	3	3
Proportion of stones and boulders	1	1	1	1	1	1	3	2	2	1	3	2	2	1
Depth to seasonal watertable	1	2	1	1	1	1	1	1	1	1	1	1	1	2
Depth to hard rock	1	1	1	1	2	2	2	2	2	2	2	2	2	2
Susceptibility of slope failure	1	2	1	2	1	1	1	1	1	1	1	1	1	2
Linear shrinkage i); ii)	1:1	1:2	1:2	2:3	1:2	1:2	2:3	2:3	2:3	2:3	1:2	1:1	1:1	1:2
Flooding risk	5	5	4	1	1	1	1	1	1	3	1	1	1	3

B.6 Rural farmlet development

MAP UNITS	Qa1	Qa2	Qap	Qbe	Tse1	Tsf1	Tse2	Tsf2	Tsg2	Tsh2	Ose	Osf	Osg	Osh
Effluent disposal	5	5	3	3	3	3	4	4	4	4	4	4	3	3
Farm dams	3	3	3	3	5	5	4	3	3	3	5	4	4	3
Secondary roads	5	5	3	4	5	5	4	4	3	3	4	4	3	3
Building foundations i); ii)	5	5	3	2	2	2	2	2	2	3	2	2	2	3

APPENDIX C. SPECIFIC METHODOLOGY

C.1 Map unit determination

Map units were delineated according to geology and slope category (McDonald *et al.* 1984) using geological mapping, topographical mapping, aerial photography and field survey techniques.

C.2 Field observations

Most field descriptions are based on McDonald *et al.* (1984), Northcote (1979) and Isbell (1994). The definition for soil horizon boundaries is listed below.

S	Sharp	< 5 mm
A	Abrupt	5 - 20 mm
C	Clear	20 - 50 mm
G	Gradual	50 - 100 mm
D	Diffuse	> 100 mm
+ Continuing		

C.3 Field tests

C.3.1 Saturated hydraulic conductivity

Site selection:

Considerable time and effort is required to obtain meaningful permeability (K_{sat}) values. It is imperative that sites are chosen carefully prior to the day of measurement. The sites should have nil, or at most, minimal disturbance.

Procedure:

i) Insert five small (35 cm diameter) and five large (40 cm diameter) infiltration rings with the small rings placed inside the large rings, so that each ring is approximately 100 mm into the main clay horizon. Remove some topsoil if necessary but care should be taken to cause minimal soil disturbance.

ii) Rings need to be at least two metres apart and located at random. Relocate rings if obstacles such as stones or roots prevent an even downward movement of the ring into the soil.

iii) Fill rings with water and set up reservoir tanks so that water is added when the level drops below the outlet tube. Record the time and date on field sheets.

iv) Place lids on rings to minimise evaporation and interference.

v) Check that all containers are full and will last overnight to allow soil to saturate and conductivity rate to equilibrate.

vi) Record water levels at various times during the day (depending upon infiltration rate), and leave for 24 hour period without any interruptions to the water flow, if possible.

vii) Next day dig out each ring taking care not to disturb the soil contained within the ring. Up-end the ring and record the proportion of soil area that has been transmitting water for each ring and record if water movement has been evenly distributed or confined to root/worm holes or structural cracks. Note any other differences, i.e. rocks, sand, clay patches.

C.4 Laboratory analysis

Samples collected for each soil horizon were air dried, ground with a mortar and pestle and separated with 4.75 and 2 mm sieves into a gravel fraction (4.75 - 2 mm), and soil. The gravel fraction was reported as a percentage of the air dried field sample and discarded, while all subsequent tests were carried out on the soil samples and reported in terms of oven dried (105 ^{o}C) samples (except for EC, pH and Cl).

C.4.1 Physical properties

1. Particle size analysis

The method used for particle size analysis is based upon that of Hutton (1956), which divides the soil sample into the following four principal size groups:

Coarse sand	2.0 - 0.20 mm
Fine sand	0.20 - 0.02 mm
Silt	0.02 - 0.002 mm
Clay	< 0.002 mm

In this method the soil sample is mechanically dispersed using pentasodium triphosphate (sodium tripolyphosphate), shaken in a sedimentation cylinder, and silt and clay percentages determined on a 2% soil water mixture using a plummet balance. After hand decanting the silt and clay suspension, the sand fractions are determined by sieving and weighing the oven dried (105 ^{o}C) sand fractions.

Due to the presence of both organic material and solutes in the soil and also due to the limitations of the technique used, the sum of the four fractions does not always equal 100%. Limits of 4% variation for surface horizons and 2% variation for lower horizons are regarded as acceptable. The determination is repeated for samples outside these limits. If repeat samples still remain outside these limits, then the closest result is accepted.

2. Emerson class

Soil dispersion is tested using the method of Emerson, (1967), and based upon the Australian Standard AS1289, C8.1, (1980). This gives eight dispersion classes from E1 to E8, where E1 is the most dispersive class and E8 the least dispersive class. Class E5 was further divided into four sub-classes E5(A), E5(B), E5(C) and E5(D), where E5(A) is more dispersive than E5(D). Also, classes E2 and E3 were each divided into four sub-classes according to the modification of Loveday and Pyle (1973), as quoted in Craze and Hamilton (1991). In this classification E2(1) is less dispersive than E2(4) and E3(1) is less dispersive than E3(4).

The order of soil dispersion from most dispersive to least dispersive is therefore:

E1
E2(4), E2(3), E2(2), E2(1)
E3(4), E3(3), E3(2), E3(1)
E4
E5(A), E5(B), E5(C), E5(D)
E6
E7
E8

3. Atterberg limits

Atterberg investigated the behaviour of fine grained soil with varying water content. He used the following definitions, quoted in Hicks (1991):

(a) The liquid limit is the water content at which a trapezoidal groove of specified shape, cut in moist soil held in a special cup, is closed after 25 taps on a hard rubber plate.

(b) The plastic limit is the water content at which the soil begins to break apart and crumble when rolled by hand into threads three mm in diameter.

(c) The shrinkage limit is the water content at which the soil reaches its theoretical minimum volume, as it dries out from a saturated condition.

The plasticity index is the difference between the liquid and plastic limits, and represents the range of water contents that the soil remains in the plastic state.

Atterberg limits are determined on a sieved soil fraction with particles < 0.425 mm in size. The methods are based upon the Australian Standard 1289 (1977), as follows:

Liquid limit	AS1289. C1.1
Plastic limit	AS1289. C2.1
Plasticity index	AS1289. C3.1
Linear shrinkage	AS1289. C4.1

Soil chemical analyses were carried out by the State Chemistry Laboratory, South Road, Werribee, Vic., 3030.

C.4.2 Chemical properties

1. EC, pH, and Cl determinations

These determinations are carried out on a 1:5 soil water suspension shaken for one hour, and allowed to equilibrate.

(a) Electrical conductivity
This test is used to estimate the concentration of soluble salts in the soil. Measurements are made on the soil water suspension using a dip cell and direct reading meter. Values are determined at 25 ^{0}C.
State Chemistry Laboratory, Method 004, July 1986.

(b) pH in H_2O at 20 ^{0}C
The pH of the above suspension is determined using a calomel electrode and digital pH meter.
State Chemistry Laboratory, Method 009 (1986).

(c) pH in $CaCl_2$
This is carried out on the soil water suspension after the pH in H_2O determination. One mL of 1M calcium chloride solution is added to the soil water suspension, and the mixture stirred. The pH is then measured again.
State Chemistry Laboratory, Method 009 (1986).

(d) Chloride
A fresh 1:5 soil water suspension is titrated with a silver nitrate solution, using an electrical circuit to determine the end point of the titration. Note that this determination may be omitted if the EC determination is < 0.1 dS/m.
State Chemistry Laboratory, Method 003 (1982).

2. Oxidizable organic carbon

In this determination the soil sample is oxidised by chromic acid in the presence of excess sulphuric acid, without the application of external heat (Walkley and Black, 1934). The colour produced is measured with a spectrophotometer.
State Chemistry Laboratory, Method 014 (1987).

3. Total nitrogen

Total nitrogen is determined by a Kjeldahl method, where the sample is digested with a sulphuric acid/selenious acid mixture. The resulting solution is analysed for nitrogen colorimetrically.
State Chemistry Laboratory, Method 021 (1985).

4. Available potassium

The Skene method is used where soil potassium is extracted with 0.05M hydrochloric acid, and the potassium determined with an atomic absorption spectrophotometer (Skene 1956).
State Chemistry Laboratory, Method 011 (1987).

5. Available phosphorus

Phosphorus is determined by the Olsen method in which the soil phosphorus is extracted with a 0.5M sodium bicarbonate solution at pH 8.5, (Olsen *et al.* 1954). The phosphorus is then measured colourimetrically after reduction with ascorbic acid.
State Chemistry Laboratory, Method 010 (1982).

6. Exchangeable aluminium and manganese

The soil sample is extracted with a 1M potassium chloride solution, and both determinations are made on the one extract. Aluminium is determined colourimetrically using pyrocatechol violet. Manganese is determined by atomic absorption spectrophotometry.
State Chemistry Laboratory, Method 001 (1985).

7. Extractable bases, calcium, magnesium, potassium and sodium

The bases are extracted from the soil with a 1M ammonium acetate solution at pH 7, and the bases are then analysed by atomic absorption spectroscopy.

State Chemistry Laboratory (1993) - draft procedure.

1. Total exchangeable bases
2. This is a calculated value consisting of the sum of the exchangeable bases calcium, magnesium, potassium and sodium, as determined in method 7 (above).
3. Exchangeable hydrogen

The exchangeable hydrogen is extracted from the soil using 0.053N triethanolamine and back titrated with 0.2M hydrochloric acid. This is a method modified by Peech *et al.* (1962).
State Chemistry Laboratory, Method 005 (1984).

10. Cation exchange capacity

This is a calculated value consisting of the sum of the exchangeable bases calcium, magnesium, potassium and sodium plus exchangeable hydrogen, as determined in methods 7 and 9 (above)

APPENDIX D. PHYSICAL LABORATORY RESULTS

Map Unit	Site Number	Laboratory Number	Horizon	1:5 Soil Water Suspension			ph Buffer Capacity Index	Cl as NaCl %	Total Soluble Salts	Oxidizable Org. Carbon %	Total Nitrogen %	Skene K ug/g	Olsen P ug/g	Exchangeable Al+++ ug/g	Exchangeable Mn++ ug/g	Extractable Bases				Total of Extractable Bases	Calcium:Magnesium Ratio	Exchangeable H+ meq/100g	Cation Exchange Capacity
				pH H_2O	pH $CaCl_2$	EC dS/m										Ca ++ meq/100g	Mg++ meq/100g	K+ meq/100g	Na+ meq/100g				
Qa1	H 1	940976	A1	6.2	5.3	0.1	5	<0.05	0.03	3.30	0.25	480	15.1	<5	6	5.7	2.9	1.2	0.2	10.0	2.0	6.7	16.7
Qa1	H 1	940977	B1	6.2	5.1	0.05	3	<0.05	0.02	1.83	0.11	256	4.9	<5	<5	3.4	1.9	0.6	0.1	6.0	1.8	4.8	10.8
Qa1	H 1	940978	B21	6.1	4.9	<0.05	3	<0.05	0.02	1.12	0.07	143	2.1	<5	<5	3.7	2.7	0.4	0.1	6.9	1.4	5.1	12.0
Qa1	H 1	940979	B22	6.9	5.7	<0.05	2	<0.05	0.02	1.64	0.08	70	1.7	<5	6	5.0	3.8	0.2	0.4	9.4	1.3	3.7	13.1
Qa1	H 1	940980	B23	7.1	5.7	<0.05	2	<0.05	0.02	1.54	0.07	77	3.4	<5	6	5.4	3.9	0.2	0.4	9.9	1.4	3.6	13.5
Qa2	H 3	940985	A11	5.6	4.3	<0.05	3	<0.05	0.02	2.01	0.10	139	1.9	22	7	0.9	0.4	0.4	0.1	1.8	2.2	4.8	6.6
Qa2	H 3	940986	A12	5.5	4.3	<0.05	3	<0.05	0.02	2.02	0.06	109	1.4	31	9	1.0	0.6	0.3	0.1	2.0	1.7	4.4	6.4
Qa2	H 3	940987	A2	5.7	4.5	<0.05	1	<0.05	0.02	0.58	<0.05	69	<1	20	<5	0.8	0.9	0.2	0.1	2.0	0.9	3.1	5.1
Qa2	H 3	940988	B2	5.7	4.6	0.05	2	<0.05	0.02	0.32	<0.05	68	<1	18	<5	0.2	2.5	0.2	0.4	3.3	0.1	3.7	7.0
Qa2	H 3	940989	2B1	6.2	4.7	<0.05	1	<0.05	0.02	0.20	<0.05	97	1.0	<5	<5	0.1	2.7	0.3	0.5	3.6	<0.1	3.2	6.8
Qa2	H 3	940990	2B2	6.0	4.5	0.05	3	<0.05	0.02	0.27	<0.05	106	<1	<5	<5	0.1	4.5	0.4	0.9	5.9	<0.1	4.8	10.7
Qap	H 2	940981	1A1	5.1	4.1	0.07	4	<0.05	0.02	0.89	0.07	201	5.1	57	29	0.9	0.2	0.5	0.2	1.8	4.5	5.5	7.3
Qap	H 2	940982	1B2	7.0	6.1	0.05	2	<0.05	0.02	0.43	<0.05	126	<1	<5	<5	5.5	4.1	0.4	0.3	10.3	1.3	4.0	14.3
Qap	H 2	940983	2A1	7.4	6.1	<0.05	1	<0.05	0.02	0.35	<0.05	78	<1	<5	<5	2.3	2.6	0.2	0.3	5.4	0.9	1.4	6.8
Qap	H 2	940984	2B2	8.0	6.3	<0.05	1	<0.05	0.02	0.33	<0.05	98	1.0	<5	<5	3.3	3.2	0.3	0.8	7.6	1.0	1.7	9.3
Qbe	H 4	940991	A1	5.6	4.5	<0.05	6	<0.05	0.02	2.87	0.16	328	7.4	19	21	3.5	1.0	0.8	0.2	5.5	3.5	9.6	15.1
Qbe	H 4	940992	B1	7.6	6.4	0.07	1	<0.05	0.02	0.51	<0.05	305	<1	<5	<5	6.8	3.7	0.9	0.6	12.0	1.8	3.1	15.1
Qbe	H 4	940993	B21	8.5	7.3	0.14	1	<0.05	0.05	0.37	<0.05	345	1.3	<5	<5	9.5	8.7	1.2	1.8	21.2	1.1	2.0	23.2
Qbe	H 4	940994	B31	9.1	8.4	0.61	1	0.07	0.20	0.64	<0.05	186	<1	<5	<5	19.9	15.6	1.3	5.3	42.1	1.3	<0.4	42.1
Qbe	H 4	940995	B32	9.1	8.4	0.8	1	0.11	0.26	0.44	<0.05	188	<1	<5	<5	18.8	15.5	1.2	6.7	42.2	1.2	<0.4	42.2

APPENDIX D. CHEMICAL LABORATORY RESULTS

Map Unit	Site Number	Laboratory Number	Horizon	1:5 Soil Water Suspension			ph Buffer Capacity Index	Cl as NaCl %	Total Soluble Salts	Oxidizable Org. Carbon %	Total Nitrogen %	Skene K ug/g	Olsen P ug/g	Exchangeable Al+++ ug/g	Exchangeable Mn++ ug/g	Extractable Bases				Total of Extractable Bases	Calcium:Magnesium Ratio	Exchangeable H+ meq/100g	Cation Exchange Capacity
				pH H_2O	pH $CaCl_2$	EC dS/m										Ca ++ meq/100g	Mg++ meq/100g	K+ meq/100g	Na+ meq/100g				
Tsfl	M19	911300	A1	5.4		0.08		<0.05		4.07	0.17	177	2.2	68	6	2.3	3.5	0.4	0.2	6.4	0.7	17.1	23.5
Tsfl	M19	911301	A2	5.4		0.1		<0.05		1.65	0.07	98	<1.0	59	<5	1	3.6	0.2	0.2	5	0.3	10.4	15.4
Tsfl	M19	911302	B21	5.8		0.24		<0.05		1.1	0.06	138	<1.0	13	<5	1	7.1	0.3	1	9.4	0.1	8.5	17.9
Tsfl	M19	911303	B22	8.0		0.64		<0.05		0.68	<0.05	181	<1.0	<5	<5	1.3	9.9	0.6	3.7	15.5	0.1	2.4	17.9
Tse2	H 5	940996	A1	6.1	5.1	0.16	6	<0.05	0.05	4.32	0.27	525	10.1	<5	6	4.1	4.3	1.3	0.8	10.5	1.0	9.0	19.5
Tse2	H 5	940997	B2	9.3	8.5	0.42	1	<0.05	0.14	0.52	<0.05	388	<1	<5	<5	12.0	15.8	1.6	5.0	34.4	0.8	<0.4	34.4
Tse2	H 5	940998	B3	9.7	8.8	0.61	1	0.05	0.20	0.28	<0.05	320	<1	<5	<5	15.7	17.1	1.3	6.4	40.5	0.9	<0.4	40.5
Ose	H 6	940999	A1	5.2	4.2	0.05	8	<0.05	0.02	4.52	0.29	158	3.6	80	7	1.8	1.8	0.4	0.3	4.3	1.0	13.2	17.5
Ose	H 6	941000	B2	6.6	5.4	0.08	3	<0.05	0.03	1.00	0.08	171	<1	<5	<5	0.6	7.1	0.5	0.8	9.0	0.1	4.4	13.4
Ose	H 6	941001	B3	8.2	7.3	0.35	1	0.06	0.12	0.53	0.06	341	<1	<5	<5	0.2	17.2	1.2	3.1	21.7	<0.1	1.5	23.2
Osf	H 7	941002	A1	5.5	4.5	0.09	6	<0.05	0.03	4.67	0.20	258	3.0	20	9	1.5	2.1	0.7	0.4	4.7	0.7	9.2	13.9
Osf	H 7	941003	A2	6.1	4.8	0.07	4	<0.05	0.02	2.43	0.10	102	1.3	<5	<5	0.7	2.9	0.3	0.6	4.5	0.2	6.0	10.5
Osf	H 7	941004	B2	7.0	5.9	0.13	1	<0.05	0.04	0.89	0.08	134	<1	<5	<5	0.4	7.9	0.4	2.0	10.7	0.1	2.3	13.0
Osf	H 7	941005	B3	8.4	7.7	0.67	1	0.12	0.21	0.65	0.06	149	<1	<5	<5	0.2	11.5	0.5	4.6	16.8	<0.1	1.0	17.8

APPENDIX E. CRITERIA USED FOR ESTABLISHING RECHARGE VALUES

Characteristics of Very High Recharge Areas	
permeability of profile	> 1000 mm/day
Characteristics of High Recharge Areas	
Soil depth:	< 25 cm
and/or outcropping bed-rock:	> 10%
and/or permeability of profile:	200 - 1000 mm/day
and/or clay content of clayiest layer:	< 25%
and/or soil type:	Uniform soils: uniform sands, loamy sands, uniform loams, sandy silt loams, loams (Uc, Um, Gc) Duplex soils: red and whole coloured A2 present but not bleached high Fe_2O_3 content throughout B horizon
Side slopes:	> 25%
Characteristics of Moderate Recharge Areas	
Soil depth:	25 - 100 cm
Outcropping bed-rock:	1 - 10%
Profile permeability:	50 - 200 mm/day
Clay content of clayiest layer:	> 25 - 35%
Soil type:	Gradational Duplex acid, whole coloured Duplex, A2 may be present and sporadically bleached
Characteristics of Low-Nil Recharge Areas	
Soil depth:	> 100 cm
Outcropping bed-rock:	= 0
Profile permeability:	< 50 mm/day
Clay content of clayiest layer:	> 35%
Soil type:	Uniform clays (Uf) Uniform cracking clays (Ug) Duplex soils with conspicuously bleached A2, mottled B horizons and/or gleying characteristics.

APPENDIX F. LAND SYSTEMS HIERARCHY

F.1 Land systems

A land system is an area of land, distinct from the surrounding terrain, that has a specific climatic range, parent material and landform pattern. These features are expressed as a recurring sequence of land components. Land system mapping is generally at a scale of 1:100 000 or 1:250 000 and is appropriate for large scale planning exercises, such as regional planning.

Land units or components are distinguished by recurring slope, soil, aspect and vegetation patterns. Land units are therefore subject to similar forms of land degradation. A map unit may be the same as a land unit, however a larger mapping scale allow land units to be divided into further distinct areas based on more specific soil and topographical characteristics. The hierarchy of the Land System concept has been maintained in this study.

In Table F.1 below, the close relationship between the mapped units of the two more-detailed studies can be seen. Where clear relationships do not occur, the 1:25 000 land capability study has invariably been able to map and identify more accurately the landform and soil type.

Table F.1 Land systems.

(i) Land Systems of Victoria (Rowan, 1990) 1:250 000	(ii) A Study of the Land in the Campaspe River Catchment (Lorimer & Schoknecht ,1987) 1:100 000		(iii) Map Units in the District of Huntly (This study) 1:25 000		
land system	**land system**	**major soil**	**map units**	**soil major**	**soil minor**
4.2 Pf5 4.1 Ffc4	Re	Dr Ug	Qap Qa1 Qa2	Dr3.13 Uf Dy3.42	Dr2.42 Dy3.42 Uf
7.2 Pv4	Mi	Ug	Tbe	Uf	Dr3.13
2.1 Gs4	-	-	Tse2 Tsf2 Tsg2 Tsh2	Uf Uf Uf Uf	Dr3.13 Dr3.13 Dr3.13 Dy3.42
2.1 Gs5	WH	Dr Dy	Tse Tsf Tsg	Dy3.41 Dy3.41 Dy3.41	Dy3.42 Dy3.42 Dy3.42
2.1 Gs5 Gs4	Wd	Gn Dy Dr	Ose Osf Osg Osh	Dr2.12 Dr3.42 Dr3.42 Dy3.42	Dr3.12 Dy3.42 Dy3.42 Uf
2.1 Gs4	Gt	Dr Gn Dy	Ose Osf Osg Osh	Dr2.12 Dr3.12 Dr3.12 Dy3.42	Dr3.12 Dr3.42 Dr3.42
2.1 Ss5 Gs5	Kn	Gn Dy	Osa Osb Osc Osd Ose Osf Osh	Dy2.11 Dy2.11 Dy2.11 Dy2.11 Dy2.11 Dy3.42 Dy3.42	Um Um Gn3.11 Gn3.11 Gn3.11 Gn3.11 Uf

GLOSSARY

The following definitions have been extracted from Charman and Murphy (1991) and McDonald *et al.* (1984).

Acidification:

An increase in acidity in the soil due to changes in land use, particularly agriculture. Soils that are most susceptible are generally of light texture in high rainfall areas.

Aluminium (Al) toxicity:

Plant growth in agricultural crops may be affected if aluminium levels are greater than 15 µg/g. For the purposes of this report soils with aluminium levels greater than 15 µg/g are regarded as being potentially toxic and lime may be required to promote plant growth. (State Chemistry Laboratory, pers. comm.).

Apedal:

Describes a soil in which none of the soil material occurs as peds in the moist state. Such a soil is without apparent structure and is typically massive or single-grained.

Available water for plant growth:

The amount of water in the soil that can be held between field capacity and the moisture content at which plant growth ceases.

Bleaching:

The near-white colouration of an A2 horizon which has been subject to chemical depletion as a result of soil-forming processes including eluviation. The colour is defined for all hues as having a value greater than or equal to 7 with a Chroma less than or equal to 4 on dry soils. Conspicuous bleaching means that > 80% of the horizon is bleached whereas sporadic bleaching means that < 80% of the horizon is bleached.

Consistence:

Consistence refers to the strength of cohesion and adhesion in soil. Strength will vary according to soil water status.

Dispersibility:

Value (Emerson)	*Interpretation*
E6, E7, E8	Very low
E3(1), E3(2), E4, E5	Low
E3(3), E3(4)	Moderate
E2	High
E1	Very high

Drainage:

Drainage is a term used to summarise local soil wetness conditions. It is affected by internal attributes which include soil structure, texture, porosity, hydraulic conductivity, water holding capacity, and external attributes such as evapotranspiration, gradient and length of slope and position in the landscape.

Categories are as follows:

Very poorly drained: Free water remains at or near the surface for most of the year. Soils are usually strongly gleyed. Typically a level or depressed site and/or a clayey subsoil.

Poorly drained: All soil horizons remain wet for several months each year. Soils are usually gleyed, strongly mottled and/or have orange or rusty linings of root channels.

Imperfectly drained: Some soil horizons remain wet for periods of several weeks. Subsoils are often mottled and may have orange or rusty linings of root channels.

Moderately well-drained: Some soils may remain wet for a week after water addition. Soils are often whole coloured, but may be mottled at depth and of medium to clayey texture.

Well-drained: No horizon remains wet for more than a few hours after water addition. Soils are usually of medium texture and not mottled.

Rapidly drained: No horizon remains wet except shortly after water addition. Soils are usually of coarse texture, or shallow, or both, and are not mottled.

Duplex soil:

A soil in which there is a sharp change in soil texture between the A and B horizons (such as loam overlying clay).

The soil profile is dominated by the mineral fraction with a texture contrast of 1.5 soil texture groups or greater between the A and B horizons. Horizon boundaries are clear to sharp.

Electrical conductivity (EC):

A measure of the conductivity of electricity through a 1:5 soil water suspension. It is used to determine the soluble salts in the extract. The unit of electrical conductivity is the 'Siemens' and soil salinity is expressed here as decisiemens per metre at 25^{o}C.

Value range (dS/m)	*Interpretation*
< 0.30	Very low
0.30 - 0.53	Low
0.53- 1.26	Moderate
1.26- 2.50	High
> 2.50	Very high

Flooding:

Includes overbank flow from streams and overland-channel flow along drainage depressions.

Gradational soil:

A soil in which there is a gradual change in soil texture between the A and B horizons (for example, loam over clay loam over light clay). The soil is dominated by the mineral fraction and shows more clayey texture grades on passing down the solum of such an order that the texture of each successive horizon changes gradually to that of the one below. Horizon boundaries are usually gradual or diffuse. The texture difference between consecutive horizons is less than 1.5 soil texture groups, while the range of texture throughout the solum exceeds the equivalent span of one texture group.

Gully erosion:

Erosion of soil or soft rock material by running water that forms channels larger and deeper than rills (i.e. 300 mm).

Hardpan:

A hardened and/or cemented horizon, or part thereof, in the soil profile. The hardness is caused by mechanical compaction or cementation of soil particles with organic matter or with materials such as silica, sesquioxides or calcium carbonate. Such pans frequently reduce soil permeability and root penetration, and thus may give rise to plant growth and drainage problems.

Land capability assessment:

A systematic and rational method of determining the relative ability of different areas of land to sustain a specific land use under a nominated level of management without being degraded or causing any long term off-site degradation.

Land units or components:

An area of land, distinct from adjacent units or components because of specific slope, soil, or geomorphological characteristics, e.g. crest, lower slope.

Land pattern/system:

An area of land, distinct from surrounding terrain, that has a specific climatic range, parent material and modal slope. Made up of a recurring sequence of land elements or components, e.g. sedimentary rolling hills.

Linear shrinkage:

See Shrink/swell potential.

Mottling:

Irregular patches of colour interspersed with and different from the dominant soil colour, that vary in number and size. Mottling can indicate impeded drainage but may also be a result of parent material weathering.

Nutrient status:

Sum of exchangeable base cations (Ca, Mg, K)

Value range (meq/100g)	*Interpretation*
< 4	Very low
4 - 8	Low
9 - 18	Moderate
19 - 30	High
> 30 Very high	

Organic matter:

All constituents of the soil arising from living matter i.e. plant and microfauna detritus, fresh or decomposed. The following values for organic matter have been used in this report:

Value range (%)	*Interpretation*
< 1	Very low
1 - 2	Low
2 - 3	Moderate
> 3	High

(organic matter % = organic C% x 1.72)

Parent material/rock:

The geologic material from which a soil profile develops. It may be bed-rock or unconsolidated materials including alluvium, colluvium, aeolian deposits or other sediments.

Permeability:

The characteristic of a soil, soil horizon or soil material which governs the rate at which water moves through it. It is a composite expression of soil properties and depends largely on soil texture, soil structure, the presence of compacted or dense soil horizons and the size and distribution of pores in the soil. In this study, the permeability has been measured as K_{sat} (saturated hydraulic conductivity). Where estimates have been made, based on the properties of the soil profile, this is clearly indicated.

Value range (mm/day)	*Interpretation*
< 10	Very slow
10 - 100	Slow
100 - 500	Moderate
500 - 1500	Rapid
1500 - 3000	Very rapid
> 3000	Excessive

pH (soil reaction):

A measure of the acidity or alkalinity of a soil. A pH (H_2O) of 7.0 denotes neutrality, higher values indicate alkalinity and lower values indicate acidity. Strictly, it represents the negative logarithm of the hydrogen ion concentration in a specified 1:5 soil water suspension on a scale of 0 to 14. Soil pH (H_2O) levels generally fall between 5.5 and 8.0 with most plants growing best in this range.

Phosphorus (P):

Deficient when less than 6 µg/g

Plasticity index:

The plasticity index of a soil is the numerical difference between the plastic limit and the liquid limit.

Potassium (K):

K deficiency	
Light textures	< 80 µg/g
Medium textures	< 110 µg/g
Heavy textures	< 120 µg/g

Marginal levels of K	
Light textures	80-120 µg/g
Medium textures	110-160 µg/g
Heavy textures	120-180 µg/g

Rill erosion:

Erosion by small channels less than 300 mm deep which can be completely smoothed by normal cultivation.

Recharge:

Movement of surface water down into the underlying groundwaters.

Rock outcrop:

Any exposed area of rock that is inferred to be continuous with the underlying parent material.

Sheet erosion/sheet wash:

The relatively uniform removal of soil from an area without the development of conspicuous channels.

Shrink/swell potential:

The capacity of soil material to change volume with changes in moisture content, frequently measured by a laboratory assessment of the soil's linear shrinkage. It relates to the soil's content of montmorillonite type clays. High shrink swell potential in soils, such as cracking clays, can give rise to problems in earth foundations and soil conservation structures. Categories used are:

Shrink/swell potent. (%)	*Linear shrinkage*
0 - 6	Very low
7 - 12	Low
13 - 17	Medium
18 - 22	High
> 22	Very high

Slaking:

The partial breakdown of soil aggregates in water due to the swelling of clay and the expulsion of air from pore spaces. It is a component, along with soil dispersion and soil detachment, of the process whereby soil structure is broken down in the field.

Slope:

Landform element that is neither a crest or a depression and that has an inclination greater than 1%. Slope can be broken up into the following categories:

Value range (%)	*Interpretation*
< 1%	Level
1 - 3%	Very gentle slope
4 - 10%	Gentle slope
11 - 20%	Moderate slope
21 - 32%	Moderately steep slope
> 32%	Steep slope

Soil colour:

Determined by comparison with a standard Munsell soil colour chart or its equivalent. It includes three variables of colour; hue, value and chroma.

Soil horizon:

A layer within the soil profile with distinct morphological characteristics which are different from the layers above and/or below. Horizons are more or less parallel to the land surface, except that tongues of material from one horizon may penetrate neighbouring horizons.

Soil profile:

A portion of a soil exposed in a vertical section, extending usually from the land surface to the parent material. In very general terms, a profile is made of three major layers designated A, B and C horizons. The A and B horizons are those modified by soil development. The C horizon is weathering parent material that has not yet been significantly altered by soil forming processes.

Soil texture:

The relative proportions of sand, silt and clay particles in a sample of soil. The field assessment of texture is based on the characteristics of a bolus of wetted soil moulded by hand. Six main soil texture groups are recognised

Texture group	*Approx. clay content*
1. Sands	< 10%
2. Sandy loams	10 - 20%
3. Loams	20 - 30%
4. Clay loams	30 - 35%
5. Light clays	35 - 40%
6. Heavy clays	> 45%

Unified soil group:

A soil classification system based on the identification of soil materials according to their particle size, grading, plasticity index and liquid limit. These properties have been correlated with the engineering behaviour of soils including soil compressibility and shear strength. The system is used to determine the suitability of soil materials for use in earthworks, optimal conditions for their construction, special precautions which may be needed, such as soil ameliorates, and final batter grades to be used to ensure stability.

clays, silty clays OL: Organic silts or organic silt-clays of low
plasticity MH: Inorganic silts, micaceous
fine sandy or silty soils CH: Inorganic clays of high
plasticity OH: Organic clays of moderate to
high plasticity Pt: Peat
Uniform soil:
A soil in which there is little, if any change in soil texture between the A and B horizons (for example, loam over loam, sandy clay over silty clay). The soil is dominated by the mineral fraction and shows minimal texture difference throughout, such that no clearly defined texture boundaries are to be found. The range of texture throughout the solum is not more than the equivalent span of one soil texture group.

GW: Well graded gravels, gravel-sand mixtures
GP: Poorly graded gravels, gravel-sand mixtures
GM: Silty gravels, poorly graded gravel-sand-silt mixtures
GC: Clayey gravels, poorly graded gravel-sand-clay mixtures
SW: Well graded sands
SP: Poorly graded sands
SM: Silty sands, poorly graded sand-silt mixtures
SC: Clayey sands, poorly graded sand-clay mixtures
ML: Inorganic silts and very fine sands, clayey fine sands with slight plasticity

CL: Inorganic clays of low to medium plasticity, sandy clays, silty clays
OL: Organic silts or organic silt-clays of low plasticity
MH: Inorganic silts, micaceous fine sandy or silty soils
CH: Inorganic clays of high plasticity
OH: Organic clays of moderate to high plasticity
Pt: Peat

Uniform soil:

A soil in which there is little, if any change in soil texture between the A and B horizons (for example, loam over loam, sandy clay over silty clay). The soil is dominated by the mineral fraction and shows minimal texture difference throughout, such that no clearly defined texture boundaries are to be found. The range of texture throughout the solum is not more than the equivalent span of one soil texture group.