LAND RESOURCE ASSESSMENT FOR THE NORTH EAST CATCHMENT MANAGEMENT AUTHORITY REGION

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Preface

The purpose of this study has been to guide further agricultural development across the North East Catchment Management Authority (NECMA) region of Victoria. This has necessitated the production of soil-landform information at a scale of 1:100 000 for all freehold land in north-east Victoria. Although a number of historical land resource surveys have been undertaken within this region, they cover smaller areas or are at coarser scales with less detail. The North East Land Resource Assessment (NELRA) project undertaken by the Department of Natural Resources and Environment's (NRE's) Centre for Land Protection Research (CLPR) therefore represents the most comprehensive soil-landform survey completed thus far in this region of Victoria.

The data gathered during this NELRA project has been used to develop a generic agricultural capability map as well as erosion risk maps. However, the availability of soil-landform data and soil point data allows for more specific and detailed applications in future. It will enable a clear understanding of the potential to develop land for agriculture and identify limitations linked to the natural resource base. The ability to access detailed soil point information and soil-landform units will benefit many modelling applications currently used to assess land resource management and water quality aspects such as Land Use Impact Model (LUIM), Soil and Water Assessment Tool (SWAT) and the Catchment Assessment Tool (CAT). Furthermore, the soil point information will be input to the Statewide Soil Site Database which will allow access to soil point information for incorporation in a range of modelling tools.

At the map scale of this project (1:100 000), soil-landform units are not homogeneous. For each defined soil-landform unit, dominant soil types were identified prior to assessing their capability to support various enterprises. Often a co-dominant and minor soil type have been described as part of this process. Importantly it should be noted that soil attributes (for example soil depth, soil structure, size and abundance of coarse fragments, sodicity, pH) are expected to vary between acquired soil sites.

As the variability of soil attributes within a map unit is difficult to predict, it is important to note that representative soils should be used as a guide only. Site specific mapping and soil analysis is essential prior to establishment of any new development or enterprise.

Map unit and detailed soil profile information can be accessed in the Adobe Acrobat *.pdf files included on this CD-ROM via the home.pdf file.

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Executive summary

The North East Rural Land Stewardship (Land Capability and Capacity Building) program aims to improve and maintain water quality, match land use to land capability, encourage appropriate land use and management to ensure environmental sustainability and to promote whole farm and whole community sustainability by consideration of social, economic and environmental values.

Agriculture is particularly important to the long-term prosperity of north-east Victoria. Increased agricultural production and diversification is needed to achieve sustainable growth in the region. Wise selection of appropriate land for different uses and the adoption of improved management practices will be essential to manage land use change and ensure that the natural resource base is protected.

This land resource assessment (LRA) project for the North East Catchment Management Authority (NECMA) region was commissioned to provide consistent and relevant land resource information on freehold land across the region. This information will be used to guide future agricultural development in north east Victoria. Funding has been provided by the Department of Natural Resources and Environment (NRE) and Natural Heritage Trust (NHT). Work commenced in July 2000 and was completed in September 2002.

A North East Land Resource Assessment (NELRA) steering committee was appointed to ensure that the outputs of the NELRA project would meet the following regional objectives:

- Undertake an inventory of soils and landform on freehold land and establish key soil data for the NECMA. The information from the soil point site data and the spatial land unit information will become key datasets for input into catchment and natural resource modelling applications.
- Provide land hazard information and identify potential on-site and off-site impacts to underpin decision making regarding current and future land use.
- Compile land capability information designed to attract investors to the region and to ensure that investment takes place in areas where there is low economic and environmental risk.
- Increase the efficiency and effectiveness of natural resource utilisation in the region.
- Provide specialist land resource assessment (LRA) training to Catchment and Agricultural Services (CAS) staff and other stakeholders.

Consistent land resource information products at 1:100 000 scale have now been developed for the region. The base soil-landform mapping has been generated through the refinement of existing data, the collection of new soil-landform data, and extrapolation using enhanced resource assessment (ERA) techniques and modelling approaches.

The soil-landform units are used as a platform to assess the capability of the land to support agricultural enterprises and assess the risk of land and water degradation. A generic land capability map product has been generated to relate soil, landform and climate limitations to the broad requirements of general agricultural enterprises. Map products generated from the soil-landform units for the project include:

1. Agricultural capability maps
2. Land degradation risk maps covering:
    - mass movement
    - gully and tunnel erosion
    - sheet and rill erosion
    - wind erosion.

The land degradation analysis has been undertaken for the freehold land areas that were included as part of this land resource project. The analysis indicates that there are significant areas at risk from land and water degradation in the NECMA region. Table i provides a breakdown of the area (ha) at high risk of land and water degradation hazards.

In the NECMA region, a range of soil-landform units are prone to land and water degradation. As this region is bound by the Great Dividing Range and contains the highest elevation landforms in Victoria, the primary process which influences the degradation risk is gravity. Primarily the steeper slopes are subject to mass movement and landslip while those colluvial sediments predominantly derived from sandstones and siltstones are prone to gully and tunnel erosion. Sheet and rill erosion occurs primarily at the base of the steeper slopes in the valleys and start of the Riverine Plains, whereas wind erosion occurs primarily on the plains to the north-west of the study area with the lighter subalpine soils also potentially vulnerable.

Table i Susceptibility to land degradation (area and %) on freehold* land in the NECMA region

Hazard	High and Very High		Moderate		Low and Very Low	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Mass movement	38 437	4.8	326 737	41.2	427 902	54.0
Gully and tunnel erosion	18 672	2.3	713 803	90.0	60 600	7.7
Sheet and rill erosion	56 774	7.1	491 568	62.0	244 734	30.9
Wind erosion	152 346	19.2	444 326	56.0	196 405	24.8

* **Note:** Total land area of the NECMA region is 1 933 309 ha which includes 1 140 233 ha of public land.

The land capability analysis has also identified freehold land with a high, moderate and low capacity to support agriculture in general. Table ii provides an area statement (ha) outlining the extent of each capability class for agriculture on freehold land.

Table ii Capability of freehold land area (ha and %) for agricultural productivity

High		Moderate		Low	
(ha)	(%)	(ha)	(%)	(ha)	(%)
46 838	5.9	434 396	54.8	311 842	39.3

The areas identified with the highest capability within the study area are predominantly the alluvial deposits along the river valleys and the recent alluvium of the riverine plains. Although there are some very good red soils derived from the metamorphic schists and gneisses along the ranges bordering the river valleys, these are located on steep slopes and would present a significant erosion risk upon their management. They have therefore been identified within the moderate to low capability, depending upon the actual slope class.

Over time, stakeholders and the wider community will ultimately judge the success of this project on the utilisation of the information products. It has therefore been recognised that the information must be provided in an easy to use and comprehensible format to ensure access of this information for regional decision making. Thus, the information assembled as part of this project has been transferred onto a CD-ROM. This will allow access to the information via an Adobe Acrobat reader and enable the user to print out maps, land unit information and the report text.

Important considerations

- That the report and information products generated by this project be available at regional locations to enable stakeholder and community access.
- That assessment of future land use change should be carried out with respect to hydrological processes such as salinity recharge and discharge, groundwater and surface water availability for irrigation, and surface water quality impacts. Such assessment would utilise the soil-landform units and the land capability mapping as a basis for scenario modelling.
- That suitability of land use is determined from the land capability base only after hydrological, infrastructure, economic and social issues have been included.
- That stakeholders and the community be directed to the Victorian Resources Online website (www.nre.vic.gov.au/vro) and Victorian Catchment Indicators Online (www.nre.vic.gov.au/vcio) for additional information on land and water resources in the NECMA region.

LAND RESOURCE ASSESSMENT FOR THE NORTH EAST REGION

KA Reynard, DB Rees, GB Boyle and MR Bluml

1 Introduction

The North East Catchment Management Authority (NECMA) region encompasses almost 20 000 km^2 of north-eastern Victoria. It includes the Upper Murray River basin above Lake Hume, the Mitta Mitta River Valley, the Kiewa River basin, and the Ovens and King River basins. It also incorporates the high plains from Mount Hotham to Omeo and Benambra. It is mainly comprised of public land which is used for forestry purposes, conservation and recreation, while the freehold land is used predominantly for beef and dairying enterprises in the major river valleys with wheat and sheep grazing on the plains to the west of the Hume Highway. Approximately 61% of the region is public land and 39% is private or freehold land.

In August 2000 the NECMA initiated the Rural Land Stewardship (RLS) pilot program. A major component within this program is to undertake a land capability analysis upon the freehold land within the region. It is within the framework of the RLS that the NRE's Centre for Land Protection Research (CLPR), Bendigo has undertaken a major land resource assessment (LRA) project in the NECMA region to provide detailed information to underpin any land capability assessment.

The RLS program has allowed for the development of a 1:100 000 scale land resource dataset. The land resource data in this project is a soil-landform unit dataset and is based upon geological mapping, landform mapping and soil information. Land capability mapping is a value added product and is generated by applying specific criteria based upon the soil-landform units, geology and climate to develop land capability classes. The land capability information provides the basis for determining incentives for land use change in identified high risk areas.

This report provides a consistent soil-landform dataset that will assist future opportunities to develop sustainable primary production and processing enterprises within this region. The base information (soils, geology, slope, aspect, climate) has been used to determine the broad capability of the region's landscape to support a variety of different land uses. The variety of land uses, or versatility of the land to support a broad range of agricultural enterprises, equates to agricultural land capability. This determination of agricultural capability has been carried out by establishing generic criteria for analysing the physical requirements of each land use and using a geographical information system (GIS) to locate high, moderate and low capability areas. The inherent limitations linked to the natural resource base have also been identified. In particular, land degradation risk mapping enables the identification of potential on-site and off-site impacts that can link to current and proposed land uses.

Data collected and generated as a result of this project enables all stakeholders to access key land resource information, and will help to discriminate areas suitable for various land uses and land management practices. The ability to access detailed soil point information, as well as soil and land unit spatial data will benefit many modelling applications that are currently used to assess land resource management and water quality aspects, for example, the Land Use Impact Model (LUIM) and the Catchment Assessment Tool (CAT). The project will ultimately be useful to encourage the development of a common and coordinated approach to the selection of sustainable land use options and land management practices into the future.

1.1 Objectives

The objectives of the project were:

- To undertake an inventory of soils and landform on freehold land and establish key soil data for the NECMA region. The information from the soil point site data and the spatial land unit information will become key datasets for input into catchment and natural resource modelling applications.
- To provide land hazard information and identify potential on-site and off-site impacts to underpin decision making regarding current and future land use.

- To compile land capability information designed to attract investors to the region and to ensure that investment takes place in areas where there is low economic and environmental risk.
- To increase the efficiency and effectiveness of natural resource utilisation in the region.
- To provide specialist land resource assessment (LRA) training to Catchment and Agricultural Services (CAS) staff and other stakeholders.

1.2 Links to other projects

This project is linked to a number of key projects including Regional Data Net, Victorian Catchment Indicators (http://www.nre.vic.gov.au/vcio), Victorian Resources Online (http://www.nre.vic.gov.au/vro), Victoria's Future Landscapes, and Statewide Soil Reference Sites project.

1.3 Climate

Precipitation

Precipitation is influenced by topography. Rain is the main form of precipitation, however, above 1400 mASL a large proportion of the winter precipitation falls as snow. Approximately 65% of precipitation occurs during winter from June to August.

The bulk of the study area has an average annual rainfall of between 700 and 1000 mm. In the more elevated parts around Mount Stanley and Mount Burrowa, the average annual rainfall increases to more than 1200 mm. Fairly regular snow falls at elevations above 800 mASL make some contribution to precipitation in these areas. Some areas of rain shadow occur in the more dissected valleys around Eskdale, the Mitta Mitta River Valley and Corryong.

The distribution of rainfall shows a winter peak, while January and February are the driest months. The difference between summer and winter rainfall is less marked on the plains (LCC 1984).

Temperature

The relationship between altitude and minimum temperatures is complex and also influenced by local topography.

The hottest months are December, January and February with average maximum summer temperatures ranging from 27°C at Beechworth to 30.8°C at Corryong. July is normally the coldest month with average maximum temperatures varying between 10°C at Beechworth and 12°C at Wangaratta. On the plains to the north of Wangaratta maximum daily temperatures can be very high and reach above 40°C.

Average minimum temperatures range from around 12°C to 16°C in February to between 1°C and 4°C in June. Minimum temperatures vary greatly from locality to locality due to the influence of topographic features (such as valleys and depressions) on overnight temperatures (LCC 1984).

Frosts

Frosts generally occur in the period between April and September even at the lower altitudes, with the most severe frosts generally confined to the period June to August. At high elevations frosts are more frequent and may occur throughout the year, although they are unlikely to be severe during summer (LCC 1984).

Climatic information for weather stations can be accessed via the Bureau of Meteorology Climate Averages Web site (http://www.bom.gov.au/climate)

1.4 Geomorphology

Geomorphology is the study of the evolution of the surface features of the earth along with the internal and external processes that have taken place through the earth's genesis to develop the landforms that are now evident. The study of geomorphology affords a system by which landform types may be recognised and classified.

Geomorphology is currently being used by NRE land information specialists to provide a systematic framework to describe the development of the landform at a range of scales and at varying levels of detail. For example, a broad regional description will have limited detail but will provide the framework for more detailed description. The number of levels or tiers of detail (description) will be dependent on the complexity of the environment.

There are three levels (tiers) of geomorphology presented in this study. These levels are based on current understanding of a revue of geomorphological units (GMUs) in Victoria. Tier 1 is the broadest and least detailed level and is based on geomorphological divisions. Tier 2 carries greater detail and is based on geomorphological regions. Tier 3 is the most detailed level and is based on a grouping of land systems or a singular land system generally portrayed at a scale of 1:250 000 to 1:100 000. A land system can be described as an area of land distinct from surrounding terrain within which particular classes of land features are consistently associated and are expressed as a recurring sequence of particular land components. The land system in this context, is the same as the soil-landform unit and is considered the third tier level within the hierarchy of geomorphology framework outlined below.

Each level (tier) is given a numerical identifier in a GMU. For example the GMU given as 1.3.2 is described as follows:

Tier 1 (**1**.3.2) is the geomorphological division – in this example it is the Eastern Uplands geomorphological division.

Tier 2 (1.**3**.2) is the geomorphological region – in this example it is the ridges, valleys and hills geomorphological region.

Tier 3 (1.3.**2**) is the geomorphological sub-region and comprises individual soil-landform units or an amalgamation of similar soil-landform units (land systems) – in this example it is the escarpment and gorges land system.

This hierarchical approach allows for a simpler approach to land description at the land system level by accounting for broader patterns at the geomorphological division and region level.

Complete descriptions and features associated with tier 3 GMUs found in the NECMA region are listed later in this section. The map displaying the GMU divisions (tier 1) and regions (tier 2) can be viewed by following the links from this section.

The NECMA region is composed of two divisions at the broadest level (tier 1); the Eastern Uplands (EU) and the (northern) Riverine Plain (RP). At a broad scale this is reflected in land use patterns with the predominant clearing of native vegetation on the Riverine Plain and infrastructure such as roads sited according to the terrain.

At the regional level (tier 2) there are three divisions of the Eastern Uplands (EU) and four divisions of the Riverine Plain (RP). These provide a more practical division of the landscape at the regional scale.

1. Eastern Uplands (EU)

   Elevated landscapes of eastern Victoria

1.1 High elevation (residual) landscapes

This grouping of land types are the most elevated in Victoria and are defined as those land types that are regarded as subalpine, usually defined as above the treeline, but may include snow gum (*Eucalyptus pauciflora*) communities. Historically, this has been defined for administration purposes as above 1220 mASL. Landscape features include isolated summits, plateaux, plains and broad ridges, which are further defined as tier 3 units. Note that most of these units are residual and do not include the adjoining steep dissected terrain. Examples in the study area include the high plains and Mt Buffalo. The various plains have been and are studied, and have different developments such as deposition, erosional, structural and enclosed plains (Rosengren[1] pers. comm[1].)

1.2 Intermediate elevation (residual) landscapes

This grouping of land types comprises residual landscapes below the treeline, with similar subdivisions to the 1.1 division. One major difference is the definition of a piedmont or series of footslopes that have developed at lower elevations. Examples in the study area include Pine Mountain, Koetong-Shelley, Stanley and the Warby Range.

The definition of a plateau (for example) at this scale allows for the further definition at the land system scale where landform is described in terms of its relative relief e.g. plain, rise, low hill, hill, mountain. A plateau may well be described as undulating low hills, depending on the degree of dissection of the landscape. The origin of the plateau may vary from structural control in the lower

[1] Rosengren N (geologist, La Trobe University Bendigo) May 2002

Carboniferous sediments and the Upper Devonian acid volcanics to erosional surfaces such as the Stanley plateau (Rowe 1972).

1.3 Ridges, valleys and hills

This grouping of land types comprises dissected landscapes, such as ridge and valley complexes, escarpments, outlying low hills, enclosed low hills and valleys, major valleys within the uplands and atypical landscapes such as Karst (limestone). The majority of the uplands is made up of ridge and valley complexes with examples such as the Barry Mountains and upper headwaters and mid-reaches of the major rivers. Outlying low hills are noticeable in this study area as the Eastern Uplands division give way to the Riverine Plain division at places like Chiltern and Rutherglen. Enclosed low hills and valleys (basin-like) are represented by the Omeo-Benambra area in the south of this region as well as the Murmungee area.

Valleys, terraces and floodplains within the bounds of the uplands are regarded as part of the uplands and not the plain. These units are the connection between the uplands and the plain, being the conduit for development of the plains.

4 Riverine Plain (RP)

Depositional plain of northern Victorian river systems

4.1 Modern floodplains

This grouping of land types is confined to the lowest parts of the landscape in the study area. The most distinguishable landscapes are the meander belts (floodplains) below plain level, which are generally well defined by some degree of incision/dissection of the surrounding plain. Other low landscape features include swamps and lakes (with associated lunettes). These units may be further distinguished by the degree and extent of dissection by prior stream channels in the form of billabongs (ox-bow lakes).

4.2 Older alluvial plains

This group of land types is the most extensive of the riverine plain, dominated by plains with leveed channels though the elevation changes are very low, sometimes imperceptible between levees and the backplain. Drainage lines are subdued with little incision, and in some cases have been altered by land managers for agricultural purposes. There are lakes and basins (swamps) associated with this unit.

4.3 Higher terraces and aprons

This geomorphological unit is considered to be based on earlier Shepparton Formation material, higher in the landscape than the Older alluvial plains. It is generally adjacent to the uplands and includes fans coming out of the uplands and material often part of a colluvial sequence. It is may form part of a piedmont (1.2).

4.4 Low residual hills

This geomorphological unit consists of low, gentle sloped terrain on residual outcrops (generally Palaeozoic sedimentary rocks) which have not been covered by Recent unconsolidated deposits. Examples include the Rutherglen and Chiltern areas.

Table 1 A detailed list of the GMU divisions, regions and provisional third tier descriptions for the Eastern Uplands geomorphic division

GMU	Description	Location example
1.1	***High elevation landscapes (above tree line, approx. 1220 m)***	
1.1.1	Isolated summits	(Mt Feathertop, Mt Howitt)
1.1.2	Summit plateaus	(Mt Bogong, Mt Baw Baw, Mt Buffalo)
1.1.3	Enclosed plains	(Horsehair Plain)
1.1.4	Basalt Plains	(Mt Jim-Bogong high plains, Dargo Plains, Nunniong Plains)
1.1.5	Broad ridges	(Hotham-Lock ridge, Mt Fainter ridge)
1.2	***Intermediate elevation landscapes (below tree line)***	
1.2.1	Isolated summits	(Pine Mountain, Mt Murramurraganbong, Ben Crueachan)

1.2.2	Plateaux (tableland)	(Strathbogie, Koetong-Shelly)
1.2.3	Broad ridges	(Warby Range)
1.2.4	Piedmont	
1.3	***Ridges, valleys and hills***	
1.3.1	High dissected ridges and valley relief	(Barry Mountains, upper valleys of major rivers such as the Wonnangatta, King, Kiewa)
1.3.2	Escarpments and gorges	
1.3.3	Outlying low hills	(Rutherglen)
1.3.4	Enclosed low hills and valleys	(Murmungee basin, Omeo basin)
1.3.5	Valleys, terraces and floodplains	(Wonnangatta Valley, Kiewa Valley)
1.3.6	Karst	

Table 2 A detailed list of the GMU divisions, regions and provisional third tier descriptions for the Riverine Plain geomorphic division

GMU	Description	Location example
4.1	***Modern floodplains* (Coonambidgal Formation)**	
4.1.1	Meander belt below plain level, sometimes source-bordering dunes	(Wangaratta)
4.1.2	Areas of inundation away from modern channels	
4.1.3	Lakes and basins with lunettes	
4.2	***Older alluvial plains* (Shepparton Formation)**	
4.2.1	Plains with leveed channels, sometimes source-bordering dunes	(Peachelba, Barnawatha North)
4.2.2	Plains without leveed channels	
4.2.3	Lakes and basins with lunettes (Lake Mokoan)	
4.3	***Higher terraces and aprons* (Shepparton Formation including main upland valleys)**	
4.4	***Low residual hills* (Rutherglen area)**	

1.5 Geology

The region is comprised primarily of Ordovician sediments that have undergone deformation, granitic intrusion and a phase of high grade regional metamorphism. There are local occurrences of Silurian and/or early Devonian acid volcanics. Quaternary colluvial and alluvial deposits are found in most of the major stream valleys, particularly in the north. There are only very minor areas of Tertiary sediments.

Ordovician

The oldest rocks known to outcrop in the study area are of Middle to Upper Ordovician age. These yellow-brown, brown and greenish black claystones, siltstones and sandstones were deposited in a thick, repetitive marine sequence in the Wagga Trough. The generally fine grain size of the rocks, the lack of conglomerates in the sedimentary sequence, and the presence of some graptolite shales suggest that deposition took place in deep water under reducing (anaerobic) conditions. Hence fresh rock is a grey colour whereas weathered rock is yellow-brown or brown.

Ordovician period marine sedimentation followed by intensive folding in the middle Silurian, has resulted in the steeply dipping beds of sandstones, siltstones, shales and mudstones that outcrop east of Eskdale between Yackandandah and Myrtleford, and in the Chiltern Hills.

Evidence suggests that several phases of deformation occurred. The sediments exhibit at least two cleavages and are distinctly foliated making measurement of the stratigraphic thickness difficult. Movement along the faults is thought to have persisted intermittently to the Tertiary. The persistent movement of faults, their linear form and younger faults contributed to the present day basin and range topography and commonly appear as scarps.

Some of the sediments south of Wodonga and in the Corryong district were regionally metamorphosed to slates, schists and gneisses. These rocks were subsequently faulted. The schists sometimes exhibit metamorphic zoning and two types predominate:

- those having a knotted texture, which is due to the segregation of large crystals
- biotite sillimanite schists, in which biotite is the main dark coloured mineral.

The composition of the gneisses also varies. Some are relatively homogenous whereas others are distinctly porphyro-blastic. It is considered that the gneisses form the core of the metamorphic complex and the schists the edges.

Silurian

The geological history of eastern Victoria during Silurian to Middle Devonian times is relatively complex, and includes several periods of deformation, extrusion of acid volcanics, and deposition of marine sediment.

Subsequent to the principal metamorphism, the country rocks were uplifted and exposed. In nearby areas thick rhyolites and ignimbrites containing inclusions of country rock were extruded, and are still evident in a belt around Dartmouth Dam. A further phase of tectonic deformation in the Upper Silurian resulted in extensive faulting and re-activation of the older fault systems and broad areas were highly metamorphosed.

Associated with the Middle Silurian folding, broad areas were highly metamorphosed. Also, around this time broad areas of granite were intruded into this region. They are evident today outcropping in the Corryong, Koetong and Yabba areas and are enveloped by regionally metamorphosed rocks, predominantly schist. Schists also occur in a broad belt running southwards from Wodonga and alternate with gneiss to Glen Creek. More extensive areas of gneiss occur near Bethanga and Tallangatta. The bedrock, particularly the metamorphics, contains a sub-rectangular pattern of faults that define many creek alignments and also boundaries of rock types.

Following this period was a time of extensive erosion and by the end of the Silurian, metamorphics and granite were exposed. To the south-west, cauldron like structures developed in local basin subsidence. Rhyolites and rhyodacites were intermittently extruded into these, while sandstones and conglomerates were deposited during the intervening periods.

Devonian

About the start of the Devonian (415 mya) saw the onset of a further phase of igneous activity that continued through until the Middle Devonian (approx 375 mya). This igneous activity generally intruded high in the crust as indicated by thin hornfels aureoles around the granites, and in part is associated with acid volcanism. In the north-east of the study area, sub-volcanic granites occur at Mount Mittamatite and Pine Mountain and are surrounded by dykes that in part form feeders for the volcanic rocks at Mount Burrowa. These granites also occur south-west of Wodonga at Yackandandah, Mount Pilot, Mount Stanley and Kergunyah.

Carboniferous and Permian

Outliers of Carboniferous and Permian rocks outcrop in the south-west of the study area. Conglomerates, red sandstones, siltstones and shales may be the remains of formerly more extensive basin deposits. Tillites, sandstones, conglomerates and arkosic clays of both marine and glacial origin occur near Greta and Byawatha. Deep drilling has revealed the presence of these Permian beds at depths between 44 m and 165 m below the surface. They are generally flat lying or gently tilted and are extensively faulted.

At Laceby one of the bores has drilled through the Permian beds into sediments of Carboniferous age. These deposits have been preserved in a down-faulted block and subsequently covered with younger alluvium.

A long period of weathering and denudation followed in the Mesozoic era.

Tertiary and Quaternary

Although some basalt was extruded north of Myrrhee, these two periods represent erosive phases in the geologic history of the area.

Movement of fault blocks, such as the Ovens River fault block persisted. Thick deposits of alluvium accumulated in the downthrown blocks and several deep lead systems were formed. The leads are represented by sands, pebble conglomerates, and coarse fluvial gravels. Parts of the alluvial sequence contain productive groundwater aquifers. The deposits are good clay, sand and gravel sources.

1.6 Remnant vegetation

The remnant vegetation cover of north-east Victoria has been accessed from the TREE100 GIS layer in NRE's Corporate Geospatial Data Library (CGDL). This layer was derived from LANDSAT Thematic Mapper (TM) satellite imagery and developed into a statewide layer. It has subsequently been clipped to the NECMA region boundary for the purposes of this project.

The TREE100 layer depicts polygons showing tree cover mapped down to a minimum area of one hectare and may be used as a base cover of permanent tree cover for most purposes. Areas of temporary change have been removed.

Tree cover has been derived from the classification of satellite imagery. Classifying satellite imagery for vegetation can be limiting as the image only encompasses a small portion of the infrared part of the electromagnetic spectrum. However, the image sharpness and detail offered makes the trade-off between spectral range and spatial resolution worthwhile for mapping tree cover. Tree cover is defined as woody vegetation greater than 2 m in height and with a crown cover (foliar density) greater than 10%.

Field verification of tree cover has also been undertaken for assessment of the presence or absence of tree cover.

The layer was created to give an accurate assessment of tree cover extent for the state of Victoria and to provide a baseline dataset for further projects based around tree cover. This layer shows the presence or absence of trees only.

1.7 Land use

In 1999 a report was commissioned by the Albury Wodonga Area Consultative Committee (Stewart & Bennett 1999) to undertake an evaluation of the economic impact of agriculture on north-east Victoria and southern NSW. Ten local government areas (LGAs) were considered within the study area, of which the shires of Towong, Wodonga and Indigo are within north-east Victoria. The remaining shires are all located within southern NSW. It was found the four largest industries in terms of gross value of agricultural production (GVP) are:

- timber production and processing
- grain production
- pig meat slaughtering
- beef livestock processing.

These four industries together generate 76% of total regional agricultural income. The strength of all four industries is demonstrated in the production base of raw product and the development of value adding industries in the region. Each of the four industries generate more than $50m to the regional economy, plus flow-on effects to service industries and employment in the production, processing and distribution of the commodity.

Within Victoria the major industries are timber production, and beef production. The grain production predominantly occurs in the north-west of the study area, to the west of the Hume Highway, while the pig meat slaughtering refers primarily to that of Bunge Abattoir in Corowa.

Within Victoria timber is produced in the cooler climate higher rainfall areas of Towong and Indigo and is part of an established high value industry extending into the alpine and subalpine regions of Victoria. Processors are located in the region at Myrtleford, Wangaratta and Benalla (softwood processors) as well as various smaller timber mills. Softwood timber (*Pinus radiata*) is the major component of the timber industry. There is an expanding hardwood plantation industry with potential for value adding.

Finished products include construction timber, laminates, pulp and paper products, woodchip, sawdust and bark for various uses such as landscaping and fuel as well as sawlog timber, whereas hardwood timber is processed at a number of mills located in the NECMA region.

The beef industry is a highly significant industry because it is a developed industry in each of the rural shires in the NECMA region and in the City of Wodonga. In addition, total investment in the beef industry is substantial. There are at least 50 beef producers in each rural LGA in the region, and some of the LGAs have more than 150 beef producers.

Beef is processed at a number of locations and is part of a high value industry in this region. Although this industry is valued by beef slaughterings, no assessment has been made of the value of beef breeding which is a significant component of the industry.

Although there are a number of grains produced in the region, wheat is the predominant cereal crop grown. Wheat accounts for approximately 60–70% of total cereal for grain production. Triticale and barley are also produced, each accounting for approximately 10% of production. Lesser quantities of oats and rice are grown. As well as cereal crops, there are legumes grown for grain, but these are of relatively minor importance in contrast to wheat production.

Of the middle ranking industries that generate income of between $5m and $50m GVP, dairying is the most established and financially beneficial for north-east Victoria. The dairy industry is well established in the Towong and Indigo shires generating over $20m of income to the Towong Shire in 1996–97. The river valleys in north-east Victoria, particularly in the Murray and Kiewa river valleys provide suitable climate, soil type, fertility and rainfall to maintain a sustainable dairy industry.

Other middle ranking industries generating between $5m and $50m GVP include the sheep meat industry, legumes for grain, hay production, oilseed production, the pome fruit industry and pasture seed industry. These are all established industries although legume and oilseed production are relatively ‘newer’ industries than the pastoral industries. These middle ranking industries together contribute approximately 21.6% of GVP to the regional economy.

The pome fruit industry in the Stanley area (Indigo Shire) comprises a small number of high value orchards, and is part of an intensive, diversified horticultural local area. Tourism development in the Indigo Shire, and particularly in the Stanley area, is based on both heritage values and farm gate and 'pick your own' sales of various fruits, berries and nuts.

The remaining industries each generate a GVP of less than $5m and together total approximately $20m. The largest of these smaller and/or emerging industries is the nursery industry which includes cut flowers and cultivated turf. The grape industry is based on the value of grape production, not processed grapes. As grape production is almost totally wine grape, and the region includes the high value Rutherglen wine region, these figures are a significant underestimate of the value of grapes to the region.

Other industries in this group are small but growing, for example the peppermint industry in the Shire of Towong. Honey is the silent achiever in Australian agriculture and previous studies would suggest an industry with growth potential.

2 Methodology

2.1 Generation of soil-landform units

The definition of mapping units is based upon an ecosystem concept in which several land features are integrated. Climate, geological material, landform and soil are each considered because they affect the inherent properties of the land, and its response to management (Charman & Murphy 1991). In this study, the soil-landform unit is the principle mapping unit and has been classified and mapped at 1:100 000 scale across freehold land for the entire NECMA region. Within the geomorphological framework these soil-landform units occur at or below the geomorphological sub-regional level (tier 3).

The soil-landform unit itself is made up of land components or elements. These are described as areas distinct from the surrounding terrain, having a particular combination of landform, geological classes, soil and vegetation. These provide information to another level of detail below the soil-landform unit.

The NECMA region has a wide range of land types which support various forms of land use. Due to implementing the principles of land stewardship, and recognition that in certain areas land use practices may have to be changed, the NECMA has sought information about the agricultural potential and the susceptibility to erosion hazards of rural lands within its area. This study has identified soil-landform units, provided a broad land capability assessment of the agricultural potential of the different units, and identified areas of inherent susceptibility to erosion.

The soil-landform unit is the base dataset from which the land capability assessment and the susceptibility to erosion themes are derived. For this study freehold land in the NECMA region has been mapped at 1:100 000 scale. The generation of these units incorporated information from historic reports and office-based GIS techniques in association with fieldwork to ascertain and validate soil descriptions for unique soil-landform units.

A soil-landform unit, or land unit is defined as an area of common landform in association with a dominant soil type and within a broad climatic range. Landform has been defined into categories based on relative relief such as plains, low hills and mountains. These comply with national standards as set out in the *Australian Soil & Land Survey Field Handbook* (McDonald *et al.* 1990). Different landforms were further distinguished by the make-up of their lithology (geology). Soil types are also described to national standards from field soil surveys and soil cores, and are compared on the basis of their attributes and classification, using *The Australian Soil Classification* (Isbell 1996).

For this project preliminary geological landform units were first generated. These preliminary units were used to identify areas requiring detailed soils information and to guide the field survey program. The preliminary units were generated by combining broadscale geology mapping with digital landform data. Land resource information from historical soil and land survey studies was also incorporated where it exists, and used to refine the preliminary units (refer Table 3).

Geology mapping is available for this region at 1:250 000 scale and was used as a consistent base to develop the preliminary geological landform units. A 1:100 000 scale geology digital map base was released by NRE's Minerals and Petroleum Division for the Corryong area in June 2002, but could not be incorporated into this project due to time constraints.

The refinement of the preliminary geological landform units was undertaken by integrating a number of other data layers and processes to incorporate soil property information. The development of soil-landform units at 1:100 000 scale incorporates radiometrics, DEMs, soil point site information and existing data from historical soil and land surveys.

Table 3 Existing soil and land surveys within the NECMA region

Title	Author	Year	Organisation	Reference locality	Scale
A land capability assessment of the Cassilis Valley, Swifts Creek	Rees	1995	Centre for Land Protection Research	High plains	1:25 000
An assessment of the versatility of agricultural land in the Rural City of Wangaratta	Bluml and Reynard	2000	Centre for Land Protection Research	Shire of Wangaratta	1:100 000
Land resource assessment in the western part of the Shire of Towong – former Shire of Tallangatta	Hook and Rees	1999	Centre for Land Protection Research	Tallangatta	1:100 000
A study of the land in the catchments of the Upper Ovens and King Rivers	Rowe	1984	Soil Conservation Authority	Ovens and King river catchments	1:250 000
A land capability study in the Shire of Yackandandah – erosion risk assessment	Clutterbuck and Costello	1983	Soil Conservation Authority	Shire of Yackandandah	1:50 000
A land capability study in the Rural City of Wodonga – erosion risk assessment	Clutterbuck	1980	Soil Conservation Authority	Wodonga	1:50 000
A land capability study in the Shire of Beechworth – erosion risk assessment	Ockenden and O'Meara	1980	Soil Conservation Authority	Beechworth	1:50 000
A land capability study in the Shire of Chiltern – erosion risk assessment	Ockenden and O'Meara	1980	Soil Conservation Authority	Chiltern	1:50 000
A study of the land in the catchment of the Kiewa River	Rowe	1972	Soil Conservation Authority	Kiewa River Basin	1:250 000
A study of the land in the Victorian catchment of Lake Hume	Rowe	1967	Soil Conservation Authority	Upper Murray	1:250 000

Radiometrics was useful in the detection of changes in soil properties, but need to be validated by ground truthing to determine soil properties. The use of radiometrics was particularly relevant in differentiating terrain of unconsolidated material such as the plains country and was used to identify former drainage lines, and sandier lunette country in the plains to the north of Wangaratta. Radiometrics was also used to identify colluvial outwash fans coming off the granite hills near Byawatha.

Digital elevation models (DEMs) with a 20 m pixel resolution were developed for the region (refer to Section 2.2) from 1:25 000 scale topographic data. They were resampled to 80m for this project to provide ease of processing. In the more steeply dissected country the DEMs were utilised to generate slope classes and relative elevations. These derivatives are useful to identify areas of changing landforms and break-of-slope, indicating the occurrence of a changing process. This is often used as a guide to changing soil types.

Soil and land resource information from historical surveys within the NECMA region have been utilised in the process to refine soil-landform units. The previous surveys occur within different parts of the region, and were performed at different times, by different agencies, at a range of scales and to varying standards, which made the provision of a consistent dataset of land attributes a complex task for the development of land units. The relevant surveys used to integrate historical data are listed in Table 3.

The collection of soil point site information has been used to define the dominant soil attributes within each soil-landform unit and identify soils within each component, or element. Some 280 sites were collected from field surveys during the course of this project, and incorporated with additional soil site information provided by State Chemistry Laboratories (SCL) in the areas of Springhurst–Byawatha, Rutherglen and Tallangatta Valley. The Centre for Tree Technology (CFTT) also provided some soil site information from tree plantation trials in the south-west of the region.

The soil-landform units developed as a part of the LRA project for freehold land in the NECMA region are accurate to 1:100 000 scale and represent the most comprehensive and up-to-date soil-landform survey completed in this part of Victoria. A complete range of the soil-landform units upon freehold land in the NECMA region is listed in Table 5. The soil-landform data has been used to develop a general land capability for agriculture product as well as susceptibility to erosion maps.

In future the availability of the soil-landform unit information and the soil point site data will allow for more specific and detailed applications over time. These products may be utilised to provide a clear understanding of the potential to develop land for specific agricultural enterprises and to identify specific limitations inherent within the natural resource base. The ability to access detailed soil point information, as well as soil and land spatial units will benefit many modelling applications currently used to assess land resource management and water quality aspects, for example, Land Use Impact Model (LUIM), Soil and Water Assessment Tool (SWAT), Catchment Assessment Tool (CAT).

Detailed soil-landform unit descriptions and soil profile descriptions can be found at Appendix iii.

2.2 Digital elevation models

Digital elevation models (DEMs) have become a widely used tool and product in the last 20 years. They provide a representation of the landscape and landscape features which includes values of elevation. DEMs enable better visualisation and interrogation of topographic features.

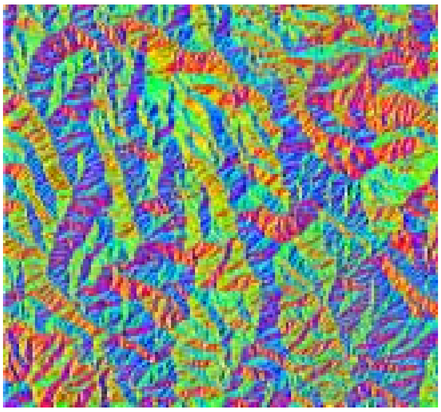
A DEM is generically described as a spatially geo-referenced dataset that is a popular way of encoding the topography for environmental modelling purposes. DEMs are also directly compatible with remotely sensed data sources and can be used to represent complex terrain units, given an adequate resolution.

Generally, DEMs have been derived from topographic data using contour data, spot heights, hydrology and boundaries (shore line, state, 1:100 000 tile) and provide the ability to analyse the shape of the surface in respect to the soils and hydrological properties of the landscape.

Some general derivatives from DEMs include:

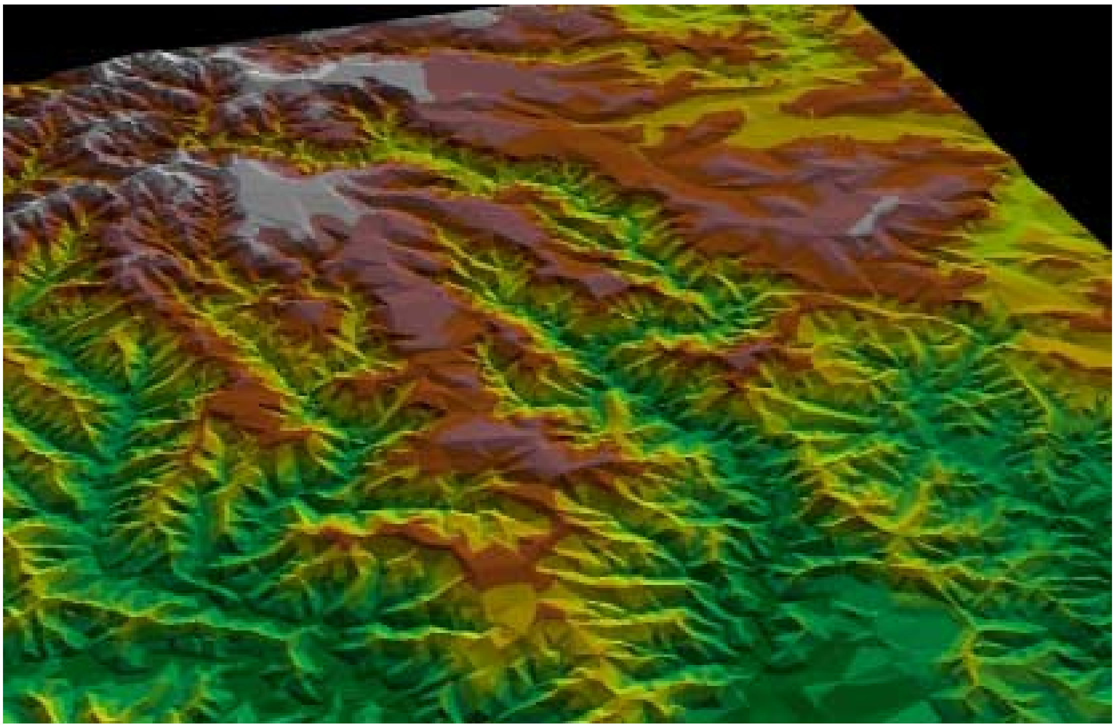
- slope, slope length and slope position
- aspect
- drainage network/catchment boundaries
- hydrological indices and watertable indices
- climate variables
- input to estimation of soil parameters
- input to land component and soil type mapping
- viewshed analysis and visualisation
- visualisation
- environment modelling including salinity, species distribution, spread models etc.

One of the most useful properties of DEMs is the ability to reclassify datasets. For example, slope, aspect and elevation can be classified to meet requirements or parameters of landscape components (as seen in Figure 1 below).



Aspect classification

Slope classification



Elevation classification

Figure 1 Three dimensional classification of DEM to three different datasets (aspect, slope and elevation)

DEMs have been developed by CLPR to generate slope ranges and formulate relationships between slope, landform and soil characteristics.

2.3 Land resource definitions

Land resource mapping

Definition: Mapping, as units that are relatively homogeneous, any character or combination of characters which is/are pertinent to the biophysical world, including man-imposed management practices.

Land resource mapping provides the data required for **land capability** and subsequent **land suitability** mapping. Units appearing on these maps derive from the underlying objectives of the mapping program and may not always be transferable from one commercial product to another (e.g. land systems mapping may not provide all of the soil attributes required for agricultural land use change). Questions of scale and data quality are important considerations before the decision to use these datasets in enhanced mapping products is made.

Main outputs: maps with accompanying reports of a land resource (e.g. remnant native vegetation) or combination of land resources (e.g. landform and associated soils).

Land capability assessment

Definition: An assessment of the ability of the land to sustain a particular broad land use, using average current management practices, without irreversible degradation occurring.

Land capability assessment focuses on the limitations to land uses (Conacher & Conacher 2000). Developed by the United States Department of Agriculture (USDA), its emphasis is on the presence or absence of limiting soil, landform and climatic factors to agricultural land use. These factors may include such parameters as soil pH, salinity, depth to the B horizon, steepness of slope, liability to erosion, annual rainfall, frost-free days etc. Measurement of some critical factors may be largely subjective (e.g. hydraulic conductivity of the soil profile), indirectly assessed from surrogate measures (e.g. erosion hazard derived from slope and surface stability) or the result of extrapolation (e.g. daily temperature derived from the nearest weather station). **Land capability assessment** essentially maps land characteristics (Conacher & Conacher 2000) and is a precursor to **land suitability**.

Main outputs: maps with accompanying reports of land capability classes (often including broad land use and management constraints).

Land suitability assessment

Definition: An assessment of the ability of the land to economically sustain a specific land use using specified management practices, without irreversible degradation occurring. Socio, economic and infrastructure information may also form part of the analysis.

According to Conacher and Conacher (2000), land suitability assessment is based on six principles:

1. Suitability is assessed with respect to specific land uses as requirements vary between them.
2. Inputs are compared with outputs for each land unit (e.g. costs versus returns).
3. The approach is multi-disciplinary.
4. The evaluation is made with respect to the physical, economic and social context of the area.
5. Land must be suitable for use on a sustained basis.
6. Different land uses are compared on an economic basis.

If these principles are accepted, the above definition would need modification to read ‘Socio, economic and infrastructure ***must*** form part of the analysis.’

Land suitability assessment requires land capability inputs (i.e. land characteristics) but maps land qualities (Conacher & Conacher 2000) (i.e. the interrelationship of various land characteristics and their interaction with sustainable management information and socio-economic considerations).

Main outputs: maps with accompanying reports of land suitability classes (often includes degrees of suitability, and major limitations and/or required improvements).

2.4 Land capability assessment for agriculture

The assessment of land capability provides a guide to the type of agriculture that can be supported by a specific land unit. As the capability of the land increases, so will the opportunities for agricultural diversification (versatility). Therefore, areas of high capability are most valued as they can provide greater flexibility for landholders seeking alternative agricultural enterprises.

Due to the complex interactions between soil, landscape and climate, purely objective assessments of land can sometimes be misleading. To this extent, agricultural capability assessment provides a general guide to the capability of land for agriculture and is useful in protecting what is considered to be high quality agricultural land. This information is desirable for the development of regional and local planning policies.

In assessing the capability of land for various forms of agriculture, a number of key factors are considered:

Climate What forms of agriculture are suited to the climatic conditions present?

Landscape Will the landscape and soil conditions present result in drainage problems and impede machinery operations or management for different forms of agriculture? Will different forms of agriculture result in unacceptable land and water degradation?

Soil Are the inherent soil conditions capable of supporting different forms of agriculture?

These are the key biophysical factors considered in developing the criteria used to assess the capability classes for agriculture. The assessment method used for determining these classes is the most limiting factor (MLF) methodology.

Most limiting factor key concepts

The most limiting factor (MLF) as used in this study identifies biophysical factors that are critical for production or the protection of the environment. The biophysical factors are then assessed in relation to the level at which they may become limiting to plant growth or protection of the environment. The approach finally assigns a capability rating based upon the most limiting factor.

The MLF methodology for the identification of agricultural capability is based on the method for determining land capability developed by the United States Department of Agriculture. The land capability approach has been extensively used in Victoria over the last 30 years to facilitate land use planning, particularly at the local government level.

The MLF is a 'rules of combination' method based on expert knowledge of the key factors (attributes) and the level at which they become critical. All factors are considered to have equal weight with respect to their impact upon growth or the environment. The simplicity of the approach allows the technique to be applied via a GIS platform or manually.

Components, factors and critical values

In this study, the capability for agricultural production is based upon the three ecosystem factors of climate, landscape and soil.

The criteria in Table 4 relates rainfall to the climate factor and slope to the landform factor. However the soil factor is far more complex and consists of many sub-factors such as texture, structure, soil colour etc. For each of the climate and landform factors and the soil sub-factors, critical values are identified and used to rate the agricultural capability to provide a three class rating system (refer to Table 4). The factors are rated for their limitation to plant growth, or potential for environmental degradation. The most limiting factor determines the class.

The rationale for assigning critical values to each of the factors is based on plant production, and protection of the natural resource base, with the aim of identifying economically and environmentally sustainable land use and management options.

Table 4 Land capability criteria used to determine broadscale agricultural capability classes

	Land capability classes		
	1	2	3
Climate-rainfall (mm)	500-1200	500-1200	<500 or >1200
Landscape (slope %)	0-10	10-32	>32
Surface texture	Loams, Sandy Loams, Silty Loams, Sandy Clay Loams, Clay Loam	Clay Loam, Fine Sandy Loams, Light Clays	Heavy Clays, Sands
Drainage status	Well drained or moderately well drained	Rapid or moderately drained	Poor
Subsoil colour	Red, brown	Brown, grey, yellow	Brown, grey, yellow
Friability	Strong to moderate friability	Not friable	Not friable
Soil aggregate stability (A horizon)	Highly stable (E6-8) to stable (E4-5)	Moderately stable (E3)	Very unstable (E1)
Depth to hard rock (cm)	>100	50-100	<50
Base nutrient status	Eutrophic (>15) and mesotrophic (5-15)	Mesotrophic (5-15)	Dystrophic (<5)
Subsurface permeability	High to slow	High to slow	Very high to very slow
pH (in water)	5 - >6	<5	<5
Soil type*	DE AA/AB, KA AA/AB, CH AA/AB, SO AA, VE, TE, KU AA, OR	DE AB/AD, KA AB/AC/AD, CH AB/AC/AD, SO AB/AC/AD/AE	RU, SO,TE, HY, SO AB/AC/AD

* Codes based on *Australian Soil Classification* (Isbell 1996)

The soil-landform units and the criteria in Table 4 have been developed from local and regional data to provide a general assessment of land capability. Due to the scale limitations of the underlying data the capability assessment does not provide sufficient information for site-specific evaluation. Additional site-specific factors that would require consideration prior to development may include site size and layout, availability of supplementary water supply, winter-spring flooding, frost risk and local soil factors such as sub-surface textures, soil profile structure, organic matter content and sodicity. Detailed site assessment is therefore required before proceeding with any new development.

2.5 Land susceptibility factors

In this study the steering committee decided to undertake analysis of four land susceptibility processes. These are listed as follows:

- sheet and rill erosion
- gully and tunnel erosion
- mass movement (landslides)
- wind erosion

These processes have been investigated in previous studies. This enabled the development of criteria and rating tables that have been applied to each soil-landform unit and provides an assessment of each unit's susceptibility to the respective land degradation process. The criteria and rating tables are detailed in Appendix i.

The main soil-landform characteristics influencing the susceptibility of land to sheet and rill erosion are topsoil texture, slope of the land and length of slope. Other factors include hydrophobicity, percentage stone cover, tendency for aggregates to slake and disperse, size and weight of surface particles or aggregates, and the probability of intense summer rainfalls. Table 13 (Appendix i) provides an erodibility index based upon soil parameters. This index can then be considered in relation to landform factors (Table 14 – Appendix i) to enable the development of a five class rating of the susceptibility to sheet and rill erosion.

The susceptibility of land to tunnelling and gully erosion depends on a number of interrelated factors. Table 15 (Appendix i) describes the soil and landform factors considered in the assessment of susceptibility to gully and tunnel erosion. Other factors that could be considered are principally rainfall intensity, vegetation cover, rooting depth, microrelief, position in landscape and contributing upslope area. As the volume of overland flow increases and becomes channelised, the erosive power increases and resistance of the soil aggregates and particles to detachment becomes critical. The size and weight of the soil particles and their cohesion, or the tendency to slake or disperse will determine the resistance.

Landform is a key feature within this assessment of susceptibility to mass movement and landslip as gravity is the primary force acting to dislodge and transport land surface materials. It is a function of the gravitational stress acting on the land surface and the resistance of the surface soils and/or rock materials to dislodgement. When the gravitational stress exceeds this resistance, mass movement occurs. The occurrence of mass movement depends on the interaction of various factors including landform, lithology, soil type, rainfall intensity and duration, drainage characteristics and vegetation cover.

The classification of susceptibility to mass movement is a two step process and requires a determination of available water capacity (AWC) of soils. Calculations have been carried out by Salter and Williams (1969) to correlate soil texture with AWC and are outlined in Tables 16 and 17 (Appendix i). The results of AWC for a particular soil-landform unit are then applied to a landform class (Table 18 – Appendix i) providing classification from very low to very high susceptibility to mass movement.

Wind erosion is the movement of soil particles by wind. It occurs when the lift forces of the wind exceed the gravity and cohesion of the soil grains at the surface. Susceptibility of land to wind erosion has been determined by taking into account the inherent topsoil features of the soil, principally focussing on topsoil structure, organic matter and texture (Table 19 – Appendix i). Land use and management may have a major influence on the degree of deterioration, particularly if dry soils are exposed when erosive winds are likely to occur. Wind erosion is likely to reduce the organic matter and nutrients available in the topsoil, while the reduction in topsoil depth also leads to reduced water infiltration causing increased runoff and a fall in productivity.

3 Results

3.1 Soil-landform units

Soil-landform units have been developed using the methodology outlined in Section 2.1. There are 54 discrete soil-landform units mapped for the freehold land in the NECMA region, and 142 soil components identified. A soil-landform unit is based primarily on land pattern while the land component, or element is a subset of these (refer to *Australian Soil & Land Survey Field Handbook,* McDonald *et al.* 1990). Although historical surveys and existing land resource information were used as a guide in the development of these soil-landform units, an additional 270 soil sites were collected using CLPR's purpose-built soil corer. These additional sites contributed to the detailed soil profile information and, when related to the local landform features, provides the basis of the soil-landform unit.

The soil-landform units defined for this study are listed in Table 5 giving a discrete code and brief unit location description, as well as the area and proportion of freehold land each unit consists of. Soil-landform units are also referenced in Appendix iii of this report however they are individually stored on this CD. For access to the detailed description of each soil-landform unit on the CD follow the links from Table 5, or the links from the soil-landform map base.

Within the soil-landform unit descriptions the landform features, the factors that may influence the soil forming process, and the susceptibility to erosion rating for each component are described. The land component descriptions provide a major soil type and in many cases, a minor soil type. The soil recognised as being the major soil type for each land component is then described in detail with full profile information. This data then becomes the basis of the agricultural capability assessment and is also used to derive the susceptibility to erosion processes.

Table 5 provides the total area (in ha) of each soil-landform unit as well as area statements which indicate the proportion of freehold land in the NECMA region which falls into each soil-landform unit, given as a percentage of the total freehold land. The area statements indicate the soil-landform units taking up the greatest proportion of freehold land in the NECMA are within the alluvial plains units (ALP1, ALP2) which encompass the broad area along the Ovens River valley and the riverine plain to the north-west of the study area. The next major unit exists in the floodplain zone (FLP3) along the major river valleys that dissect the region.

Other common landform types that support agricultural activities on freehold land occur on the colluvial footslopes derived from sedimentary rock (CLSy1) and colluvium derived from granite (CLG2), gneiss (CLGn) and schist (CLSs) in the Upper Murray region. The low hills on sedimentary in the King Valley (LHSy1), low hills on granite (LHG2), hills on granite (HG2), hills on gneiss (HGn) and hills on schist (HSs2) units are also commonly used for agriculture within the NECMA region. The most significant occurrence of agricultural activity on steep slopes is found on the granite (MG) on the steeply dissected terrain near Tallangatta, gneiss (MGn) and schist (MSs) metasediments in the Upper Murray region. Agricultural activities are able to occur on these mountainous units with less concern about susceptibility to erosion due to the more reliable rainfall and consistent vegetative cover of the slopes.

The soil-landform units are used as a platform to assess the capability of the land to support agriculture and assess the risk of land and water degradation. A generic land capability map product has been generated to relate soil, landform and climate limitations to the broad requirements of general agricultural enterprises. Map products generated from the soil-landform units for the project include:

1. Soil-landform unit base map
2. Agricultural capability map
3. Land degradation risk maps covering:
    - mass movement
    - gully and tunnel erosion
    - sheet and rill erosion
    - wind erosion.

These maps can be found on the CD-ROM accompanying this report and can be accessed by following the links from the front index to the map section.

Table 5 Soil-landform units and their components showing areas (ha) and the respective proportion (%) area of freehold land in the NECMA region

LU Code	Unit / component description	Geology	GMU	Freehold area (ha)	Proportion of freehold land (%)	No. of compon-ents	Major/ minor	Reference site
ALF1	**Alluvial fan, type 1, Reedy Creek**	**Quaternary or Recent alluvium**	**1.3.5**	**12 349**	**1.6**	**2**		
ALF1_lc1	Plain						Major	NELRA250
ALF1_lc2	Terrace flat or valley flat						Minor	NELRA249
ALF2	**Alluvial fan, type 2, 15 Mile Creek**	**Quaternary or Recent alluvium**	**1.3.5**	**3543**	**0.4**	**2**		
ALF2_lc1	Plain						Major	NELRA28
ALF2_lc2	Drainage depression and minor floodplain						Minor	NELRA273
ALP1	**Alluvial plain with prior stream channels, type 1, Ovens River**	**Quaternary sediments**	**4.2.1**	**55 776**	**7.1**	**3**		
ALP1_lc1	Prior stream levee						Major	NELRA252
ALP1_lc2	Plain						Minor	NELRA253
ALP1_lc3	Drainage depression or swamp						Minor	NELRA3
ALP2	**Older alluvial plain, type 2, Ovens River**	**Quaternary sediments**	**4.2.2**	**83 591**	**10.5**	**2**		
ALP2_lc1	Plain						Major	NELRA253
ALP2_lc2	Drainage depression or swamp						Minor	NELRA3
ALP3	**Alluvial plain, type 3, broad river valleys**	**Quaternary alluvium**	**1.3.5**	**20 793**	**2.6**	**3**		
ALP3_lc1	Elevated plains and alluvial terraces						Major	NELRA54 (Co10)
ALP3_lc2	Recent alluvial plain						Minor	NELRA46 (Co1)
ALP3_lc3	Drainage areas and depressions						Minor	NELRA51 (Co7)
ALP4	**Alluvial plain, type 4, Benambra Basin**	**Quaternary alluvium, swamp deposits and terraces**	**1.3.4**	**3327**	**0.4**	**2**		
ALP4_lc1	Plains and swamps						Minor	EG100

ALP4_lc2	Terrace							Major	EG99
ALP5	**Alluvial plain, type 5, Barnawartha North**	**Alluvium derived from Palaeozoic sediments, metasediments and igneous rocks**	**4.2.1**	**9856**	**1.3**	**3**			
ALP5_lc1	Levee, near plain							Minor	NELRA259
ALP5_lc2	Plain							Major	NELRA257
ALP5_lc3	Depressions							Minor	NELRA197
ALP6	**Alluvial plain, type 6, narrow upper river valleys**	**Quaternary alluvium**	**1.3.5**	**8525**	**1.1**	**3**			
ALP6_lc1	Elevated plains and alluvial terraces							Minor	Tallang Valley 25
ALP6_lc2	Alluvial plain and flats							Major	Tallang Valley 32
ALP6_lc3	Minor floodplain							Minor	Tallang Valley 27
CLG1	**Colluviumn derived from Devonian granite, type 1, Warby Ranges**	**Quaternary colluvium**	**1.3.5**	**11 449**	**1.5**	**2**			
CLG1_lc1	Hill slope							Minor	NELRA258
CLG1_lc2	Footslope							Major	NELRA275
CLG2	**Colluvium derived from granite, type 2, Upper Murray**	**Ordovician-Silurian-Devonian granite and granodiorite**	**1.3.4**	**27 990**	**3.5**	**3**			
CLG2_lc1	Moderate slopes on colluvium							Minor	Tall 33
CLG2_lc2	Gentle to very gentle slopes on colluvium							Major	NELRA53 (Co9)
CLG2_lc3	Minor depressions, drainage lines and seeps on colluvium							Minor	Tall 28
CLGn	**Colluvium derived from metamorphic gneiss**	**Colluvium and alluvium derived from Silurian granites and metasediments (gneiss)**	**1.3.5**	**20 650**	**2.6**	**3**			
CLGn_lc1	Upper slopes							Minor	NELRA270
CLGn_lc2	Lower slopes							Major	NELRA265

CLSs	**Colluvium derived from schist**	**Colluvium and minor alluvium derived from Ordovician metasediments (schist)**	**1.3.5**	**23 589**	**2.9**	**3**		
CLSs_lc1	Upper slopes						Major	NELRA266
CLSs_lc2	Lower slopes						Minor	NELRA237
CLSy1	**Colluvial footslopes and valleys derived from Ordovician sediments, type 1, footslopes and valleys**	**Quaternary to Recent colluvium and alluvium derived from Ordovician sediments**	**1.3.5**	**33 822**	**4.3**	**3**		
CLSy1_lc1	Moderate hill slopes						Minor	O&K531
CLSy1_lc2	Footslopes						Major	O&K501
CLSy1_lc3	Valley flat						Minor	O&K521
CLSy2	**Colluvium derived from Ordovician sediments, type 2**	**Colluvium and alluvium derived from Ordovician sediments and minor Silurian granite and associated metamorphics**	**1.3.5**	**416**	**0.1**	**2**		
CLSy2_lc1	Mid slopes						Minor	Kiewa343
CLSy2_lc2	Lower slopes and footslopes						Major	Kiewa343
CLSy3	**Colluvium derived from Tertiary sediments, type 3, Omeo West**	**Tertiary sediments**	**1.3.4**	**114**	**0.1**	**1**		
CLSy3_lc1	Gentle to moderate slopes						Major	EG59
CLSy4	**Colluvium derived from Ordovician sediments, type 4, Beloka**	**Colluvium and alluvium from associated Ordovician sediments**	**1.3.4**	**5922**	**0.7**	**2**		
CLSy4_lc1	Hillslope; mid to lower slope						Major	EG103
CLSy4_lc2	Drainage flats						Minor	EG102
CLSy5	**Colluvium derived from Ordovician sediments, type 5, Upper Murray**	**Colluvium and alluvium from associated Ordovician sediments**	**1.3.4**	**5734**	**0.7**			
CLSy5_lc1	Moderate to gentle slopes						Major	NELRA222
CLSy5_lc2	Lower slopes						Minor	Tallang Valley 26

CLV	**Colluvial footslopes derived from Devonian rhyolite and rhyodacite**	**Devonian rhyolite and rhyodacite**	**1.3.1**	**4316**	**0.5**	**3**		
CLV_lc1	Hill slopes						Minor	O&K528
CLV_lc2	Footslopes						Major	O&K554
CLV_lc3	Valley flat						Minor	O&K525
FLP1	**Floodplain, type 1, Murray River**	**Alluvium derived from Palaeozoic sediments, metasediments and igneous rocks**	**4.1.1**	**11 071**	**1.4**	**2**		
FLP1_lc1	Flat; close to river						Major	NELRA199
FLP1_lc2	Flat; away from river						Minor	NELRA260
FLP2	**Floodplain, type 2, Ovens River**	**Quaternary sediments**	**4.1.1**	**4142**	**0.5**	**4**		
FLP2_lc1	Terrace plain						Minor	O&K521
FLP2_lc2	Terrace flat, type 1						Major	OvBuf31
FLP2_lc3	Terrace flat, type 2 with occasional wetlands						Minor	NELRA251
FLP2_lc4	Channel bench						Minor	OvBuf10
FLP3	**Floodplain, type 3, upper river valleys**	**Alluvium derived from Palaeozoic sediments, metasediments and igneous rocks**	**1.3.5**	**42 582**	**5.4**	**3**		
FLP3_lc1	Flat; lower reach floodplain						Major	NELRA269
FLP3_lc2	Flat; upper reach floodplain						Minor	NELRA268
FLP3_lc3	Terrace flat						Minor	NELRA261
HB	**Hills, basaltic**	**Tertiary basalt and associated colluvium**	**1.3.4**	**1169**	**0.2**	**2**		
HB_lc1	Steep and moderate hillslopes						Minor	EG113
HB_lc2	Moderate to gentle hillslopes and footslopes						Major	EG112
HG1	**Hills on Devonian granite, type 1, Springhurst/Byawatha/Warby Ranges**	**Devonian granite**	**1.3.1**	**31 947**	**4.1**	**3**		

HG1_lc1	Hill crest						Minor	NELRA247
HG1_lc2	Steep to moderate slopes						Major	NELRA248
HG1_lc3	Footslopes						Minor	NELRA78
HG2	**Hills on granite, type 2, Upper Murray Valley**	**Ordovician, Silurian and Devonian granite, granodiorite and diorite**	**1.3.4**	**20 425**	**2.6**	**4**		
HG2_lc1	Crest						Minor	NELRA209
HG2_lc2	Steep slopes						Minor	Tall 110
HG2_lc3	Moderate slopes						Major	Tall 75
HG2_lc4	Gentle to moderate footslopes						Minor	NELRA215
HG3	**Hills on granite, type 3, Dargo**	**Palaeozoic granitic rocks, associated metamorphics and colluvium**	**1.3.4**	**9057**	**1.1**	**4**		
HG3_lc1	Moderate upper and mid slopes						Major	GL45
HG3_lc2	Steeper rocky slopes						Minor	GL45
HG3_lc3	Slopes on colluvium						Minor	Minor occurrences - no component descriptions available (taken from GRES report)
HG3_lc4	Flats, gentle slopes on alluvium						Minor	Minor occurrences - no component descriptions available (taken from GRES report)
HG4	**Hills, granitic, type 4, Omeo South**	**Silurian tonalite (granitic) and associated colluvium**	**1.3.4**	**2865**	**0.4**	**2**		
HG4_lc1	Moderate to steep slopes						Minor	EG71
HG4_lc2	Gentle to moderate slopes						Major	EG71
HGn	**Hills on gneiss, Tallangatta/Leneva/Bethanga**	**Ordovician gneiss and gneissic pegmatite**	**1.3.1**	**39 758**	**5.1**	**3**		
HGn_lc1	Steep slopes						Minor	Tallang 102
HGn_lc2	Moderate slopes						Major	Tallang 107

HGn_lc3	Gentle footslopes							Minor	NELRA113
HSs1	**Hills on metamorphic schist, type 1, Kiewa Valley**	**Ordovician metasediments (schists and minor gneiss) and associated colluvium and alluvium**	**1.3.1**	**10 776**	**1.4**	**2**			
HSs1_lc1	Upper slopes and crests							Minor	Kiewa345
HSs1_lc2	Moderate mid slopes							Major	Kiewa354
HSs2	**Hills on schist, type 2, Hinnomunjie**	**Metasediments and associated colluvium**	**1.3.1**	**38 804**	**4.9**	**3**			
HSs2_lc1	Crests and steeper slopes							Minor	EG51
HSs2_lc2	Moderate slopes							Major	EG60
HSs2_lc3	Gentle slopes in lower landscape position							Minor	EG55
HSs3	**Hills on Ordovician schist, type 3, Upper Murray Valley**	**Ordovician schist**	**1.3.1**	**18 624**	**2.3**	**3**			
HSs3_lc1	Crests and steep slopes							Minor	Tall 96
HSs3_lc2	Moderate slopes							Major	NELRA231
HSs3_lc3	Gentle slopes in lower landscape positions							Minor	NELRA245
HSy1	**Hills on Ordovician sediments, type 1, Upper Murray Valley**	**Ordovician greywacke, sandstone, siltstone, shale, mudstone**	**1.3.1**	**8736**	**1.1**	**3**			
HSy1_lc1	Hill crest							Minor	NELRA220
HSy1_lc2	Moderate to steep hill slopes							Major	NELRA219
HSy1_lc3	Gentle footslopes							Minor	NELRA242
HSy2	**Hills on Ordovician sediments, type 2, Beloka**	**Ordovician sediments and associated colluvium and alluvium**	**1.3.4**	**1789**	**0.2**	**2**			
HSy2_lc1	Steep to moderate upper and midslopes							Minor	EG105
HSy2_lc2	Gentle to moderate mid and lower slopes							Major	EG105
HSy3	**Hills on Ordovician sediments, type 3, Bowman / Carboor / Myrrhee / Dandongadale**	**Ordovician greywacke, sandstone, siltstone, shale, mudstone**	**1.3.1**	**15 697**	**1.9**	**3**			

HSy3_lc1	Hill crest						Minor	NELRA220
HSy3_lc2	Moderate to steep hill slopes						Major	O&K522
HSy3_lc3	Gentle footslopes						Minor	O&K521
LHG1	**Low hills on granite, type 1, Benambra North/Limestone Road**	**Silurian granite and associated colluvium**	**1.3.4**	**9362**	**1.2**	**2**		
LHG1_lc1	Undulating upper and mid slopes						Major	EG117
LHG1_lc2	Flats or drainage depressions						Minor	EG116
LHG2	**Low hills on granite, type 2, Shelley/Koetong/Yackandandah**	**Silurian granite, minor metamorphics and derived colluvium and alluvium**	**1.3.4**	**47 949**	**6.1**	**3**		
LHG2_lc1	Moderate rolling slopes						Major	NELRA271
LHG2_lc2	Gentle terrain						Minor	NELRA265
LHG2_lc3	Flat						Minor	O&K524
LHSy1	**Low hills on Ordovician sediments, type 1, Myrrhee/Carboor**	**Ordovician greywacke, sandstone, siltstone, shale, mudstone**	**1.3.3**	**33 799**	**4.3**	**3**		
LHSy1_lc1	Gentle crests						Minor	NELRA254
LHSy1_lc2	Moderate to gentle hill slopes						Major	NELRA20
LHSy1_lc3	Valley flat or drainage depression						Minor	NELRA26
LHSy2	**Low hills on Permian sediments, type 2**	**Permian tillite, conglomerate, sandstone**	**1.3.3**	**6890**	**0.8**	**3**		
LHSy2_lc1	Broad hill crests (residual hill cappings)						Minor	NELRA33
LHSy2_lc2	Moderate hill slopes						Major	NELRA255
LHSy2_lc3	Footslopes						Minor	NELRA34
LHSy3	**Low hills on Carboniferous sediments, type 3**	**Lower Carboniferous conglomerate, sandstone siltstone and shale**	**1.3.3**	**2064**	**0.3**	**3**		
LHSy3_lc1	Broad hill crest						Minor	NELRA38
LHSy3_lc2	Gentle to moderate hill slopes						Major	NELRA256
LHSy3_lc3	Valley flat or drainage depression						Minor	NELRA40

LHSy4	**Low hills on Ordovician sediments, type 4, northern footslopes**	**Ordovician sediments, associated colluvium and alluvium**	**1.3.3**	**15 807**	**1.9**	**3**			
LHSy4_lc1	Upper and mid slopes							Minor	NELRA261
LHSy4_lc2	Gentle to moderate mid slopes							Major	NELRA262
LHSy4_lc3	Gentle slopes and flats							Minor	NELRA263
MG	**Mountains on granite, Tallangatta/Pinnacles**	**Ordovician, Silurian and Devonian granite, granodiorite and diorite**	**1.3.1**	**30 754**	**3.9**	**5**			
MG_lc1	Crests and steep upper slopes							Minor	Tall T9
MG_lc2	Moderate to steep slopes with gradational soils							Major	Tall 109
MG_lc3	Moderate to steep slopes with duplex soils							Minor	Tall 41
MG_lc4	Moderate slopes in lower landscape positions							Minor	Tall 112
MG_lc5	Gentle to moderate slopes in the lower landscape position							Minor	Tall 37
MGn	**Mountains on gneiss**	**Ordovician gneiss and gneissic pegmatite**	**1.3.1**	**18 609**	**2.3**	**4**			
MGn_lc1	Crests and side slopes							Minor	Tall 107
MGn_lc2	Gentle to moderate slopes in lower landscape position							Minor	Tall 102
MGn_lc3	Steep upper slopes							Major	Tall 93
MGn_lc4	Moderate mid slopes							Minor	Tall 24
MSs1	**Mountains on Ordovician schist, type1, Upper Murray Valley/Tawonga**	**Ordovician schist**	**1.3.1**	**13 094**	**1.6**	**3**			
MSs1_lc1	Crests and side slopes							Minor	Tall 7
MSs1_lc2	Steep upper slopes							Major	NELRA235
MSs1_lc3	Moderate mid to lower slopes							Minor	NELRA202

MSs2	**Mountains on schist, type 2, Feathertop**	**Ordovician metasediments (slates and schists), gneiss, associated colluvium and alluvium and minor granitic rocks**	**1.1.1**	**42**	**0.1**	**3**		
MSs2_lc1	Steep to very steep slopes, on ridges						Major	Kiewa 232
MSs2_lc2	Scarps						Minor	Kiewa 231
MSs2_lc3	Steep to very steep slopes, on edge of plateau						Minor	Kiewa 231
MSy1	**Mountains on sedimentary rock, type 1, Porepunkah/Buckland/Upper Murray**	**Ordovician sandstone, shale and siltstone**	**1.3.1**	**13 720**	**1.7**	**2**		
MSy1_lc1	Crests and steep side slopes						Major	Tall T13
MSy1_lc2	Steep upper slopes and mid slopes						Minor	NELRA218
MSy2	**Mountains on Carboniferous sediments, type 2, Koonika**	**Lower Carboniferous conglomerate, sandstone, siltstone and shale**	**1.1.5**	**1115**	**0.1**	**2**		
MSy2_lc1	Steep crests and upper slopes						Minor	O&K10
MSy2_lc2	Steep and moderate hill slopes						Major	O&K509
MV1	**Mountains on rhyolite and rhyodacite, type 1, Upper Murray Valley**	**Silurian and Devonian rhyolite and rhyodacite**	**1.2.1**	**182**	**0.1**	**1**		
MV1_lc1	Crests and side slopes						Major	Tall T5
MV2	**Mountains on rhyolite and rhyodacite, type 2, King Valley**	**Upper Devonian rhyolite and rhyodacite**	**1.3.1**	**2770**	**0.4**	**3**		
MV2_lc1							Minor	Minor occurrences - no component descriptions available
MV2_lc2	Steep hill slopes						Major	O&K527
MV2_lc3							Minor	O&K528
PHB	**Plateaux on basalt hills**	**Tertiary basalt and associated colluvium**	**1.2.2**	**1511**	**0.2**	**2**		
PHB_lc1	Hillslope and undulating plain						Major	EG113

PHB_lc2	Hillslopes and undulating plain on colluvium						Minor	EG112
PHGn	**Plateaux on gneiss hills, Big Ben**	**Coarse and medium metamorphics; gneiss, minor schist**	**1.2.2**	**752**	**0.1**	**1**		
PHGn_lc1	Upper, mid and lower slopes						Major	Kiewa 228
PHSy	**Plateaux on sedimentary hills, High Plains**	**Ordovician sediments and associated colluvium and alluvium**	**1.2.2**	**2829**	**0.4**	**2**		
PHSy_lc1	Hillslopes on Ordovician sediments						Major	Kiewa 342
PHSy_lc2	Hillslopes on colluvium, alluvium						Minor	Kiewa 342
PMB	**Plateau associated with mountains <1220 m,Tertiary basalt**	**Tertiary basalt overlying Lower Carboniferous sediments or Devonian rhyolite and rhyodacite**	**1.2.2**	**680**	**0.1**	**2**		
PMB_lc1	Hillcrest and moderate hillslopes						Major	O&K513
PMB_lc2	Broad crest or minor plateau						Minor	O&K508
PMSs	**Plateaux on schist mountains, high plains**	**Ordovician metasediments, gneiss, associated colluvium and alluvium and Tertiary basalt**	**1.1.2**	**121**	**0.1**	**3**		
PMSs_lc1	Rolling hills and rises on Ordovician metasediments						Major	Kiewa231
PMSs_lc2	Undulating topography on colluvium and alluvium						Minor	Kiewa232
PMSs_lc3	Residual hills or ridges						Minor	Kiewa231
PMSy	**Plateau associated with Carboniferous mountains <1220 m, Wabonga**	**Lower Carboniferous conglomerate, sandstone, siltstone and shale**	**1.2.2**	**1857**	**0.2**	**4**		
PMSy_lc1	Gentle hill slopes						Major	O&K556
PMSy_lc2	Gentle crest						Minor	O&K553
PMSy_lc3	Steep hill slopes (scarp slope)						Minor	O&K509
PMSy_lc4	Drainage depressions						Minor	Minor occurrences - no component descriptions available

PMV	**Plateau on Devonian rhyolite and rhyodacite mountains <1220 m, Toombullup**	**Upper Devonian rhyolite and rhyodacite**	**1.2.2**	**362**	**0.1**	**3**		
PMV_lc1	Crest or moderate slopes						Minor	O&K515
PMV_lc2	Gentle hill slopes or undulating plain						Major	O&K515
PMV_lc3	Drainage depressions						Minor	Minor occurrences - no component descriptions available
PUB	Public land							
UNK	Unknown							
wb	Water bodies							

3.2 Agricultural capability

The soil-landform units are the basis for generating the agricultural capability maps associated with this report. The criteria detailed in Table 4 have been applied to the units to arrive at a three class rating system. Table 6 lists a range of broad agricultural enterprises, forestry production and nature conservation as potential land uses within the constraints of each capability class. These have been grouped based on their broad capability levels. The enterprise groupings are distinguished by their requirements for certain soil and landform characteristics. Where no limiting conditions are present, the land has a high capability and will support many forms of agricultural enterprise, however if a single limitation exists or few to many limitations exist, the land has a moderate to low capability and will support fewer forms of agriculture.

Table 6 Definitions for agricultural capability classes

Capability class		Description	Enterprise groups
1	High	High to moderate productivity on the alluvial floodplain and wider alluvial plain. Suited to a wide variety of horticultural applications on the floodplain and generally suited to grazing, viticulture and opportunistic cropping on the wider alluvial plain. Note: Flooding risk needs to be considered in floodplain areas. Note: Waterlogging is an issue on the wider alluvial plain. Note: Remnant vegetation needs to be considered within this class.	Irrigated horticulture, irrigated broadacre cropping, dairying, broadacre cropping, broadacre grazing, viticulture, forestry, nature conservation
2	Moderate	Moderate productivity on moderate to gentle slopes. Commonly suited to grazing and viticulture. Note: Flooding risk needs to be considered in floodplain areas. Note: Remnant vegetation needs to be considered within this class.	Broadacre grazing, broadacre cropping on gentler slopes, viticulture, forestry, nature conservation
3	Low	Low to moderate productivity or severe landform constraints exist (e.g. very steep slopes, rock outcrop). Typically utilised for forestry and marginal grazing, or nature conservation.	Forestry, marginal broadacre grazing, nature conservation

These enterprise groupings not only reflect the landform and soil limitations that impact on the various forms of agriculture, but also highlight areas with the flexibility to diversify into new and competitive industries. The land capability classes (1-high to 3-low) provide an indication of the likely risks associated with development, as well as highlighting the better quality land that may be able to support new and diverse industries. It is generally acceptable to steer development to land classed as high capability where landform and soil limitations are minimal. Subsequently, standard design and management techniques can safely be used to develop the land without the risk of failure. Therefore, lower maintenance costs and land management skills are required to manage the land and minimise on-site and off-site environmental impacts.

Areas of moderate classed land exhibit some landform and soil limitations and its use is generally restricted to broadacre enterprises. Where more intensive enterprises are considered it will require significant investigation and in many cases, specialist design to enable a cost-effective and efficient operation.

Land within the low capability class has significant landform and soil limitations. Under these circumstances, land uses such as effluent disposal, gravel roads and farm dams can be expected to fail and it is not acceptable to guide development to these areas without detailed investigation and specialist design to overcome these limitations, if this is even possible. This detailed investigation may result in a marked increase in infrastructure and maintenance costs. In addition, landowners would require a much higher skill level to cope with the associated on-site and off-site land management issues.

In this study the land capability analysis has identified freehold land with a high, moderate and low capacity to support agriculture in general. Table 7 summarises the area (ha) outlining the extent of each capability class for agriculture on freehold land in the NECMA region.

Table 7 Agricultural capability (ha and %) on freehold* land in the NECMA region

High		Moderate		Low	
ha	%	ha	%	ha	%
46 838	5.9	434 396	54.8	311 842	39.3

* **Note:** Total land area of the NECMA region is 1 933 309 ha which includes 1 140 233 ha of public land.

The areas identified with the highest capability within the study area are predominantly the alluvial deposits along the river valleys and the recent alluvium of the riverine plains. Although there are some very good red soils derived from the metamorphic schists and gneisses along the ranges bordering the river valleys, these are located on steep slopes and would present a significant erosion risk upon their management. They have therefore been identified within the moderate to low agricultural capability, depending upon the actual slope class.

The information provided in Table 7 and associated land capability maps assist the NECMA with implementing the principles of land stewardship and identifying where land use and land management practices may need to change, as well as identifying areas of greater potential for regional development. However, the product generated here is a generic agricultural capability product and is likely to differ for specific crops and agricultural enterprises. Therefore to evaluate a specific crop or enterprise it is recommended that specific criteria be used for assessing the capability rating. The soil-landform units can be used as the basis of specific enterprise analysis but the critical values or parameters may change within each factor.

To consider the suitability of an area for a particular agricultural enterprise, other information such as social, infrastructure and economic datasets need to be incorporated within the biophysical data used for the capability assessment.

3.3 Susceptibility of land to erosion

The land degradation analysis has been undertaken for the freehold land areas that were included as a part of this NELRA project. The analysis indicates that there are significant areas at risk from land and water degradation in the NECMA region. Table 8 provides a breakdown of the area (ha) at high risk of land and water degradation hazards.

In the NECMA region, a range of soil-landform units are prone to land and water degradation. As this region is bound by the Great Dividing Range and contains the highest elevation landforms in Victoria, the primary process which influences the degradation risk is gravity. Primarily the steeper slopes are subject to mass movement and landslip while those colluvial sediments predominantly derived from sandstones and siltstones are prone to gully and tunnel erosion. Sheet and rill erosion occurs primarily at the base of the steeper slopes in the valleys and start of the riverine plains, whereas wind erosion occurs primarily on the plains to the north-west of the study area with the lighter subalpine soils also potentially vulnerable.

Table 8 Susceptibility to land degradation (ha and %) on freehold* land in the NECMA region

Hazard	High and Very High		Moderate		Low and Very Low	
	ha	%	ha	%	ha	%
Mass movement	38 437	4.8	326 737	41.2	427 902	54.0
Gully and tunnel erosion	18 672	2.3	713 803	90.0	60 600	7.7
Sheet and rill erosion	56 774	7.1	491 568	62.0	244 734	30.9
Wind erosion	152 346	19.2	444 326	56.0	196 405	24.8

* *Total land area of the NECMA region is 1 933 309 ha which includes 1 140 233 ha of public land.*

The terms hazard and susceptibility are often used interchangeably, causing much confusion. Susceptibility of land to a specific deterioration process is defined here as a constant inherent feature, but the hazard changes depending upon the level of management and the type of land use.

Soil erosion and sedimentation is considered to be a major problem and can reduce the productivity of agricultural land. Sediment is the greatest pollutant of the world's surface waters as it degrades water quality and may carry adsorbed polluting chemicals (Robinson 1971). Furthermore most soils have very slow rates of formation and should be considered as a non-renewable resource thus the management of these soils is a very important consideration. It is therefore prudent to assess the risk, or susceptibility, of land to various forms of degradation.

As a result susceptibility to erosion maps have been generated for each of the four erosion themes discussed below. A three class rating of high, medium and low susceptibility has been developed based upon criteria outlined in Tables 9 to 12.

Sheet and rill erosion

The susceptibility of land to sheet and rill erosion is governed largely by the topsoil texture, slope of the land and length of slope. Other factors include hydrophobicity, percentage stone cover, tendency for aggregates to slake and disperse, size and weight of surface particles or aggregates, and the probability of intense summer rainfalls.

Soil loss from sheet and rill erosion is difficult to assess because of variability in soil loss within an area and the problem of measuring something that is not there. Sheet and rill erosion greatly reduces productivity, particularly in the case of texture contrast soils. The topsoil or A horizon is where most nutrients, organic matter, seed and macroporosity so desirable for a seedbed exists. If this is stripped away through soil loss the fertility of the soil is lost and productivity reduced.

The land characteristics and management factors involved in sheet and rill erosion are described in Table 9.

Gully and tunnel erosion

The susceptibility of land to tunnelling and gully erosion depends on a number of interrelated factors. These are principally rainfall intensity, vegetation cover, rooting depth, microrelief, slope, position in landscape, contributing upslope area, soil permeability, soil depth, soil cohesion and dispersibility. As the volume of overland flow increases and becomes channelised, the erosive power increases and resistance of the soil aggregates and particles to detachment becomes critical. The size and weight of the soil particles and their cohesion, or the tendency to slake or disperse will determine the resistance.

Gully erosion occurs particularly in areas on Ordovician sediments, but is also common on granitic and glacial parent material. When gradational soils and stony loams on crests and upper slopes are cleared of the native deep-rooted vegetation, some rain percolates through the soil profile to the watertable, but some becomes overland flow with the potential to sheet erode the sloping land and scour out drainage depressions.

The presence of gullies and tunnels adversely affects productivity in a number of ways. As well as the land directly lost from production, the soil adjacent to the gully or tunnel is excessively drained thus reducing the vigour and number of plant species able to survive.

The land characteristics and management factors involved in gully and tunnel erosion are described in Table 10.

Mass movement (landslip)

Mass movement encompasses erosion processes in which gravity is the primary force acting to dislodge and transport land surface materials. It is a function of the gravitational stress acting on the land surface and the resistance of the surface soils and/or rock materials to dislodgement. When the gravitational stress exceeds this resistance, mass movement occurs. The occurrence of mass movement depends on the interaction of various factors including landform, lithology, soil type, rainfall intensity and duration, drainage characteristics and vegetation cover.

Landslip is seldom the result of a single factor as failure is the end result of activities and processes that have taken place over many years prior to the actual movement. In general, failures occur when the weight of the slope exceeds its restraining capacity. The most common triggering agent is the infiltration of water into the sloping land surface, which has the effect of both reducing the shear strength of the soil material and increasing the mass loading on the slope.

Within the study area there are a number of steeply sloping areas which may be susceptible to landslip if not managed correctly. The land characteristics and management factors involved in mass movement or landslip are described in Table 11.

Wind erosion

Wind erosion is the movement of soil particles by wind. It occurs when the lift forces of the wind exceed the gravity and cohesion of the soil grains at the surface.

Susceptibility of land to wind erosion is determined by taking into account the inherent features of the soil, the climate and position in landscape. The erodibility of the topsoil is a major factor, but structure, texture, stoniness and organic matter are all significant. Land use and management may have a major influence on the degree of deterioration, particularly if dry soils are exposed when erosive winds are likely to occur. Wind erosion is likely to reduce the organic matter and nutrients available in the topsoil, while the reduction in topsoil depth also leads to reduced water infiltration causing increased runoff and a fall in productivity.

The loose sandy topsoils on granitic parent materials are highly susceptible, while the open plains with fine sandy loam topsoils, and the lower slopes of the drier granitic areas have moderate susceptibilities.

The land characteristics and management factors involved in wind erosion are described in Table 12.

Table 9 Land characteristics and management factors involved in sheet and rill erosion ....

Processes	Land characteristics affecting processes	Factors affected by land characteristics	Management factors that modify land characteristics
	<u>Vegetation</u>		
Sheet and rill erosion occur when the forces due to rainfall, flowing water and gravity overcome the cohesion and weight of the soil particles/aggregates. Detachment and transport of exposed soil may be caused by: • raindrop impact • rain splash • surface flow. Surface flow occurs on any sloping surface when the rainfall rate exceeds the infiltration rate. Off-site effects include increased sedimentation and runon in streams and on lower lands.	• structure • percent surface cover (including litter) • leaf area • rooting depth • perenniality	• exposure of surface soil • intensity of raindrop impact • infiltration/run-off ratio • velocity of surface flow • transpiration and hence infiltration rate and volume of surface flow	All aspects of the vegetation are affected by selection of species and control of biomass by practices such as: • cultivating • clearing • trafficking • fertilising • grazing • trampling • harvesting • burning
	<u>Climate</u>		
	• rainfall intensity and duration • seasonal rainfall and evapotranspiration regime	• intensity of raindrop impact • volume of water exceeding infiltration rate and hence • volume of surface flow • soil water content and hence infiltration rate and volume of surface flow	
	<u>Geology</u>		
	• permeability of rock or unconsolidated sediments	• soil water content and hence infiltration rate and volume of surface flow	
	<u>Topography</u>		
	• microrelief • slope degree and length • slope and landform shape • position in landscape	• infiltration/runoff ratio • velocity of surface flow • volume and velocity of surface flow • tendency to concentrate surface flow • volume of runon	Contour cultivating, contour banking and strip cropping reduce slope length and affect microrelief.
	<u>Soil</u>		
	• profile permeability • depth and water-holding capacity • size and weight of surface particles or aggregates • cohesion of surface particles or aggregates, including tendency to slake and disperse • tendency to surface seal and hydrophobicity • percent stone cover	• infiltration rate and hence volume of surface flow • infiltration/runoff ratio • detachment and transport • detachment • infiltration rate and hence volume of surface flow • infiltration/runoff ratio and velocity of surface flow	The above management practices controlling biomass affect soil organic matter content, which in turn affects all listed soil characteristics except surface rock. Direct soil compaction and disruption by trampling, trafficking and cultivating affect soil permeability, waterholding capacity and size/weight and cohesion of aggregates.

Source: Aldrick *et al.* (1988)

Table 10 Land characteristics and management factors involved in gully and tunnel erosion

Processes	Land characteristics affecting processes	Factors affected by land characteristics	Management factors that modify land characteristics
	Vegetation		
Gully and tunnel erosion occur when the forces due to rainfall, flowing water and gravity overcome the cohesion and weight of the soil particles/aggregates. Detachment of exposed surface soil is caused by: • raindrop impact • channelised overland flow • surface cracking. Detachment of subsoil is caused by: • subsurface flow in permeable strata and along cracks and tunnels. Transport of particles and aggregates occurs by: • channelised overland flow • subsurface flow • gravity collapse. Gully erosion is regarded as having occurred when the channel is too deep to be crossed or cannot be obliterated by tillage. Off-site effects include increased sedimentation and runon in streams and on lower lands.	• structure • percent surface cover (including litter) leaf area • rooting depth • perenniality	• exposure of surface soil • intensity of raindrop impact • velocity of channelised flow and hence particle detachment and transport • transpiration and hence infiltration rate and volume of surface and subsurface flow	All aspects of the vegetation are affected by selection of species and control of biomass by practices such as: • cultivating • clearing • trafficking • fertilising • grazing • trampling • harvesting • burning.
	Climate		
	• rainfall intensity and duration • seasonal rainfall and evapotranspiration regime	• intensity of raindrop impact • volume of surface and sub-surface flow • volume of surface and sub-surface flows via regulation of soil water content	
	Geology		
	• perviousness of rock or unconsolidated sediments	• soil water content and hence infiltration rate and volume of surface and subsurface flow • lateral or vertical movement of water	
	Topography		
	• microrelief (both of channel and catchment to a site) • channel slope degree and length • position in landscape and catchment area • catchment slope degree and length • slope and land-form shape	• infiltration/run-off ratio • velocity of surface flow • volume of surface and sub-surface flows reaching site • tendency to concentrate surface flow	Contour and diversion banking, strip cropping and contour cultivating reduce catchment slope length and catchment area; they also affect microrelief.
	Soil		
	• profile permeability • depth and water-holding capacity • size/weight of soil • particles/aggregates • cohesion of particles/aggregates, including tendency to crack, slake and disperse differential permeability within a horizon due to the presence of cracks and channels • percent stone cover	• infiltration rate and hence volume of surface and sub surface flow • lateral or vertical movement of soil water • volume of surface and sub- surface flow • detachment and transport • detachment • movement of water along preferred channels • volume surface flow	Type and amount of biomass production will affect soil organic matter content, which will in turn affect most listed soil characteristics. Soil disruption and compaction by trampling, burrowing, cultivating and trafficking will affect profile permeability, water-holding capacity and size/weight and cohesion of soil particles/aggregates.

Source: Aldrick *et al.* (1988)

Table 11 Land characteristics and management factors involved in mass movement

Processes	Land characteristics affecting processes	Factors affected by land characteristics	Management factors that modify land characteristics
	<u>Vegetation</u>		
Landsliding occurs when the shear forces exceed soil or regolith strength. This generally occurs when soil or regolith strength is reduced by an increase in water. Mass movement is caused by: • infiltration ofwater • wetting of basal plane • saturation of soil (mudflow) • shearing and movement of • soil mass by gravity.	• total leaf area and canopy type • root depth and mass • perenniality	• transpiration and hence soil water content • volume of water held by canopy and hence volume available for infiltration • anchorage of soil by roots harvesting	All aspects of the vegetation are affected by selection of species and control of biomass by practices such as: • cultivating • clearing • trafficking • fertilizing • grazing • trampling • burning.
	<u>Climate</u>		
Secondary causes of mass movement may be: • loading of soil mass resulting in an increase in shear strength	• seasonal rainfall and evapotranspiration regime	• soil water content	
	<u>Geology</u>		
• removal of material from slope toe resulting in reduced slope support. Types of landslides covered by this table are: • rock and earth slides	• perviousness of rock or unconsolidated sediments • wet strength of rock/regolith • angle of dip	• soil water content • shearing tendency	
	<u>Topography</u>		
• earth flow (downslope movement of unsaturated soil and weathered rock on a lubricated basal shear plane) • mudflow (movement of saturated soil and rock)	• slope degree • microrelief and position in landscape	• lateral gravitational component • run-on, site drainage and hence soil water content	
	<u>Soil</u>		
• combination slide/flows.	• topsoil permeability • presence of slowly permeable layer • cohesion of particles and aggregates including tendency to slake and disperse • depth • clay mineralogy	• infiltration/run-off ratio • water content of soil immediately above layer • soil strength • soil water content	Compaction and soil disruption by stock and vehicles, and by cultivating, will affect profile permeability.

Source: Aldrick *et al.* (1988)

Table 12 Land characteristics and management factors involved in wind erosion

Processes	Land characteristics affecting processes	Factors affected by land characteristics	Management factors that modify land characteristics
	Vegetation		
Wind erosion occurs when the force due to wind is sufficient to overcome the cohesion and weight of the soil particles and to allow their movement. Detachment and transport is caused by: • abrasion and suction • creep • saltation and suspension. Deposition occurs by: • entrapment • reduced wind velocity.	• structure • percent surface cover (including litter) • leaf area • rooting depth • perenniality	• exposure of surface soil • depth of zero velocity layer • transpiration and hence soil moisture content and particle cohesion	All aspects of the vegetation are affected by selection of species and control of biomass by practices such as: • grazing • trampling • harvesting • burning • cultivating • clearing • trafficking, • fertilising.
	Climate		
	• rainfall/evapotranspiration regime • wind strength • wind direction	• soil moisture content and hence particle cohesion • detachment and transport • site exposure	
	Geology		
	• perviousness of rock or unconsolidated sediments	• soil moisture content and hence particle cohesion	
	Topography		
	• microrelief • slope degree • position in landscape	• surface wind strength • run-on, site drainage and hence soil moisture content and particle cohesion	Retention or construction of windbreaks, cloddy cultivation and ridging affect microrelief.
	Soil		
	• percent stone cover • size/weight of surface particles/aggregates • aggregate stability (influenced by factors such as presence ofcarbonates, iron oxides and organic matter, clay mineralogy and biological activity) • profile permeability • depth and water-holding capacity • size/weight of surface soil	• surface wind strength • detachment and transport • detachment • soil moisture content and hence particle cohesion and weight or particles/aggregates	Soil disturbances such as trampling cultivating affect aggregate stability. Any practices affecting biomass alter the organic matter content of the topsoil.

Source: Aldrick *et al.* (1988)

List of abbreviations

AWC	available water capacity of soils
CAS	Catchment and Agricultural Services, NRE
CAT	Catchment Assessment Tool
CAW	Catchment and Water Division, NRE
CLPR	Centre for Land Protection Research, Bendigo
DEM	digital elevation model
ERA	enhanced resource assessment
GIS	geographic information systems
LRA	land resource assessment
LUIM	Land Use Impact Model
mASL	metres above sea level
mya	million years ago
NECMA	North East Catchment Management Authority
NELRA	North East Land Resource Assessment
NHT	Natural Heritage Trust
NRE	Department of Natural Resources and Environment
RLS	Rural Land Stewardship Program
SCL	State Chemistry Laboratories, Werribee
SWAT	Soil and Water Assessment Tool

References

Aldrick JM, Hook RA, van de Graff RHM, Nicholson BM, O'Beirne DA, Schoknecht NR (1988) ‘A study of the land in the catchment of the Gippsland Lakes’ Department of Conservation Forests and Lands, Victoria.

Bluml MR, Reynard KA (2000) ‘An assessment of the versatility of agricultural land in the Rural City of Wangaratta’ Centre for Land Protection Research, Vic. Folio Report 2000/6, Department of Natural Resources and Environment, Bendigo.

Charman PEV, Murphy BW (1991) ‘Soils their properties and management. A soil conservation handbook for New South Wales’ (Sydney University Press, Sydney)

Clutterbuck RS (1980) ‘A land capability study in the Rural City of Wodonga - erosion risk assessment’ Folio Report FR 1444, Soil Conservation Authority, Kew, Victoria.

Clutterbuck RS, Costello R (1983) ‘A land capability study in the Shire of Yackanadandah - erosion risk assessment’ Soil Conservation Authority, Kew, Victoria.

Conacher AJ, Conacher J (2000) ‘Environmental planning and management in Australia’ (Oxford University Press, South Melbourne.)

Elliot GL, Leys JF (1991) Soil erodibility. In ‘Soils: their properties and management’ (Eds. PEV Charman and BW Murphy), (Sydney University Press.)

Hook RA, Rees DB (1999) ‘Land resource assessment in the western part of the Shire of Towong – former Shire of Tallangatta’ (Centre for Land Protection Research, Vic.) Technical Report No. 52 Department of Natural Resources and Environment, Bendigo.

Isbell R (1996) ‘The Australian soil classification’ (CSIRO Publishing: Melbourne.)

LCC (1974) ‘Report on the north east study area, districts 3, 4 and 5’ Land Conservation Council, Melbourne.

LCC (1984) ‘Report on the north eastern (Benalla – Upper Murray) review’ Land Conservation Council, Melbourne.

Lorimer MS (1985) Estimating the susceptibility of soil to wind erosion in Victoria. *Journal of Australian Institute of Agricultural Science* **51**, 122-126

McDonald RC, Isbell RF, Speight JG, Walker J, Hopkins MS (1990) ‘The Australian soil and land survey field handbook’ 2nd edn. (Inkata Press: Melbourne.)

Northcote KH (1979) ‘A factual key for the recognition of Australian soils’ 4th edn. (Rellim Technical Publications: Adelaide.)

Ockenden PL, O’Meara M (1980a) ‘A land capability study in the Shire of Chiltern - erosion risk assessment’ Folio Report FR 1445 (Soil Conservation Authority: Victoria)

Ockenden PL, O’Meara M (1980b) ‘A land capability study in the Shire of Beechworth - erosion risk assessment’ Folio Report FR 1446 (Soil Conservation Authority: Victoria)

Rees DB (1995) ‘A land capability assessment of the Cassilis Valley, Swifts Creek.’ Centre for Land Protection Research, Technical Report No. 27. Department of Natural Resources and Environment, Bendigo.

Robinson AR (1971) Sediment, our greatest pollutant? *Agricultural Engineering* **53**, 406-8.

Rowe K (1967) 'A study of the land in the Victorian catchment of Lake Hume.' Technical Communication TC-5. Soil Conservation Authority: Victoria.

Rowe K (1972) 'A study of the land in the catchments of the Kiewa Rivers.' Technical Communication TC-8. Soil Conservation Authority: Victoria.

Rowe K (1984) 'A study of the land in the catchments of the upper Ovens and King Rivers.' Technical Communication TC-16. Soil Conservation Authority: Victoria.

Salter PJ, Williams JB (1969) The influence of texture on the moisture characteristics of soil. Relationships between particle size composition and moisture contents at the upper and lower limits of available water. *Journal of Soil Science.* **20**, 126-131.

Stace HCT (1968) 'A handbook of Australian soils.' (Rellim Technical Publications: Adelaide.)

Stewart C, Bennett B (1999) 'Technical development of agricultural industries study.' Albury Wodonga Area Consultative Committee. (RuralBiz Pty. Ltd.: Wooragee)

Appendices

Appendix i. Criteria for determining susceptibility to erosion

Susceptibility of soil to sheet and rill erosion by water

The following table (Table 13) 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)). These have then been related to slope to determine a rating for susceptibility. The final rating for susceptibility to sheet/rill erosion is determined from Table 14 once the erodibility of the topsoil and the slope of the area have been assessed.

Table 13 Erodibility of topsoils

Soil parameters			**Soil dispersibility**		
Texture group (A1)	**Structure grade (A1)**	**Horizon depth (A1 + A2)**	**Very Low – Low E3(1), E3(2), E4,E5, E6, E7, E8**	**Medium – High E3(3), E3(4), E2**	**Very High E1**
Sand	apedal	< 0.2 m	M		
		0.2 - 0.4 m	L		
		> 0.4 m	L		
Sandy loam	apedal	< 0.2 m	M	H	
		0.2 - 0.4 m	L	M	
		> 0.4 m	L		
	weakly pedal	< 0.2 m	H	E	
		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 pedal	< 0.2 m	H	E	
		0.2 - 0.4 m	M	V	
		> 0.4 m	M		
	peds evident	< 0.2 m	H	E	
		0.2 - 0.4 m	H		
		> 0.4 m	H		
Clay loam	apedal	< 0.2 m	M	H	
		0.2 - 0.4 m	L	M	
		> 0.4 m	L		
	weakly pedal	< 0.2 m	H	E	
		0.2 - 0.4 m	M	V	
		> 0.4 m	M		
	peds evident	< 0.2 m	H	E	
		0.2 - 0.4 m	H	E	
		> 0.4 m	M		
Light clay	weakly pedal	< 0.2 m	H	E	E
		0.2 - 0.4 m	M	V	E
		> 0.4 m	M	V	E
	peds evident	< 0.2 m	M	V	E

		0.2 - 0.4 m	M	H	E
		> 0.4 m	M	H	E
	highly pedal	< 0.2 m	H	E	
		0.2 - 0.4 m	M	V	
		> 0.4 m	M	V	
Medium to heavy clay	weakly pedal	< 0.2 m	M	H	E
		0.2 - 0.4 m	M	H	V
		> 0.4 m	M	H	V
	peds evident	< 0.2 m	H	E	E
		0.2 - 0.4 m	M	V	E
		> 0.4 m	M	V	E
	highly pedal	< 0.2 m	H	E	E
		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 14 Susceptibility of soil to sheet and rill erosion*

Slope %	**Topsoil erodibility (from Table 13)**				
	Low	**Moderate**	**High**	**Very high**	**Extreme**
< 1 %	Very low	Very low	Low	Low	Moderate
1 - 3 %	Very low	Low	Moderate	Moderate	High
4 - 10%	Low	Moderate	Moderate	High	Very high
11 - 32%	Moderate	Moderate	High	Very high	Very high
> 32%	Moderate	High	Very high	Very high	Very high

***Note:** Topsoil erodibility is determined from the texture, structure, depth and dispersibility of the topsoil (Table 13). The susceptibility of the topsoil to sheet and rill erosion relates to the combined effect of slope and topsoil erodibility (Table 14).

The ratings for sheet and rill erosion as outlined in the table above, may be adjusted to account for regional factors, ie. where areas have high growth rate and ground cover during the summer months, the values may be adjusted in comparison to much drier regions with little growth and ground cover during the summer months.

Susceptibility to gully and tunnel 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 five class rating system. This is detailed in Table 15.

Table 15 Susceptibility to gully and tunnel erosion

Criteria	**Description**	**Score**
Slope	< 1%	1
	1 - 3%	2
	4 - 10%	3
	11 - 32%	4
	> 32%	5
Sub-soil dispersibility	E1	5
	E2, E3(3), E3(4)	4
	E3(1), E3(2)	3
	E4, E5	2
	E6, E7, E8	1

Depth to rock/hardpan	0 - 0.5m	1
	0.6 - 1.0m	2
	1.1 - 1.5m	3
	1.6 - 2.0m	4
	> 2.0m	5
Subsoil structure	Apedal, massive	1
	Weak	
	fine < 2 mm	3
	moderate 2 - 10 mm	2
	coarse > 10 mm	1
	Moderate	
	fine < 2 mm	4
	moderate 2 - 10 mm	3
	coarse > 10 mm	2
	Strong	
	fine < 2 mm	5
	moderate 2 - 10 mm	3
	coarse > 10 mm	1
	Apedal, single grained	5
Lithology of substrate	basalt	1
	volcanic	2
	rhyodacite	2
	granite	4
	alluvium	3
	colluvium	5
	tillite	4
	Ordovician sandstone/mudstone	5
	Silurian sandstone/mudstone	4
Rating for susceptibility to gully erosion:	**Class**	**Total score**
	1. Very low	6 - 10
	2. Low	11 - 13
	3. Moderate	14 - 17
	4. High	18 - 20
	5. Very high	21 - 25

Note: The ratings for gully and tunnel erosion as outlined above, may be adjusted to account for regional factors, i.e. where areas have high growth rate and ground cover during the summer months, the values may be adjusted in comparison to much drier regions with little growth and ground cover during the summer months.

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 landslips are the result of factors such as soil depth, slope, soil texture, volume of water held in the soil (available water capacity), permeability of the solum and the underlying parent material. Available water capacity (AWC) is a measure of the amount of useable 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 point (permanent wilting point). There is a reasonable correlation between soil texture and AWC (Salter and Williams 1969) (Table 16).

Table 16 Available water capacity (AWC) of soils

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

Note: The total amount of water available to plants can be calculated by adding the amount of available water in each horizon down to a maximum depth of 2m. Gravel content of the soil horizons should be taken into account.

Table 17 Example use of AWC (from Table 16 above)

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

Note: The total amount of water in the worked example above = 167 (Class 2)

Since the quantity of water in a profile is itself a function of soil texture, depth and permeability, Table 18 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 18 Susceptibility to slope failure (mass movement)

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

This enables a five class rating system from very low to very high susceptibility to mass movement.

Susceptibility of soil to erosion by wind

The susceptibility of land to wind erosion is a function of soil erodibility, the probability of erosive winds when the soil is dry and the exposure of the land component to wind (Lorimer 1985). Soil erodibility is a very important factor to consider in land capability rating tables (Table 19).

Table 19 Topsoil 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

Note: The ratings for wind erosion as outlined in the table above, may be adjusted to account for regional factors, i.e. where areas have higher growth rate and ground cover during the summer months, the values may be adjusted in comparison to much drier regions with little growth and ground cover during the summer months