A LAND CAPABILITY STUDY OF THE CASSILIS VALLEY, SWIFTS CREEK

August 1995

CENTRE FOR LAND PROTECTION RESEARCH

Technical Report No. 27

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ISBN No. **0 7306 7954 3**

ISSN No. **1038 216X**

Land Protection Branch

Department of Conservation and Natural Resources

Further Information

This report has been prepared to assist broad scale planning in the Omeo 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.

Rees, D. B.
A land capability study of the Cassilis Valley, Swifts Creek.

Bibliography.
Includes index
ISBN 0 7306 7954 3.

I. Land capability for agriculture - Victoria - Swifts Creek Region.
2. Land use, Rural - Victoria - Swifts Creek Region - Planning.
3. Landscape assessment - Victoria - Swifts Creek Region - Planning
4. Regional Planning - Victoria - Swifts Creek Region.
I. Victoria. Land Protection Branch. II. Centre for Land Protection Research. III. Title. (Series : Technical report (Centre for Land Protection Research (Vic.)) ; no.27) .

333.73099456

TABLE OF CONTENTS

LIST OF TABLES

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.

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 primary objective has been to provide the municipality with detailed land resource information, consisting of base data on the nature of the land and of assessments 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 innappropriate land use can be avoided.

A similar approach has been adopted for this study in the Cassilis Valley where financial and personnel input has come the Land Evaluation Unit and East Gippsland Area staff of the Department of Conservation and Natural Resources and from the (former) Shire of Omeo.

SUMMARY

The Cassilis Valley was formerly part of the Shire of Omeo and is now incorporated into the Municipality of East Gippsland in 1994.

The study area is approximately 30 km^2 in size and adjoins the Township of Swifts Creek to the south-east. Rural residential development has occurred close in the Cassilis Valley with increasing pressure for further development. The remaining area is predominantly extensive grazing, uncleared and public land (State Forest) .

The Cassilis Valley has already seen a great deal of development with the discovery of gold both in the valley and the surrounding district (Omeo) . This led to the population of the area increasing considerably and subsequent development which put considerable pressure on the land through clearing and mining activities. Currently the Valley has a number of extensive grazing properties, some of which have to some extent been recently subdivided. A number of newer enterprises have started up such as deer farming, anghora goat rearing and a winery. Another important feature of the valley is that it provides water for the Valley residents. The quality and quantity of this water is a significant local issue which has implications in terms of land use.

The majority of the Valley consists of Ordovician metamorphic sediments with some variation in lithology and some granitic outcrops to the south and minor occurrences closer to the main valley. Slopes are generally steep due to the downcutting of the valley but there are some gentler slopes around the main watercourses. The steeper areas are highly susceptible to all forms of water erosion, particularly sheet and gully erosion given the steep slopes and climatic conditions. Past development based on gold prospecting and mining have disturbed the local environment and left sediment dumps in the valley as well as previous workings.

Development of these lower areas for residential and rural residential purposes has resulted in the more obvious development sites being utilised with some deterioration of land and water quality due to complications with roading, access tracks, house siting and effluent disposal. The range in capability ratings reflects the range of soil properties and topography within some map units/complexes.

This current study provides information for planning decisions to be made in a systematic fashion. *A detailed land capability assessment will provide valuable supporting information to any new amendment of a planning scheme and enable new development proposals to be readily assessed*.

Table 1.1 Summary of land capability ratings

Note: The map unit tables on the specific land capability map or the map unit description in Section 5 of this report detail the reason(s) for ratings of 3, 4 or 5

.MAP UNIT		LAND CAPABILITY RATING					
Symbol	**Description**	**Agriculture**	**Effluent Disposal**	**Farm Dams**	**Secondary Roads**	**Building Foundations**	**Rural Residential**
Qa1/Qa2	Quaternary alluvium, alluvial plain	$C_4T_2S_2$	3-5	3-4	4-5	3	3-5
Qa3	Quaternary alluvium, floodplain	$C_4T_3S_{2-4}$	4	3-4	4-5	4-3	4
Omf/Qcf	Ordovician metasediments/colluvium, gentle slopes	$C_4T_3S_{2-4}$	4-5	3	4	4-3	4
Omd	Ordovician metasediments, moderate slopes	$C_4T_4S_3$	3	4	4	4	4
Omc (i)	Ordovician metasediments, moderate slope Type (i)	$C_4T_4S_3$	4	5	4	4	4
Omc (ii)	Ordovician metasediments, moderate slope Type (ii)	$C_4T_4S_5$	5	5	4	4	4-5
Omb	Ordovician metasediments, steep slope	$C_4T_5S_{4-5}$	5	5	5	5	5
Oma	Ordovician metasediments, crests	$C_4T_5S_5$	5	5	4	4	5
Omc/d1	Ordovician metasediment; moderate/moderately steep slopes	$C_4T_4S_3$	3-4	3-4	4	4	4

1. INTRODUCTION

1.1 Overview

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 requirement 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 Cassilis Valley. 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.

Previous studies covering the Cassilis Valley have provided background information for this study; particularly 'A study of the land in the Catchment to the Gippsland Lakes, Vol.1 & 2'. by Aldrick, Hook, van de Graaff, Nicholson, O'Beirne & Schoknecht (1992) ; compiled and edited by M S Lorimer.

1.2 Users' guide

The user guide is designed to assist document users in finding and cross referencing information contained within the 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 the land capability classes for each form of land use and map unit. Refer to Section 4 and Appendix B for a detailed description of map units and capability classes.

Section 1: The introduction highlights specific planning concerns within the Cassilis Valley, district of Omeo and identifies how land capability assessment can be utilized as a sound base for future rural planning.

Section 2: The land capability assessment section describes the approach to 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 2.2 to 2.6; 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 further description of the parameters that influence land use.

Section 4: This section provides an overview of environmental (biophysical) information, the context for the more specific information in Section 5.

Section 5: This is the core section of the report and contains individual map unit descriptions and land capability classes for each map unit. The dual page format provides general and specific landform and soil information, including susceptibility to land degradation. The land capability assessment lists the capability class and the major limiting feature(s) for each form of land usE. Refer to appendix B for other limiting features not listed as the major limiting feature(s).

Appendixes: There are five 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.

1.3 Location

The Cassilis Valley is located immediately to the west and northwest of the township of Swifts Creek, as shown in Figure 1.1. The study area is approximately 30 km^2 in size.

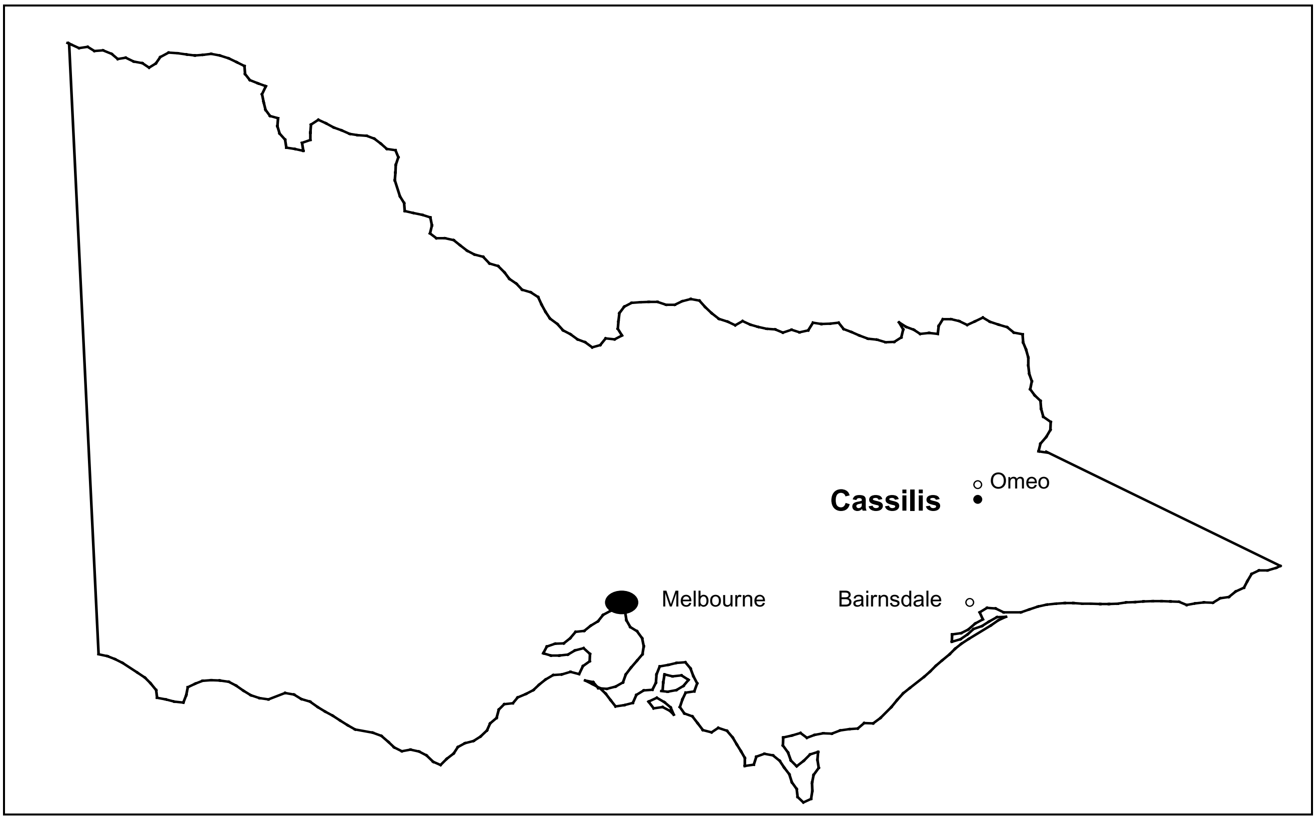


Figure 1.1 Location of the Cassilis Valley

1.4 Purpose Of The Study

The Cassilis Valley, located north west of Swift's Creek has been identified as being subject to increasing pressure of use, requiring greater understanding and management of the land.

The variety of landform has produced variety in the capability of the land which has been illustrated by past land use activities particularly the search for gold in the late 19th and early 20th centuries. During this time this valley came under intense use, not only via the stream system being dredged and altered but also the large number of people and works in the valley and the need for timber.

The current situation consists of an old land tenure framework with increasing demands on the land such as subdivision as well as water supply provision for Swift's Creek Township. Therefor a systematic land inventory is required for assessment and planning consistency. A measure of the ability of the land to sustain development in the long term is also required, giving an indication of the level and type of management inputs likely to maintain developments without long term off-site effects.

1.5 Objectives

Major Objective:

To provide land resource information to the Municipality of East Gippsland that will facilitate the planning of future land use in the Cassilis Valley.

More specifically:

1. To map and describe the land of the Cassilis Valley at a scale of 1:25 000 (predominantly the freehold) 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:
   * effluent disposal (septic tanks)
   * building foundations
   * secondary roads
   * farm (earthen) dams
   * agriculture

3. To provide maps at 1:25 000 scale of :
   * topographic base map and map units

* thematic land use maps of land capability ratings for nominated uses/activities

4. To assist the Municipality of East Gippsland in the incorporation of this land resource information into its planning strategies for the district of Omeo.

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 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 provide a means of analysing basic land information and identifying the effect of natural land characteristics on 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.

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 conventionally done within this model of land resource mapping is to identify areas of land that exhibit patterns or 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(s) 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 map unit in Section 4.2 for details) .

vi) The permeability of the soil profile (generally the subsoil) 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 thematic capability 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

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 Class 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 (1:25 000) , 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) 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 1 to 5 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

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 assessment identifies the versatility and potential productivity of an area for a range of agricultural uses, and its ability to support disturbance such as various levels of cultivation.

November 1992

CLASS	CAP ABILITY	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. Recommended for low disturbance agriculture such as grazing or perennial horticulture. Moderate production levels possible with specialist management such as improved pasture establishment with minimum tillage techniques.
Class 5	Very poor	Very low capability to resist disturbance. Minimal grazing levels or non-agricultural uses recommended. Areas of low productive capacity.

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

See Table 2.3 for explanation of the agricultural rating system.

Table 2.2 Land Capability Classes for Effluent Disposal, Farm Dams, Secondary Roads, Building Foundations, and Rural Residential Development

CLASS	CAPABILITY	DEGREE OF LIMITATION TO DEVELOPMENT	GENERAL DESCRIPTIONS AND MANAGEMENT GUIDELINES
CLASS 1	Very good	The limitation of long term instability, engineeri ng 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

January 1993

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 - 10	10 - 8	7 - 5	4 - 2	< 2
T : Topography	Slope (%)	< 1	1 - 3	4 - 10	11 - 32	> 32
S : Soil	Top soil condition *	25 - 21	20 - 16	15 - 11	10 - 6	5 - 1
	Depth of top soil (mm)	> 300	300 - 160	150 - 110	100 - 50	< 50
	Depth to rock/hardpan (m)	> 2.0	2.0 - 1.6	1.5 - 1.1	1.0 - 0.5	< 0.5
	Depth to seasonal watertable (m)	> 5.0	5.0 - 2.1	2.0 - 1.6	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 (dSm^{-1}) *	<0. 3	0.3 - 0.6	0.7 - 1.4	1.5 - 3.5	> 3.5
	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

* See Appendix A

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 would be 4; with soil factors being the major limiting features.

Table 2.4 Land capability assessment for on-site effluent disposal

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).

November 1992

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 - 1.6	1.5 - 1.1	1.0 - 0.5	< 0.5
Depth to hard rock/impermeable layer (m)	> 1.5	1.5 - 1.1	1.0 - 0.76	0.75 - 0.5	< 0.5
No. of months/year when average daily rainfall > K_{sat} *	0	1	2	3	> 3
Permeability (K_{sat} mm/d) *	> 500 **	500 - 101	100 - 51	50 - 10	< 10

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

* See Appendix A

** Permeabilities > 1000 mm/d could pollute groundwaters

Table 2.5 Land capability assessment for earthen dams

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.

November 1992

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	8 - 10	11 - 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 - 3.1	3 - 2.1	2 - 1	< 1
Permeability (K_{sat} mm/d) *, ***	< 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: Rock outcrop, depth of top soil and flooding risk were also considered but have not been included for reasons given in Appendix A. Dispersibility of subsoil has not been included as it is only limiting when associated) with other parameters such as linear shrinkage and permeability.

* See Appendix A

** If there is a high linear shrinkage but a low dispersion, increase rating by one class

*** As the subsoil is compacted during the construction of a dam, the permeability is effected by the dispersion characteristics of the soil. Therefore, when there is an Emerson class of 1, 2 or 3, the permeability rating is upgraded 1 class. When the Emerson class is a 5 or 6 it remains the samE.

Table 2.6 Land capability assessment for secondary roads

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

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	5-2.1	2-1.1	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	1.5-0.76	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
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

* See Appendix A

Table 2.7 Land capability assessment for building foundations

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

November 1992

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 31 - 45	 >30 >45
Drainage *	Rapidly drained	Well drained	Moderately well drained	Imperfectly drained	Poorly drained
Depth to seasonal watertable (m)	>5	5 - 2.1	2 - 1.1	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 - 0.76	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	 23 - 30 18 - 22	 >30 >22
Flood risk	Nil	Low	Moderate	High	Severe

* See Appendix A

3. 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 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.

3.2 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.

3.3 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.

3.4 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.

3.5 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.

3.6 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.

3.7 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 landform, 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 different 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 construction. 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.

3.8 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.

3.9 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.

3.10 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.

3.11 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 dependent 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.

3.12 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.

3.13 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.

3.14 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 are leached from the soil that were fixed by pasture legumes, and 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 of Victoria have become more acid ($pH<5.5$ in H_20) and aluminium toxicity has increased. Acid soils and aluminium toxicity can result in a decline in plant vigour and growth.

3.15 Stones and gravel

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

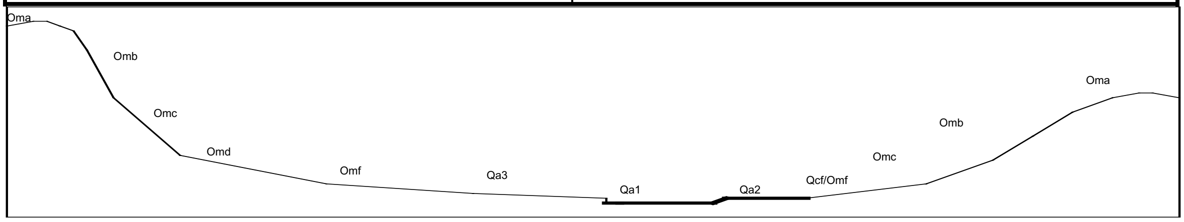
i) reducing the available water content and nutrient supply in the profile;

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 land surface.

MAP UNIT SYMBOL: **Qa1, Qa2**	MAP UNIT: **Alluvial Complex**



A. GENERAL DESCRIPTION

This land unit complex incorporates land units within the main valley such as the floodplain (Qa1) and associated Terraces (Qa2). These units are confined in the upper half of the Valley and more extensive downstream as more tributaries join Swifts Creek. The soils range from Hydrosols (seasonally saturated), coarse uniform soils with dark surface horizons (Rudosols and Tenosols), black organic rich medium textured friable soils (on some terraces- Tenosols) and some colluvial often duplex soils (Chromosols) and recent deposition of coarse material (Rudosols) due to landuse. Vegetation can be varied with Manna Gum, Blue Gum, Mountain Ash as well as Yellow Box higher up in the floodplain. The main floodplain is subject to peak flows.

SITE CHARACTERISTICS

Parent Material Age:	Quaternary: Recent	**Depth to Seas. Watertable:**	0-1.5m
Parent Material Lithology:	unconsolidated sediments	**Flooding Risk:**	Moderate to-Very High
Landform Pattern:	Floodplain/Terraces	**Drainage:**	Very Poor-Moderately Well
Landform Element:	Floodplain/Terraces	**Rock Outcrop:**	0
Slope a) common:	2%	**Depth to Hard Rock:**	>2m
Slope b) range:	0-4%	**Present Land Use:**	Reserve, pasture
Potential Recharge to Groundwater:			
Major Native Vegetation Species:	Manna, Blue, Grey Gum, Blackwood, Basket Wattle, Willow		

LAND DEGRADATION

Land Degradation	**Water Erosion**		**Wind Erosion**	**Mass Movement**	**Salting**	**Acidification**
	sheet/rill	**gully**				
Susceptibility	L	M	VL	VL	L	L-M
Incidence						

B. SOIL PROFILE

PROFILE DESCRIPTION (Site 13, Site 36)

A11	0-0.2 m	Dark grey brown (10YR3/3) organic fine sandy clay loam, weak subangular blocky structure, earthy fabric, weak consistence, less than 2% gravel, pH 7.0. Clear transition to
A12	0.2-0.35 m	Brown (7.5YR5/4) fine sandy loam, weak coarse subangular blocky structure, earthy fabric, moderately weak consistence, little or no gravel, pH 5.75-6. Clear transition to
B/D	0.35-1.6 m+	Brown (7.5YR3.5/5) heavy loamy sand, apedal, moderately weak consistence, some (2-10%) gravel, pH 7.0. Continues.

CLASSIFICATION

Factual Key:	Dominant: Uc4.22/Uc5.21, Um7.11/Uc1.23 Minor: Dd/Db
Australian Soil Classification:	Melanic, Regolithic, Chernic-Leptic, TENOSOL; medium, non-gravelly, loamy/loamy, very deep
Unified Soil Group:	ML, SM

INTERPRETATION OF LABORATORY ANALYSIS (SITE 36)

Horizon	pH ($H_2O/CaCl_2$)	% Gravel	E.C. (salts)	Nutrient Status	P	K	Al	Organic matter	Dispersibility
A12	7.0/6.0	0	VL	M	S	S	S	VH	L
C	7.2/6.5	10	L	L	S	S	S	L	L

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

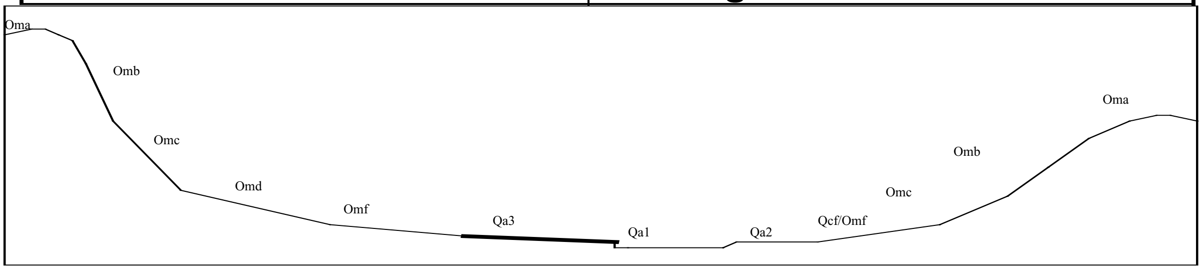
SOIL PROFILE CHARACTERISTICS:

Permeability:	High (0.45 m/day)
Available Water Capacity:	High (175 mm H_2O; top 1m)
Linear Shrinkage (B horizon):	Very low (5%)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature (s)/Land Use
Agriculture	$C_4T_2S_{2-3}$	Growing season
Effluent Disposal (septic tanks)	3-5	5 on floodplain; flood return period 2-3 on terraces; seasonal watertable, permeability
Farm Dams	3-4	Depth of clay layer, permeabilty
Secondary Roads	3-5	Flooding risk, drainage, depth to seasonal watertable
Building Foundations		
slab	3-5	Qa1; drainage, depth to seasonal water table, flood risk. Qa2; Flood risk (5)
stumps/footings	2-4	Drainage, depth to seasonal water table.

MAP UNIT SYMBOL: **Qa3**	MAP UNIT: **Recent tributary drainagelines**



A. GENERAL DESCRIPTION

This unit consists a complex of tributary drainagelines and asociated terraces and flats which drain into the main valley. These include Stockyard Creek, Rileys Creek and Shelton Gully and have surrounding metamorphic terrain with some granitic influence coming from the south (headwaters of Rileys Creek and Shelton Gully). The soil types vary from heavy deposits (Brown and black Chromosols), medium textured soils (Tenosols) and colluvial duplex soil (Chromosols) associated with the surrounding terrain. Vegetation is varied with Manna, Blue Gums on heavier moister terrain with Yellow Box on the drier areas.

SITE CHARACTERISTICS

Parent Material Age:	Quaternary;Recent	**Depth to Seas. Watertable:**	0-2 m
Parent Material Lithology:	Unconsolidated sediments	**Flooding Risk:**	Moderate
Landform Pattern:	Floodplain/Terrace	**Drainage:**	Imperfectly drained
Landform Element:	Valley floor	**Rock Outcrop:**	0
Slope a) common:	5%	**Depth to Hard Rock:**	>2 m
Slope b) range:	0-9%	**Present Land Use:**	Grazing
Potential Recharge to Groundwater:	Moderate		
Major Native Vegetation Species:	Manna Gum, Blue Gum, Mountain. Ash, Yellow Box		

LAND DEGRADATION

Land Degradation	**Water Erosion**		**Wind Erosion**	**Mass Movement**	**Salting**	**Acidification**
	sheet/rill	**gully**				
Susceptibility	H	M	M	VL	L-M	L
Incidence						

B. SOIL PROFILE

PROFILE DESCRIPTION (Site 8 : Heavy profile)

A1	0-0.22 m	Dark yellowish brown (10YR3/6), organic light sandy clay loam, weak subangular blocky structure, weak consistence, little or no gravel, pH of 6.0 clear transition to
A2	0.22-0.35 m	Yellowish Brown (10YR5/4), light sandy clay loam, weakly structured, subangular blocky/massive, moderately weak consistence, pH 6.5. Clear transition to
B21	0.35-0.5 m	Dark Yellowish brown/Very dark greyish brown (10YR4/4/10YR3/2) medium heavy clay, weak to moderately structured, angular blocky to subangular, smooth ped fabric, firm consistence, minor gravel, pH 7.0. Clear transition to
B22	0.5-0.6 m	Dark brown (10YR3/3), motlled (yellow and red) medium clay, weak subangular blocky structure, smooth ped fabric , firm consistence, gravelly, pH 7.0. Gradual transition to
B23	0.6-0.8 m	Dark brown (10YR3/3), mottled (red and brown), medium clay, weak subangular blocky structure, rough ped fabric, weak consistence, minor gravel,pH 7.0. Gradual transition to
B24	0.8-1.0 m+	Brown (10YR4/3) mottled medium clay, strong slaking, minor gravel, pH7.5. Continues.

CLASSIFICATION

Factual Key:	Db2.22/ Dd2.22
Australian Soil Classification:	Melanic, Eutrophic, Brown/black CHROMOSOL; thick, non-gravelly, loamy/clayey, deep
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($H_2O/CaCl_2$)	% Gravel	E.C. (salts)	Nutrient Status	P	K	Al	Organic matter	Dispersibility
A1	6.3/5.2	2	VL	L	D	S	S	M	VL
A2	6.3/5.4	1	VL	L	D	S	S	L	L
B21	6.9/5.9	2	VL	M	D	S	S	L	M
B24	7.8/6.6	0	VL	M	D	S	S	VL	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

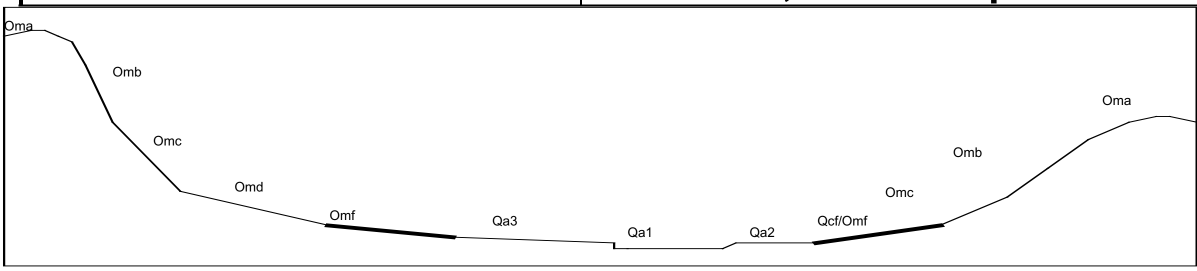
SOIL PROFILE CHARACTERISTICS:

Permeability:	Moderate (0.13 m/day)
Available Water Capacity:	Moderate (140 mm H_2O; top 1metre)
Linear Shrinkage (B horizon):	Low (12%)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature (s)/Land Use
Agriculture	$C_4T_3S_4$	Growing season, susceptibility to sheet & rill erosion
Effluent Disposal (septic tanks)	4	Drainage, flood return period, depth of seasonal watertable
Farm Dams	3-4	Permeability,depth of clay layer
Secondary Roads	4	Drainage, flooding risk, depth of seasonal watertable
Building Foundations		
slab	3	Drainage, depth of seasonal watertable, slope
stumps/footings	3	Drainage, depth of seasonal watertable

MAP UNIT SYMBOL: **Omf/Qcf**	MAP UNIT: **Ordovician metasediments, colluvium;Gentle slopes**



A. GENERAL DESCRIPTION

These are gently sloping map units between 3-10% slope but cover a range of landform such as lower slopes with shallow soils often dissected, as well as colluvial slopes with deeper soils (Qcf) and minor drainage depressions. These land units potentially provide a range of land use options, which are dependent on the iinternal variation of the unit. Soil types range from the shallow (Rudosols, Tenosols) to the deeper, often duplex soils (Chromosols), some with A2 horizons and the very clayey duplex profiles described below (site 21). Most soil profiles have neutral or slightly acidic pH trends. Native vegetation includes Yellow Box with White Box in higher and drier positions.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician/Quaternary	**Depth to Seas. Watertable:**	
Parent Material Lithology:	sediments/colluvium	**Flooding Risk:**	L
Landform Pattern:	Mountain/Piedment	**Drainage:**	P-MW?
Landform Element:	Lower slope	**Rock Outcrop:**	-
Slope a) common:	7	**Depth to Hard Rock:**	0.2-1.5m
Slope b) range:	3-10	**Present Land Use:**	Grazing
Potential Recharge to Groundwater:	M		
Major Native Vegetation Species:	Yellow Box, White Box		

LAND DEGRADATION

Land Degradation	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	M-H	M	L	L	L-M	L
Incidence						

B. SOIL PROFILE

PROFILE DESCRIPTION (Site 21)

A1 0-0.15 m Dark reddish brown (5YR3/4) humic light sandy clay loam, moderate subangular blocky structure, rough ped fabric, weak consistence, gravelly, pH 6.0. Clear transition to

B2 0.15-0.8 m+ Dark red (2.5YR3/6) heavy clay strong angular blocky/prismatic structure, smoothped fabric,very firm consistence,slightly gravelly, pH 7.0. Continuing

CLASSIFICATION

Factual Key:	Dr2.12/Dr4.12
Australian Soil Classification:	Haplic, Eutrophic, Red, CHROMOSOL; medium, gravelly, silty/clayey, moderately deep/deep
Unified Soil Group:	CH

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($H_2O/CaCl_2$)	% Gravel	E.C. (salts)	Nutrient Status	P	K	Al	Organic matter	Dispersibility
A1	6.7/5.6	11	VL	M	D	S	S	H	VL
B2	7.8/6.8	0	VL	H	D	S	S	L	VL

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

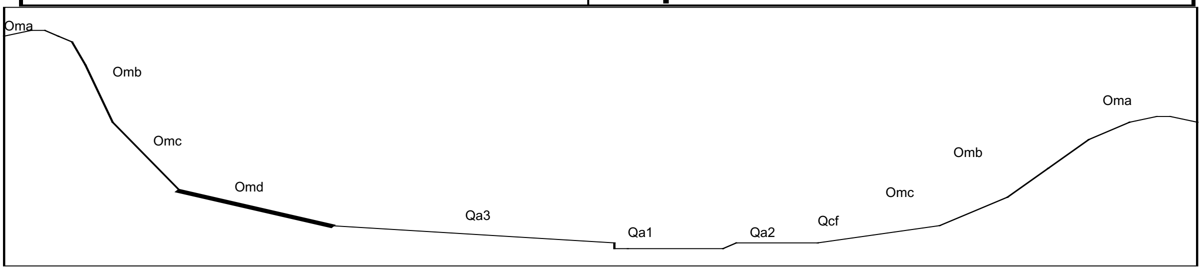
SOIL PROFILE CHARACTERISTICS:

Permeability:	Very low (<0.01 m/day)
Available Water Capacity:	Moderate (140mm H_2O; for top 1 m)
Linear Shrinkage (B horizon):	high (20%)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature (s)/Land Use
Agriculture	$C_4T_3S_4$	Growing season, permeability
Effluent Disposal (septic tanks)	3-5	Drainage, Permeability
Farm Dams	3-4	Dispersibilty (Stable Structure)
Secondary Roads	4	Linear shrinkage
Building Foundations		
slab	3	Coefficient of linear shrinkage, drainage, depth of seasonal watertable
stumps/footings	3	Drainage, depth of seasonal watertable

MAP UNIT SYMBOL: **Omd**	MAP UNIT: **Ordovician metasediments moderate slopes**



A. GENERAL DESCRIPTION

These map units have moderate slopes (11-20%) and generally are in lower slope positions as part of the concave section of most of the Mountain terrain. These map units which are generally limited in size may have a range of features such as shallow soils on rocky ridges a well as colluvial accumulations with deeper soils and minor infilled drainagelines, dissecting these lower slopes. Soil types include shallow unifom textured (Tenosols), deep red and brown duplex (Chromosols) and occassional gradational profiles (Dermosols), most with neutral pH trends and some parent material angular gravel. Native vegetation is predominantly White Box and Yellow Box, however most of this land has been cleared.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician/Quaternary	**Depth to Seas. Watertable:**	
Parent Material Lithology:	Metasediments, colluvium	**Flooding Risk:**	Low
Landform Pattern:	Mountain	**Drainage:**	Well drained
Landform Element:	Lower slope	**Rock Outcrop:**	Very Low
Slope a) common:		**Depth to Hard Rock:**	0.3-1.5m+
Slope b) range:	11-20%	**Present Land Use:**	Grazing
Potential Recharge to Groundwater:	Low-Moderate		
Major Native Vegetation Species:	Yellow Box, White Box		

LAND DEGRADATION

Land Degradation	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	H	M	M-H	M	L	L-M
Incidence						

B. SOIL PROFILE

PROFILE DESCRIPTION (Site 35)

A11	0-0.13 m	Dark reddish brown (5YR3/2) organic loam with fine sand, moderate subangular blocky structure, earthy fabric, weak consistence, slightly gravelly, pH 6.0. Clear transition to
A12	0.13-0.27 m	Dark reddish brown (5YR3/2) humic fine sandy loam, weak subangular blocky structure, rough ped fabric, gravelly, pH 6.0. Clear transition to
A2	0.27-0.5 m	Dark brown (7.5YR4/3) heavy sandy loam, massive/weak structure, earthy fabric, firm consistence, gravelly, pH 6.5. Clear/gradual transition to
B2	0.5 -0.8 m	Dark reddish brown (5YR3/4) fine sandy clay,strong angular blocky/prismatic structure, smoothped fabric, firm consistence, gravelly, pH 7.0. Clear transition to
B3	0.8-1.2 m	Reddish brown (5YR4/4) sandy clay, moderate angular blocky/prismatic structure, roughped fabric, firm consistence, very gravelly, pH7.0. Variable transition to parent material
C/R	1.2 m+	Weathered parent material

CLASSIFICATION

Factual Key:	Dr4.22/Dr2.22
Australian Soil Classification:	Melanic, Eutrophic, Red CHROMOSOL; thick, gravelly, loamy/clayey, deep
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS* (SITE 34)

Horizon	pH ($H_20/CaCl_2$)	% Gravel	E.C. (salts)	Nutrient Status	P	K	Al	Organic matter	Dispersibility
A1	6.7/6.0	45	L	M	S	S	S	H	VL
A2	5.9/4.2	29	VL	L	D	S	S	L	VL
B21	6.6/5.6	37	VL	M	D	S	S	L	M
B22	6.5/5.5	36	VL	M	D	S	S	VL	M
B23	7.2/6.2	31	VL	M	D	S	S	VL	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

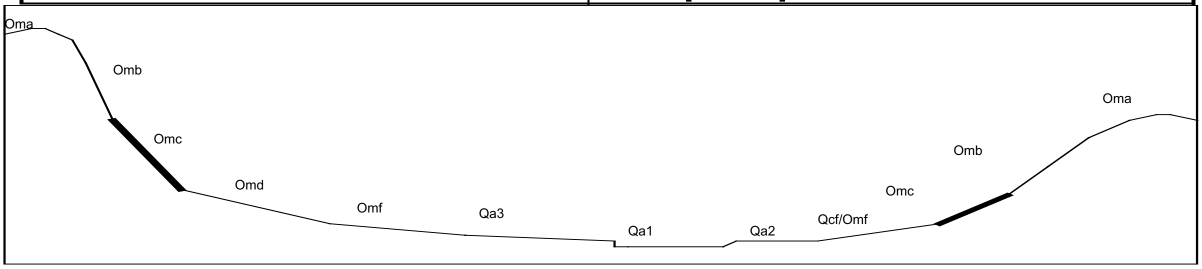
SOIL PROFILE CHARACTERISTICS: (SITE 34, SITE 35)

Permeability:	Moderate to slow (105mm/day)
Available Water Capacity:	Moderate to Very high (140 mm for top 1 metre, 215 mm+ for profile)
Linear Shrinkage (B horizon):	Low-medium (11-13%)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature (s)/Land Use
Agriculture	$C_4T_4S_3$	Growing season, slope, gravel, wind erosion, available water capacity, topsoill condition, susceptibility to sheet & rill erosion
Effluent Disposal (septic tanks)	3	Slope
Farm Dams	4	Slope, permeability, susceptibility to slope failure
Secondary Roads	4	Slope, susceptibility to slope failure
Building Foundations		
slab	4	Slope, proportion of stones, susceptibility to slope failure
stumps/footings	3-4	Slope, proportion of stones

MAP UNIT SYMBOL: **Omc (i)**	MAP UNIT: **Ordovician metasediments moderately steep slopes**



A. GENERAL DESCRIPTION

These map units have moderately steep slopes (21-32%) in lower to mid slope positions as part of the concave to middle section of most of the Mountain terrain or occassionally upper slopes. These land units which are generally limited in size may compose a range of features such as shallow soils on rocky ridges a well as colluvial accumulations with deeper soils. This component (i) of the map unit has primarily deeper soils found on the lower slopes of the main valley. Soil types include deep red and brown duplex (Chromosols), occassionally gravelly and shallow, occassional gradational profiles (Dermosols) and shallow unifom textured (Tenosols) and most with neutral pH trends and shattered parent material angular gravel/stone based on colluvium. Native vegetation is predominantly White Box, however most of these land units have been cleared.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician	**Depth to Seas. Watertable:**	
Parent Material Lithology:	Metasediments, colluvium	**Flooding Risk:**	Very low
Landform Pattern:	Mountain	**Drainage:**	Well drained
Landform Element:	Lower,Middle slopes	**Rock Outcrop:**	-
Slope a) common:	24%	**Depth to Hard Rock:**	1.6m
Slope b) range:	20-32	**Present Land Use:**	Grazing
Potential Recharge to Groundwater:	Moderate		
Major Native Vegetation Species:	White Box, Yellow Box		

LAND DEGRADATION

Land Degradation	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	H	H	M-H	M	L	L-M
Incidence						

B. SOIL PROFILE

PROFILE DESCRIPTION (Site 34; colluvial)

A1	0-0.12 m	Dark reddish brown (5YR3/2) humic sandy loam, weak subangular blocky, earthy fabric, weak consistence, slightly gravelly, pH 5.5. Clear transition to
A2	0.12-0.25 m	Reddish brown (5YR5/5) sandy loam, apedal, massive, earthy fabric, firm consistence, slightly gravelly, pH 6.0. Clear transition to
B21	0.25-0.35 m	Dark red (5YR3/4) medium clay, strong angular blocky/prismatic structure, smoothped fabric, very strong consistence, gravelly, pH6.0. Clear transition to
B22	0.35-0.7 m	Strong brown (7.5YR4/6) light medium clay, mottled (faint, common, red), moderate prismatic structure, smooth ped fabric, firm consistence, moderately gravelly, pH 6.5. Gradual transition to
B23	0.7-1.2 m	Strong brown (7.5YR4/5) heavy clay, mottled (distinct, common, red & gray), weak to moderate prismatic structure, smooth ped fabric, firm consistence, moderately gravelly, pH 6.5. Gradual transition to
B/C	1.2-1.5 m+	Brown (7.5YR5/2) gritty medium clay, mottled (distinct, common, yellow & gray), weak angular blocky structure, smooth ped fabric, firm consistence, moderately gravelly, pH 7.0. Gradual transition to parent material at approximately 1.8-2 m

CLASSIFICATION

Factual Key:	Dr4.22
Australian Soil Classification:	Haplic, Eutrophic, Red CHROMOSOL; medium, slighly gravelly, loamy/clayey, deep
Unified Soil Group:	CL

INTERPRETATION OF LABORATORY ANALYSIS* (SITE 34)

Horizon	pH ($H_2O/CaCl_2$)	% Gravel	E.C. (salts)	Nutrient Status	P	K	Al	Organic matter	Dispersibility
A1	6.7/6.0	45	L	M	S	S	S	H	VL
A2	5.9/4.2	29	VL	L	D	S	S	L	VL
B21	6.6/5.6	37	VL	M	D	S	S	L	M
B22	6.5/5.5	36	VL	M	D	S	S	VL	M
B23	7.2/6.2	31	VL	M	D	S	S	VL	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

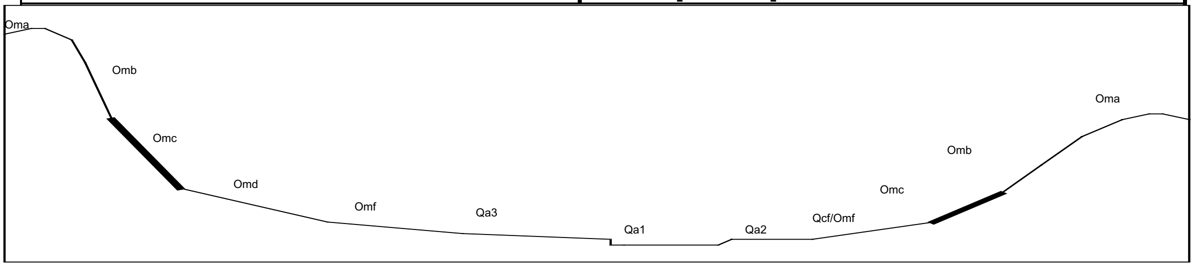
SOIL PROFILE CHARACTERISTICS:

Permeability:	Moderate (0.1 m/day); Site 35
Available Water Capacity:	Moderate to Very high (140 mm for top 1 metre, 210 mm for profile)
Linear Shrinkage (B horizon):	Low-Moderate (11-13%)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature (s)/Land Use
Agriculture	$C_4T_4S_3$	Growing season, slope
Effluent Disposal (septic tanks)	4	Slope
Farm Dams	5	Slope
Secondary Roads	4	Slope, susceptibility to slope failure
Building Foundations		
slab	4	Slope, proportion of stones
stumps/footings	4	Slope, proportion of stones

MAP UNIT SYMBOL: **Oms**	MAP UNIT: **Ordovician metasediments moderately steep slopes**



A. GENERAL DESCRIPTION

These land units have moderately steep slopes (21-32%) predominantly in lower to mid slope positions as part of the concave to middle section of most of the Mountain terrain or occassionally upper slopes. These land units which are generally limited in size may compose a range of features such as shallow soils on rocky ridges a well as colluvial accumulations with deeper soils. This component (ii) of the map unit has primarily shallow soils with the main examples are lower in the catchment in Shelton Gully. Soil types include shallow stony unifom textured (Tenosols), shallow,stoney duplex (Chromosols),occassionally deep and occassional gradational profiles (Dermosols), most with neutral pH trends and shattered parent material. Native vegetation is predominantly White Box, however most of these land units have been cleared.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician	**Depth to Seas. Watertable:**	
Parent Material Lithology:	Metasediments	**Flooding Risk:**	Very Low
Landform Pattern:	Hill	**Drainage:**	Well drained
Landform Element:	Upper slope	**Rock Outcrop:**	Low
Slope a) common:	30%	**Depth to Hard Rock:**	0.25-0.5 m
Slope b) range:	26-32%	**Present Land Use:**	Grazing
Potential Recharge to Groundwater:			
Major Native Vegetation Species:	White Box, Yellow Box		

LAND DEGRADATION

Land Degradation	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	VH	M	H	L-M	L-M	M
Incidence						

B. SOIL PROFILE

PROFILE DESCRIPTION (Site 17)

A1	70 mm	Dark reddish brown (5YR3/2) humic, heavy fine sandy loam, weak subangular blocky structure, earthy fabric, very weak consistence, slightly gravelly, pH 6.0. Abrupt transition to
A2	160 mm	Dark yellowish brown (10YR4/4) sandy loam, massive, earthy fabric,very gravelly, pH unknown. Clear transition to
B2	240 mm	Dark red (2.5YR3/6) light medium clay, mottled (distinct, common, brown), moderate angular blocky structure, smooth ped fabric, gravelly, pH 7.0. Abrupt to
C/R	240 mm+	weathered parent material; schists, phyllites and sedimentary rock

CLASSIFICATION

Factual Key:	Dr5.22
Australian Soil Classification:	Haplic, Eutrophic, Red CHROMOSOL; thin, slightly gravelly, loamy/clayey,shallow
Unified Soil Group:	CL (estimate)

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($H_20/CaCl_2$)	% Gravel	E.C. (salts)	Nutrient Status	P	K	Al	Organic matter	Dispersibility
A1	5.1/4.5	68%	VL	VL	D	S	NA	H	VL
A2	NA	NA	NA	NA	NA	NA	NA	NA	NA
B2	NA	NA	NA	NA	NA	NA	NA	NA	NA

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

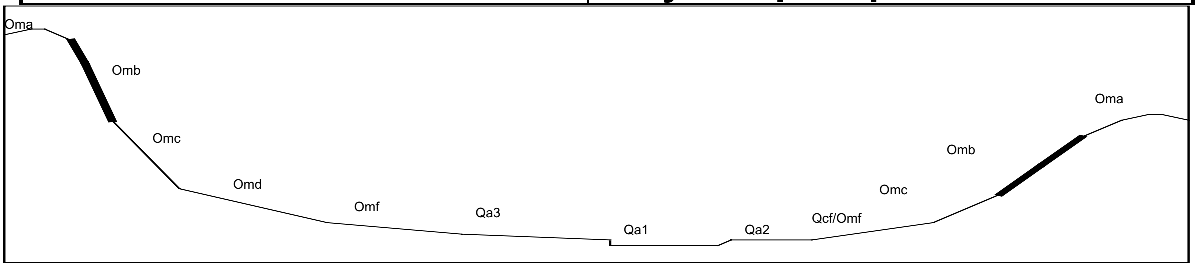
SOIL PROFILE CHARACTERISTICS:

Permeability:	Moderate (0.4 m/day; site 15)
Available Water Capacity:	Very low (40 mm)
Linear Shrinkage (B horizon):	7-11 (estimate)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature (s)/Land Use
Agriculture	$C_4T_4S_5$	Soil depth, susceptibility to sheet & rill erosion
Effluent Disposal (septic tanks)	5	Depth to impermeable layer
Farm Dams	5	Slope, depth of clay layer, depth to hard rock
Secondary roads	4	Slope, depth to impermeable layer, proportion of stones
Building Foundations		
slab	4	Depth to hard rock, slope, proportion of stones
stumps/footings	4	Depth to hard rock, slope, proportion of stones

MAP UNIT SYMBOL: **Omb**	MAP UNIT: **Ordovician metasediments steep and very steep slopes**



A. GENERAL DESCRIPTION

These land units have steep to very steep slopes (>32%) in mid to upper slope positions often as part of the convex to middle section of most of the Mountain terrain or occassionally river terrace sides. These land units which are extensive may compose a range of features such as shallow soils on rocky terrain which vary according to aspect and lithological controls. Soil typesare predominantly shallow unifom textured (Tenosols), shallow and often stoney and brown duplex (Chromosols) and occassional gradational profiles (Dermosols, Kandosols), most with neutral pH trends and parent material angular gravel/stone. Native vegetation is predominantly White Box of varying size. These are generally the most erosion prone land units, particularly for sheet erosion.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician	**Depth to Seas. Watertable:**	
Parent Material Lithology:	metasediments	**Flooding Risk:**	Very low
Landform Pattern:	Mountain	**Drainage:**	Rapidly drained
Landform Element:	Mid and upper slope	**Rock Outcrop:**	Low (crests)
Slope a) common:	46%	**Depth to Hard Rock:**	0-600 mm
Slope b) range:	32-80%	**Present Land Use:**	Conservation
Potential Recharge to Groundwater:			
Major Native Vegetation Species:	White Box, Yellow Box		

LAND DEGRADATION

Land Degradation	**Water Erosion**		**Wind Erosion**	**Mass Movement**	**Salting**	**Acidification**
	sheet/rill	**gully**				
Susceptibility	VH	M-H	M-H	H	L	L
Incidence						

B. SOIL PROFILE

PROFILE DESCRIPTION (Site 5)

A1	120 mm	Dark brown (7.5YR3/2) humic sandy loam, weak subangular structure, earthy fabric, weak consistence, gravelly and pH 6.5. Clear transition to
B2	550 mm	Strong brown (7.5YR4/5) sandy loam, weak subangular blocky, rough ped fabric, weak consistence, moderately gravelly and pH 7.0. Clear varible transition to
C/R	600 mm+	shattered parent material

CLASSIFICATION

Factual Key:	Dominant; Uc5.21 Also Gn2.22, Um5.51, Dr4.22
Australian Soil Classification:	Basic, Lithic, Orthic, TENOSOL; medium, gravelly, loamy/loamy, shallow
Unified Soil Group:	ML

INTERPRETATION OF LABORATORY ANALYSIS* (SITE 5)

Horizon	pH ($H_20/CaCl_2$)	% Gravel	E.C. (salts)	Nutrient Status	P	K	Al	Organic matter	Dispersibility
A1	5.8/5.1	6	VL	M	S	S	S	H	VL
B2	6.8/5.8	32	VL	L	D	S	S	VL	L

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

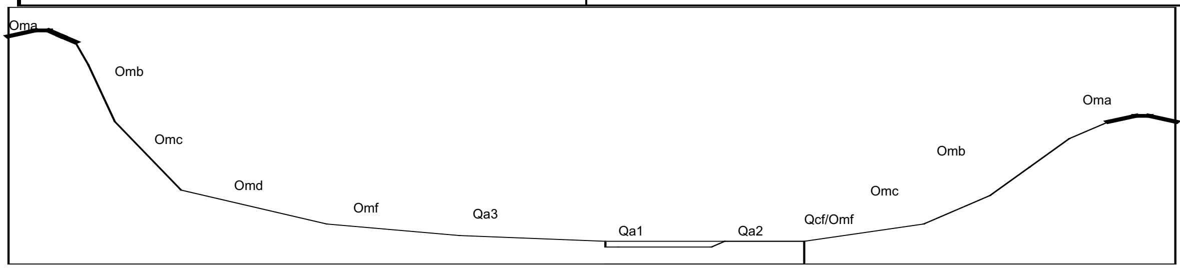
SOIL PROFILE CHARACTERISTICS:

Permeability:	Moderate (Estimate)
Available Water Capacity:	Low (80 mm)
Linear Shrinkage (B horizon):	Very Low (2%)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature (s)/Land Use
Agriculture	$C_4T_5S_{4-5}$	Slope, soil depth, susceptibility to sheet & rill erosion
Effluent Disposal (septic tanks)	5	Slope, depth to hard rock, depth to impermeable layer
Farm Dams	5	Slope, depth of clay layer, depth to hard rock, slope instability, subsoil suitability
Secondary Roads	5	Slope, depth to hard rock
Building Foundations		
slab	5	Slope
stumps/footings	4-5	Slope, slope failure risk

MAP UNIT SYMBOL: **Oma**	MAP UNIT: **Ordovician metasediment crests**



A. GENERAL DESCRIPTION

These land units have gentle to moderate slopes with steep to very steep sideslopes as part of the upper section of the Mountain terrain or occassionally as lower crests. These land units which are not extensive have shallow soils on rocky terrain which vary according to lithological controls. Soil types are predominantly shallow unifom textured (Tenosols), shallow and occassionally stony and brown duplex (Chromosols) and gradational profiles (Dermosols, Kandosols), most with acid or neutral pH trends and parent material angular gravel/stone. Native vegetation is predominantly White Box, generally of low height.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician	**Depth to Seas. Watertable:**	
Parent Material Lithology:	Metasediments	**Flooding Risk:**	Very low
Landform Pattern:	Mountain	**Drainage:**	Rapidly drained
Landform Element:	Crest	**Rock Outcrop:**	Low
Slope a) common:	10%	**Depth to Hard Rock:**	0-500 mm
Slope b) range:	0-15%	**Present Land Use:**	Conservation
Potential Recharge to Groundwater:	High		
Major Native Vegetation Species:	White Box		

LAND DEGRADATION

Land Degradation	Water Erosion		Wind Erosion	Mass Movement	Salting	Acidification
	sheet/rill	gully				
Susceptibility	H	M	H	L	VL	L
Incidence						

B. SOIL PROFILE

PROFILE DESCRIPTION (Site 23)

A1	100 mm	Dark brown (7.5YR3/3) humic fine sandy loam, weak subangular blocky, earthy fabric weak consistence, slight water repellancy, moderately gravelly, pH 4.5. Clear transition to
B2	300 mm	Brown (7.5YR4/4) fine sandy loam, rough ped fabric, weak consistence, slight water repellancy, moderately gravelly, pH 5.0. Gradual varible transition to parent material.

CLASSIFICATION

Factual Key:	Um5.51
Australian Soil Classification:	Acidic, Lithic,Orthic TENOSOL; thin, moderately gravelly, loamy/loamy,shallow
Unified Soil Group:	ML, SM

INTERPRETATION OF LABORATORY ANALYSIS* (ESTIMATES)

Horizon	pH ($H_20/CaCl_2$)	% Gravel	E.C. (salts)	Nutrient Status	P	K	Al	Organic matter	Dispersibility
A1	4.5/NA	20	VL	VL	D	NA	T	M	VL
B2	5.0/NA	40	VL	VL	D	NA	T	VL	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

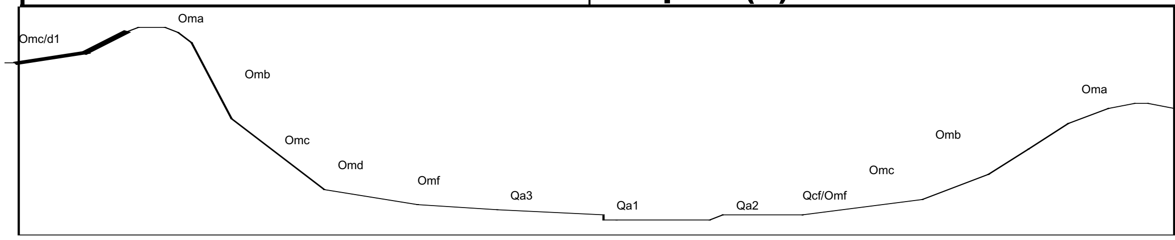
SOIL PROFILE CHARACTERISTICS:

Permeability:	Moderate (estimate)
Available Water Capacity:	Very Low (50 mm)
Linear Shrinkage (B horizon):	2% (estimate)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature (s)/Land Use
Agriculture	$C_4T_3S_5$	Soil depth, available water capacity
Effluent Disposal (septic tanks)	5	Depth to hard rock
Farm Dams	5	Depth to hard rock, depth of clay layer
Secondary Roads	4	Depth to hard rock, proportion of stones
Building Foundations		
slab	5	Depth to hard rock, proportion of stones
stumps/footings	5	Depth to hard rock, proportion of stones, USG B horizon

MAP UNIT SYMBOL: **Omc/d1**	MAP UNIT: **Ordovician Metasediments moderate/moderately steep slopes (1)**



A. GENERAL DESCRIPTION

These units are located at a higher elevation compared to those in the Cassilis Valley and straddle the Divide. They have a north-westerly aspect and were not subject to the same downcutting processes which resulted in the Cassilis Valley. These units consist of undulating terrain (not incised here) with variable depth to various metasediments (schists,gneiss) with consequent variable soil development. Soil types are predominantly acidic yellow and brown Duplex (Chromosols, Kurosols) and some Uniform, coarse soil (Tenosols), generally gravelly/stony. Native vegetation has an overstorey of Candlebark (*Eucalyptus rubida*, Snow Gum (*E.pauciflora*), Narrowleaved Peppermint (*E.radiata*) and Mountain Gum (*E.dalrympleana)* with *Poa* and *Hibbertia spp.* as understorey.

SITE CHARACTERISTICS

Parent Material Age:	Ordovician	**Depth to Seas. Watertable:**	
Parent Material Lithology:	Metasediments	**Flooding Risk:**	Very low
Landform Pattern:	Hill, Plateau	**Drainage:**	Well -imperfectly drained
Landform Element:	Mid and lower slope	**Rock Outcrop:**	
Slope a) common:	15%, 21%	**Depth to Hard Rock:**	450-1200 mm
Slope b) range:	10-16%, 18-27%	**Present Land Use:**	Grazing/subdivision
Potential Recharge to Groundwater:			
Major Native Vegetation Species:	Candlebark, Narrowleaved Peppermint, Mountain Gum		

LAND DEGRADATION

Land Degradation	Water Erosion sheet/rill	gully	Wind Erosion	Mass Movement	Salting	Acidification
Susceptibility	H	M-H	M-H	M	M	L-M
Incidence						

B. SOIL PROFILE

PROFILE DESCRIPTION (Site 3)

A11	100 mm	Dark brown (10YR3/1) humic sandy loam, weak subangular blocky, earthy fabric, very weak consistence, moderate water repellancy, gravelly, pH 7.0. Sharp transition to
A12	400 mm	Dark reddish gray (5YR4/2) humic heavy sandy loam, weak subangular blocky, earthy fabric, weak consistence, moderate water repellancy, gravelly, pH 5.0. Clear transition to
A2	600 mm	Strong brown (7.5YR5/6) light sandy clay loam, apedal, massive, weak consistence, moderate-very gravelly, pH 5.5. Clear transition to
B21	1000 mm	Yellowish red (5YR5/6) medium clay, yellow (distinct), brown and red (faint) mottles, strong angular blocky/prismatic structure, smooth ped fabric, firm consistence, gravelly, pH 5.5. Gradual transition to
B22/B3	1200 mm	Bownish yellow (10YR6/6) medium clay, red and light gray (faint)mottles, strong prismatic/angular blocky structure, smooth ped fabric, firm consistence, moderately gravelly, pH 5.5. Gradual transition to parent material

CLASSIFICATION

Factual Key:	Dy3.21
Australian Soil Classification:	Melacic-mottled, Magnesic, Red, CHROMOSOL; thick, gravelly, loamy/clayey, deep
Unified Soil Group:	MH

INTERPRETATION OF LABORATORY ANALYSIS*

Horizon	pH ($H_20/CaCl_2$)	% Gravel	E.C. (salts)	Nutrient Status	P	K	Al	Organic matter	Dispersibility
A11	6.3/5/4	30	VL	L	S	S	S	VH	VL
A12	5.3/4.2	17	VL	VL	D	D?	T	H	VL
A2	NA	NA	NA	NA	NA	NA	NA	NA	NA
B21	5.8/4.2	3	VL	L	D	S	T	VL	L
B22/B3	NA	NA	NA	NA	NA	NA	NA	NA	NA

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:	High (630 mm/day)
Available Water Capacity:	High (150 mm for top 1 metre, 175 mm for profile)
Linear Shrinkage (B horizon):	Moderate (14%)

C. LAND CAPABILITY ASSESSMENT

Land Use	Class	Major Limiting Feature (s)/Land Use
Agriculture	$C_4T_4S_{3-4}$	Growing season, slope, depth to rock, gravel content, susceptibility sheet, rill & gully erosion
Effluent Disposal (septic tanks)	3-4	Slope
Farm Dams	3-4	Slope, depth to hard rock
Secondary Roads	4	Slope
Building Foundations		
slab	4	Slope
stumps/footings	3-4	Depth to hard rock, slope, proportion of stone

4. DESCRIPTION OF TXE ENVIRONMENT

4.1 Overview

4.1.1 Physiography and Geology

The Cassilis Valley is at the head of the Divide and has dissected into Ordovician metasediments with some granitic outcrops nearby (ie. Brookville). This dissection (most slopes over 40%) contrasts with the gentler terrain to the northwest of the Divide (Cassilis Gap). The main stream flows southeast to Tongio Munjie West and then heads more easterly. The Valley broadens out a little particularly after Riley's Creek with a number of tributaries joining the main valley before joining the main Tambo Valley.

4.1.2 Climate

The regional climate is dominated by a rain shadow effect which results in lowered rainfall with Omeo (677 m asl) receiving an annual average rainfall of 682 mm, Swifts Creek (260 m asl) 627 mm, Tongio (320 m asl) 657 mm and Brookville (750 m asl) 794 mm (Bureau of Meteorology 1988). Cassilis (500 m asl) received an annual average of 826 mm (1988-94); the long term average is probably closer to 800 mm or less. The rainfall is generally greatest in the spring but there are often significant falls in the summer as thunderstorms, which are erosive and less effective for plant growth.

The rainfall in the Cassilis Valley varies, with greater rainfall at Cassilis compared to Swifts Creek. Rainfall in combination with temperature, has an effect on vegetation type and distribution, due to elevation and topography. Note the higher rainfall averages for Brookville and Cassilis compared to Swifts Creek and Omeo.

For Omeo and Cassilis, average daily maximum temperatures range from 25.8°C (27.5°C) in January to 10°C (11.6°C) in July and average daily minimum temperatures range from 9.6°C (12.4°C) in February to -0.3°C (2.3°C) in July. The Cassilis values for January and July are in the brackets.

The growing season ranges between 2 to 5 months according to location and annual fluctuations. Frost occurrence and occasional snow falls are also considerations.

4.1.3 Vegetation

The remnant native vegetation at the Cassilis Gap (780 m asl) is Sub-alpine Woodland-Montane Open Forest characterised by Snow Gum (*Eucalyptus pauciflora*) with Candlebark (*E. rubida*) as a frequent associate and Broad-leaved Peppermint (*E. dives*) occasionally present with some scattered Mountain Gum (*E. dalrympleana*). The middle storey consists of Blackwood (*Acacia melanoxylon*) and Silver Wattle (*A dealbata*) and an understorey which varies from grasses with scattered shrubs to densely shrubby; *Themeda* spp., *Poa* spp., *Hibberta* spp., Tall Rice Flower (*Pimelea ligustrina*), Handsome Flat-Pea (*Platylobium formosum*), *Leucopogon* spp., Woolly Grevillea (*Grevillea lanigera*), Dogwood (*Cassinia aculeata*), Dusty Daisy Bush (*Olearia phlogopappa*) and Rough Coprosma (*Coprosma hirtella*).

Further down the valley (0.6km) Red Stringybark (*E. macrorhyncha*) appears with Wild Cherry (*Exocarpus cupressiformis*) and Lightwood (*A. implexa*) in the Candlebark-Narrowleaf Peppermint (*Eucalyptus radiata)* alliance as the Snow Gums disappear. At 1.4 km from the Gap the main valley is dominated by Blue Gum (*E. globulus*) with White Box (*E. albens*) and Red Box (*E. polyanthemos*) emerging on the drier slopes. In the understorey Bursaria (*Bursaria spinosa*), Shiny Cassinia (*Cassinia longifolia*) and Black Wattle (*A. mearnsii*) contribute to the species diversity.

At approximately 3 km from the top of the catchment Yellow Box (*E. melliodora*) is evident along the roadside and Blue Gum continues in the gully. The accompanying species include White Box, Red Box, Lightwood and Blackwood.

Further on, a cleared section with cropped alluvial flats occurs, with poplars and willows along the river.

At the Cassilis bridge (No.2), 530 m asl, the native vegetation returns with Blue Gum along the river while Yellow, White and Red Box and their Acacia understorey occur on the drier slopes. Further down the valley Long leaved Box (*E. nortonii*) becomes noticeable.

At Tongio Munjee West (Grey's Bridge No.1), 400 m asl, the density of Blue Gum decreases and Manna Gum (*E. viminalis*) becomes dominant on the valley floor. The Box Woodland/Open Forest on the slopes consist largely of Red Box and White box with Blackwood and Black Wattle in the second stratum. The understorey is sparse with Shiny Cassinia and Bursaria as the key species. This vegetation continues down the remaining section of the catchment more or less diminishing as cleared land becomes the dominant land feature.

4.2 Map Unit Group Descriptions

4.2.1 Quaternary Alluvial Map Units

The alluvial map units occur along the major drainagelines which are generally tightly controlled by the surrounding terrain. The major alluvial unit is the Cassilis valley with the headwaters consisting of Grays Creek which is joined by Swifts Creek at Tongio Munjie West, coming from the south. The Cassilis valley alignment is from northwest to southeast becoming east. A number of tributaries of variable size enter the main valley system, including Stockyard Creek, Riley Creek and Shelton Gully. The larger tributaries are lower down the catchment.

Within the main alluvial unit, there are a number of components such as terraces (up to two levels) as well as the floodplain which are difficult to identify separately at this mapping scale and have been altered in the past by human activity. Tributary drainage lines also have terraces as well as being incised in places.

Gold prospecting during the nineteenth century was responsible for significant disturbance in this area. This entailed bringing material to the stream to be washed as well as panning the alluvial material. The streams have been diverted and/or dammed as part of this process. There are a number of waste dumps near the major stream. The stream environs are often intensively used or altered as in the case of dam construction in the upper part of the catchment and other uses including a winery. This valley supplies the local residents with water. The quality of the water is not consistently suitable for human consumption. The quantity of water available when required is also a local issue.

The alluvial terraces have generally medium or coarse textured soils with thick organic rich surface soils which overlie coarser (loamy sand) or deep dark medium textured profiles which have neutral pH, occasionally alkaline at depth (Tenosols; Kandosols; Isbell, 1994). There may also be sand and gravel deposits. The tributaries have a range of profiles including subangular gravel in headwater situations (basically colluvium), duplex profiles (Chromosols), which reflect other colluvial processes and longer term deposition with the further build up of organic deposits which have come from the surrounding terrain. The organic and clay deposition has resulted in dark duplex or approximate to fine uniform profiles (clays). Soil drainage is generally well drained apart from the heavier soil textures.

The vegetation is primarily riparian with an intergrade on the edge of these units. The vegetation is often very diverse in a number of depositional areas which have been stable for some time. The major overstorey species is Manna Gum (*E. viminalis*) with some Blue Gum (*E. globulus*), Mountain Ash (*E. regnans*), Yellow Box (*E. melliodora*) and White box (*E. albens*) which is associated with the surrounding metamorphic geology.

The degree of disturbance in these units has resulted in a redistribution of sediment, particularly since gold prospecting (and dredging occurred). Bank erosion as well as aggradation occur. This situation is exacerbated by the surrounding steep terrain and occurrences of summer thunderstorms which produce high peak flows.

LAND MANAGEMENT CONSIDERATIONS

The major considerations for these Units are flooding risk, sedimentation and water quality and quantity.

As mentioned above these land units are prone to occasional flooding with high peak flows which affect access to local residences, and causes deposition and erosion. Most of the major floodplain is native vegetation with cleared land and residences on terraces.

Flooding also brings sediment which is often trapped in dams on or near the major drainageline. There is often limited floodplain width to accommodate high peak flows, which also has implications for residential development. Flooding may move coarse and fine material, with gravel and stone moved less distance down the drainagelines which afeects on site developments as well as downstream effectson habitat and development.

Existing terraces provide some of the most fertile land in the area with uses such as grazing and intensive horticulture (orchards and vines). The location of the majority of residences in the Cassilis valley is close to the major streams which highlights issues of water supply (quantity and quality), effluent disposal, environmental quality (and habitat) and weeds.

The effect of development, including intensive agricultural industries on the whole catchment needs to be considered, particularly the impact downstream.

4.2.2 Ordovician Metasediments; Gentle to Moderately Sloping Map Units

These map units have gentle (3-10%) to moderate (10-20%) slopes based mainly on Ordovician metasediments: metamorphic rocks such as schist, phyllites and some hornfels/hornblende, gneiss, slate and relatively unaltered sediments. Also included in this group of units are colluvium and minor alluvium components associated with these slopes.

These units are associated with the lower slopes of the terrain apart from crests, which are generally small in size and occurrence. These units occur above the Alluvial complex with steeper land units and crests above. These units are more spatially confined in the upper section of the Cassilis Valley, whereas they are more extensive lower in the Valley around the Riley Creek and Shelton Gully areas.

These units represent some of the more useable land in the Valley and have been used for a range of purposes in the past, residential or agricultural. They are nearly all cleared and therefore there is some disturbance, particularly the topsoil. Current land use is grazing with mainly sheep, some cattle and an Angora goat stud farm.

The soil types vary mainly in relation to topographical position, with the deeper profiles on the lower, gentler slopes. Soil types range from very stony shallow Uniform coarse and medium textured soils (Rudosols and Tenosols) on crests and spurs to deep red Duplex soils (Chromosols) on lower slopes, particularly with a high colluvial component. The latter have variable gravel/stone content and often exhibit an A2 horizon which overlies the clayey B horizon.

Many of these soils do not seem to exhibit much structure apart from the clayey B horizons and the A1 horizon (organic rich surface). Some of these soils may be susceptible to sheet erosion depending on the catchment area, slope, surface organic matter, vegetation and land use.

The vegetation is predominantly White Box woodland (*E. albens*) where not cleared with occasional Yellow Box (*E. melliodora*) and a grassy understorey (*Poa spp*.). There may be local variations given soil depth, aspect and other factors such as lithology (outcropping or tilted rock structures). The species may be basically the same but height and growth rates seem to be affected by these variables.

While susceptibility to sheet erosion may be important on some of the shallower sites, aggradation is also occurring, resulting in the build up of colluvial profiles.

Other metamorphic based units occur on the Divide and on the northern aspect and may have a different lithology (gneissic). These are at a higher altitude and have slightly different soil to the Valley metamorphic terrain and different vegetation such as Candlebark (*E. rubida*) and minor Snow Gum (*E. pauciflora*). Soil types are generally either moderately deep Duplex (Sodosols) or shallower Uniform medium (Tenosols).

LAND MANAGEMENT CONSIDERATIONS

These units comprise most of the better land in the Valley, given gentle slopes, low risk of flooding and favourable accessiblilty.

Risk of inundation may be moderate to high on some of the lower colluvial slopes and minor drainage lines. Soil depth may vary considerably between the highest and lowest areas (deeper soil) of the land units. The variation in soil depth and therefore likely clay accumulation is important for the location of suitable dam sites as is the dispersibility of the soil. This is generally a problem in granitic and similar lithological material. Although some strongly structured clays may not be dispersive enough for this use.

The variability of soil depth is also relevant for building (foundations) and effluent disposal. There needs to be sufficient soil depth (and limited stoniness) in sufficient continuous spatial quantity for the effective disposal of effluent. These factors are also important for the retention of nutrients from effluent disposal systems before they are able to enter the stream system.

The disturbance of these units has meant that pest plants such as St Johns Wort (*Hypesicum perforatum*) can be a problem.

4.2.3 Ordovician Metasediments; Moderately Steep to Steep Slope Map Units

These map units have moderately steep (20-32%) to Steep (>32%) slopes including very steep slopes (>56%)and make up a large proportion of the Valley, particularly higher up in the catchment.

These units comprise the mid and upper slopes of the terrain, basically an erosional landscape apart from the micro-deposition of material (terracettes, creep) as material moves down slope after rainfall. These units have long slope lengths of either convex upper slopes or straight simple slopes which facilitate water and sediment movement downslope. These units are located around the Cassilis Valley and are particularly dominant in the upper half of the Valley.

The land use in these Valley units is either public land or mainly uncleared freehold. Some freehold has been cleared in the past, generally on the lower, less steep slopes and for extensive grazing; generally sheep but one goat herd exists.

The vast majority of these units is under native vegetation, comprising White Box woodland with White Box (*Eucalyptus albens*) with some Yellow Box (*E. melliodora*), Long-leaved Box (*E. nortonii*) and Apple Box (*E. bridgesiana*) in different locations. Aspect and topographic position seem to have an influence on tree growth. There may be other overstorey species in the upper drainagelines within these units. Ground cover is generally sparse particularly on the steeper slopes, more exposed slopes, including those with greater rock outcrop.

The soil types are predominantly shallow, stony uniform textured soils (Rudosols, Tenosols), occasionally a gradational or duplex texture trend down the profile (Chromosols and Kandosols). The surface soil is generally organic rich with some structure in the root zone. The soils have dark surfaces with brown to red weakly structured subsoils where the soil has developed beyond an organic horizon lying directly on rock. Soil depth varies according to topographic position and aspect and lithological variations such that a maximum soil depth of 40 cm on the steeper upper slopes may only be 1 m away from rock outcrop or very shallow soil (<10 cm). Soil depth on the lower slopes is about 0.5 m and nearly always <1 m.

These soil types are susceptible to sheet and rill erosion due to slope steepness, lack of vegetative cover and rainfall intensity (after long dry periods) rather than the erodibility of the surface soil. The subsoil may be moderately erodible. Stoniness and rock outcrop are significant in these land units. Minor slumping (terracettes) occurs as material is washed downslope and may accumulate against obstacles.

Other metamorphic based units occur on the Divide and on the northern aspect and may have a different lithology (gneissic). These are at a higher altitude and have slightly different soil to the Valley metamorphic terrain and different vegetation such as Candlebark (*E rubida*) and minor Snow Gum (*E. pauciflora*).

Soil types on the higher elevation terrain are Sodosols and Tenosols depending on subsoil development.

LAND MANAGEMENT CONSIDERATIONS

These land units are the most hazardous in the study area. The major considerations in these units revolve around slope steepness and other terrain factors. Slope steepness affects the physical ability to traverse the land but is important in limiting rainfall detention time and with consequent shallow soils also limiting the available water storage. This is aptly demonstrated by the vegetation type and growth (or lack of vegetation).

Vegetation cover is important for maintaining slope stability, so that even weed growth may be useful for cover, although seasonality of growth may be the most important factor influencing vegetative cover.

Disturbance of these land units for roading may leave exposures that will generate sediment. The limited soil depth and stoniness would be limiting for most uses and would provide more sediment into the stream system. This would affect water quality for domestic supply as well as habitat issues. There are some areas still affected by mining such as the Cassilis Mine area.

Some of the most erodible terrain in the area is the granitic area to the south, toward Brookville. Pest animals (such as rabbits) as well as plants can be a problem on the steeper terrain.

The metamorphic terrain north of the Divide is generally rolling gneissic terrain with low relative relief compared with the dissected Cassilis Valley. There is a small portion of this terrain in the study area which has different vegetation compared with the Valley given elevation and aspect (being on the Divide). This area has been cleared for subdivision with a number of dams already constructed.

Vegetation for this higher elevation area includes Woodland with Candlebark (*E. rubida*) and some Snow Gum (*E. pauciflora*) and Mountain Gum (*E. dalrympleana*).

Soil types are yellow, brown and red Duplex as well as minor Gradational and Uniform profiles with variable depth which makes activities such as dam construction and effluent disposal difficult to plan for.

Plate 1 Soil type: Uniform coarse; Site 5

Plate 2 Soil type: Red Duplex; Site 34

Plate 3 Soil type: Red Duplex; Site 35

Plate 4 Soil type: Uniform coarse; Site 36

5. DETAILED MAP UNIT DESCRIPTIONS AND CAPABILITY RATINGS

Eleven map units have been identified in the study area relating to the Cassilis Valley. Each map unit or complex of units is described in a 2-page format in terms of the geology, topography, dominant soil, and general site characteristics. It includes a table of land capability assessment for those land uses considered important by the Shire of East Gippsland, and estimates of susceptibility to erosion and recharge. The land capability assessment table also identifies the major limiting feature(s) for each land use.

Given the degree of variation and smallness of units the alluvial system has been mapped as a complex with descriptions of units to be found in the complex.

Maps depicting the map units and the land capability assessments for the nominated land uses have been produced.

Note:
As observations only go to a maximum of 2.0 m, the depth to hardrock and to seasonal watertable have been generalised.

The pH recorded in the profile descriptions is field pH. The pH recorded in the interpretation of laboratory analyses are pH ($CaCl_2$) or pH (H_2O) as indicated.

Plate 5 View across lower slopes to steep hills, north of Shelton Gully

6. ACKNOWLEDGEMENTS

The author would like to thank Catherine Clancy for assistance in the field and an assessment of vegetation composition. Also of great assistance were Grant Boyle, Peter Humphrey, Belinda McKane and Rod Goldie for their technical advice and support in the field, and Keith Reynard patiently entered the information into the GIS. Les Russell provided managerial and planning support, Evan Jones carryied out the physical laboratory analyses. Thanks to Grant Boyle and Evan Jones also for administrative support.

Thanks extend to the Municpality of East Gippsland staff for their support; particularly Ray McComb.

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

The land capability study for the Cassilis Valley was jointly funded by the Department of Conservation and Natural Resources (Land Protection Branch and Bairnsdale sub-Area) and the former Shire of Omeo.

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APPENDIX A NOTES TO ACCOMPANY LAND CAPABILITY RATING TABLES

A.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 components 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 the table 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 identify more accurately the dominant soil. The Land Systems (1: 250 000) data is from Rowan (unpublished) while the Gippsland Lakes data is from Aldrick *et al.* (1992).

Table A.1 Land Systems

(i) Land Systems of Victoria 1:250 000	**(ii) A Study of the Land in the Catchment to the Gippsland Lakes 1:100 000**		**(iii) Map Units in the Cassilis Valley 1:25 000**		
land system	**land system**	**major soil (PPF)**	**map units**	**soil (PPF)** major	minor
1.3 Gs710	Ml	Uc1,Uc5 Gn2,Um5	Qa1,Qa2 Orf	Uc5, Uc1, Uc4 Db2.4,Dy3.2 Gn4	Um7 Um7
1.3 Gg77	Do	Dr4,Dr2 Uc1,Uc5	Om3c	Db2.4, Dy3.2 Uc4	
1.3 Ss87	Te, Bf	Um1,Uc5, Gn2, Gn3 Um1,Uc5, Gn2, Gn3 Um1,Uc5, Gn2, Gn3 Um1,Uc5, Gn2, Gn3 Uc4, Gn4, Dy3	Oma Omb Omc Omd Omf	Um ,Uc Uc5, Um Dr2, Dr4 Dr2, Dr4 Dr	Um, Dr Um1, Um7 Dr ,Um

A.2 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.2)

Table A.2 Available Water Capacity

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				

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 2 metres.

Note that gravel content of the soil horizons should be taken into account.

Worked example:

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

TOTAL AMOUNT OF WATER: 167 mm (Class 2: see Table 2.3; Land capability for agriculture)

A.3 Bearing capacity

Measurements were not taken of bearing capacities. A simple, repeatable field measurement is being sought.

A.4 Coarse fragment sizes

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

A.5 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.6 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 5-class 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 5-class rating, (Table A.3).

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.7 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.8 Depth to seasonal watertable

The Septic Tank Code of Practice (Environment Protection Authority *et al.* 1990) requires a minimum of 1 m depth of unsaturated soil for the proper functioning of effluent disposal trenches. Ideally the groundwater table should be much lower than 1 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.

A.9 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.10 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.

Table A.3 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.11 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*. 1990) and direct relevance to effluent disposal fields, building foundations and secondary roads has this criterion been retained.

A.12 Electrical conductivity

The following correlation in Table A.4 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.4 The effects of soil salting on plant growth

Class	Severity of salting	E.C. dS/m $^{-1}$*	Site characteristics
1	Nil/Very low	<0.3	Plant growth unaffected
2	Low	0.3 - 0.53	Growth of salt-sensitive plants, eg 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} = 1 dS m^{-1}

A.13 Flooding risk

Building regulations prohibit building on flood-prone land, therefore land with some risk of flooding must be identified. Flooding may 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.

A.14 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 = No. of months where monthly evapotranspiration > average monthly rainfall

T = No of months where mean monthly temperature <6^{o}C

A.15 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:

* 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.16 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 give an over-estimated 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	K_{sat} range (mm/day)	Time taken for saturated soil to drain to field capacity	Soil features
Very low	< 10	Months	Absense 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.17 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

Index for permeability/rainfall						
Permeability		**Average annual rainfall (mm/yr)**				
Estimated	**K_{sat} (mm/d)**	**< 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.18 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.19 Slope

Slope has a direct effect on erosion risk, nutrient loss, cost of construction (excavation and stabilisation), access. Also 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.20 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 A7)

Table A.7 Susceptibility to gully erosion

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

A.21 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 $H_2 0$)	**Moderate (70-170 mm $H_2 0$)**	**High (> 170 mm $H_2 0$)**
Gentle < 10	Very low	Very low	Low
Moderate 10-32	Low	Moderate	High
Steep > 33	Moderate	High	Very high

A.22 Suitability of subsoil for earthern dams

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

Table A.9 Suitability of subsoil for earthen dams

Unified Soil Group of Subsoil					
DEPTH OF SUBSOIL (m)	**SP, SW, GP, GW, t, 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.23 Susceptibility to sheet and rill erosion by water

The table below (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		VH
			VL-L E3(1),E3(2), E4, E5, E6, E , E8	M-H E2,E3(3), E3(4)	E1
Sand		apedal	< 0.2 m	M	
		0	0.2-0.4 m	L	
			> 0.4 m	L	
Sandy	apedal	< 0.2 m	M	H	
Loam		0.2-0.4 m	L	M	
		> 0.4 m	L		
	weakly	< 0.2 m	H	E	
	pedal	0.2-0.4 m	M	V	
		> 0.4 m	M		
Loam	apedal	< 0.2 m	M	H	
		0.2-0.4 m	L	M	
		> 0.4 m	L		
	weakly	< 0.2 m	H	E	
	pedal	0.2-0.4 m	M	V	
		> 0.4 m	M		
	peds	< 0.2 m	H	E	
	evident	0.2-0.4 m	H		
		> 0.4 m	H		
Clay	apedal	< 0.2 m	M	H	
Loam		0.2-0.4 m	L	M	
		> 0.4 m	L		
	weakly	< 0.2 m	H	E	
	pedal	0.2-0.4 m	M	V	
		> 0.4 m	M		
	peds	< 0.2 m	H	E	
	evident	0.2-0.4 m	H	E	
		> 0.4 m	M		
Light	weakly	< 0.2 m	H	E	E
Clay	pedal	0.2-0.4 m	M	V	E
		> 0.4 m	M	V	E
	peds	< 0.2 m	M	V	E
	evident	0.2-0.4 m	M	H	E
		> 0.4 m	M	H	E
	highly	< 0.2 m	H	E	
	pedal	0.2-0.4 m	M	V	
		> 0.4 m	M	V	
Medium to	weakly	< 0.2 m	M	H	E
Heavy Clay	pedal	0.2-0.4 m	M	H	V
		> 0.4 m	M	H	V
	peds	< 0.2 m	H	E	E
	evident	0.2-0.4 m	M	V	E
		> 0.4 m	M	V	E
	highly	< 0.2 m	H	E	E
	pedal	0.2-0.4 m	M	V	E
		> 0.4 m	M	V	E

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

*Table A.11 Susceptibility to Sheet and Rill Erosion**

Slope %	Topsoil erodibility (from Table A.8)				
	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
> 33%	Moderate	High	Very high	Very high	Very high

*Topsoil erodibility is determined from the texture, structure, depth and dispersibility of the top soil (Table A.9). The susceptibility of the topsoil to sheet and rill erosion relates to the combined effect of slope and top soil erodibility (Table A.10).

A.24 Susceptibility 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.25 Transpiration beds

Transpiration beds are more suitable than absorption trenches when:

i) soil depths are shallow, e.g. < 750 mm deep
ii) and/or when K_{sat} values are low, e.g. < 10 mm/day
iii) and/or when rainfall is > 900 mm/yr.

A 26 Susceptibility to Acidification

Table A.13 Susceptibility to Acidification

Susceptibility	Texture	pH	Annual Rainfall
Low	Heavy	All	> 450 mm
Moderate	Medium Light	> 4.5 (CaCl2) > 4.5 (CaCl2)	> 450 mm > 450 mm
High	Light	> 4.5 (CaCl2)	> 450 mm

Organic matter is not used as an indicator for susceptibility as, although it can act as a buffer, it can also contribute to nitrate leaching if there is a high legume content.

Land management, such as pasture species and stocking rates can also contribute to acidification.

A 27 Flooding Risk

Table A.14 Flooding Risk

RISK	CLASS	LIMITATION	CONDITION OF FLOOD	SUGGESTED PLANNING RESPONSE
Nil	1	No limitation	No flooding.	Nil
Low	2	Nuisance	Infrequent. 1 in 50 year	Design for
Moderate	3	Significant	Broad, slow moving, no debris. 1 in 20 to 1 in 50 year	Design for
High	4	Major	Broad, slow moving, little debris. 1 in 100 year	Discourage
Severe	5	Prohibitive	Deep channel, fast flowing, debris carrying. 1 in 100 year	Prohibit

APPENDIX C SPECIFIC METHODS

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 (refer Table A.11) are based on McDonald *et al.* (1990) or Northcote (1979). 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 six infiltration rings so that each ring is approximately 100 mm into the main clay horizon - remove some topsoil if necessary. Use the mechanical vibrator and special plate to insert rings.

ii) Rings need to be at least 2 metres apart and located at random. Relocate ring if obstacles such as stones or roots prevent an even downward movement of the ring into the soil.

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

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

v) Next day, remove water container and fill each ring. Mark that point as zero for future measurements and record zero time. At appropriate time intervals, depending on rate of infiltration - 5 min, 15 min, 30 min, 60 min, record the drop in water level in mm on sheets provided. If water levels are getting low, fill rings to zero again straight after taking readings.

vi) Record measurements for 3 hours or until the rate of infiltration is constant.

vii) 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, ie. rocks, sand, clay patches.

C.4 Laboratory Analysis

Samples collected for each soil horizon are 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 - 0.2 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 and chemically 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). However subdivision of classes 2 and 3 were made according to Loveday and Pyle (1973).

The following subdivision classifications were used:

E3(1), E3(2)	low dispersion
E3(3), E3(4)	moderate dispersion
E2(1), E2(2), E2(3	high dispersion

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 3 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

C.4.2 Chemical Properties

Soil chemical analyses were carried out by the State Chemistry Laboratory (1991), 5 MacArthur Street, East Melbourne, Victoria 3002.

Standard laboratory procedures for soil and water analyses are also described by Rayment and Higginson (1992).

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 20^0C

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 sulpuric 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.

8. Total exchangeable bases

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

9. 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 E MAP UNIT NOMENCLATURE

Geological Age	Lithology	Landform Element
Q Quaternary	a: alluvium	a: steep crest/ridge
T Tertiary	b: basalt	b: steep slope >32%
K Cretaceous	c: coluvium	c: moderately steep slope 21-32%
P Permian	f: fans	d: moderate slope 11-20%
D Devonian	g: granite\granodiorite	e: gentle crest
S Silurian	r: rhyodacite	f: gentle slope 4-10%
O Ordovician	s: sedimentary	g: very gentle slope 1-3%
C Cambrian	t: tillite	h: drainage depression
	v: volcanics	i: flat <1%
	m: metamorphic	l: former lake bed
		p: plain <1%
		r: rocky
		x: plateau
		1-5 river terraces

N.B.:** **If differentiating geology by a number the appropriate goes after the geological symbol

e.g. Dg1a = Devonian granitic, type 1, steep crest.

GLOSSARY

The following definitions have been extacted from Charman and Murphy (1991) and McDonald *et al.* (1990).

Acidification:
An increase in acidity in the soil due to increased acidic input and/or increased leaching due to changes in land use (from the native condition), 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. Soils with a pH ($CaCl_2$) <4.5 are regarded as acidic and susceptible to aluminium toxicity (greater availability at lower pH's) 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 A_2 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 ($dS\ m^{-1}$)	*Interpretation*
0.3	Very low
0.3 - 0.53	Low
0.53 - 1.26	Moderate
1.26 - 2.5	High
> 2.5	Very high

Flooding:
Includes overbankflow 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 (building block of a land system) because of specific slope, soil, or geomorphological characteristics, eg. 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, eg. 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 ie. plant and microfauna detritus, fresh or decomposed. The following values for organic matter have been used in this report:

Interpretation	*Value range (%)*
< 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 is a measure of 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. The pH ($CaCl_2$) is a measure that is less seasonally variable than the pH (H_2O) in water and used as a basis for acidification measurement.

Phosphorus (P):

Deficient when less than 6 µg/g for pasture growth.

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 potential (%)	***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:

< 1%	level
1 - 3%	very gentle slope
4 - 10%	gentle slope
11 - 32%	moderate slope
21-32%	moderately steep slope
> 33%	steep slope

Soil Colour:
Determined by comparison with a standard Munsell soil colour chart or its equivalent. It includes the 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	25%
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.

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.