LAND CAPABILITY ASSESSMENT GUIDELINES

December 1999

CONTENTS

1. INTRODUCTION

1.1 Aims of the Guidelines

The aims of the Guidelines are to:

a. Show how the processes involved in natural systems interact with land use and land management.

b. Provide an acceptable and useable means of providing land information to planners and managers in a form which can be readily integrated with other information which must be considered in planning decisions.

To this end the methods embodied in these Guidelines are intended to be explicit and produce consistent results which conform with the known performance of land under given land uses. However it is acknowledged that the system must be one which can be applied using available personnel and information. Hence it describes how to use existing data and is explicit in defining what additional information is required and how it is to be obtained.

The end result of using the Guidelines is to provide an informed basis for management decisions and for assessing costs in the planning process, not to unnecessarily restrict development in particular areas.

1.2 Content of the Guidelines

Following this introductory Section, Section 2 of the Guidelines describes how unique land units are defined, soil characteristics mapped and erosion risk determined. Section 3 shows how land capability assessment should be conducted and gives details of the hazards and constraints arising from certain land use activities and land units. Section 4 details exactly what information is required in a land capability assessment and identifies specific engineering constraints.

Three Appendices are included to elaborate on certain aspects of land capability assessment. Appendix A provides a basic description of some relevant concepts including erosion processes. Appendix B details the land resource data available in the ACT. Appendix C is an outline of basic techniques used for soil survey, data analysis etc.

1.3 Statutory Requirements

The statutory imperative for these Guidelines derives from the Territory Plan, the principal planning document in the ACT. The Territory Plan stipulates that:

> *The pattern of development is to reflect land capability constraints resulting from topography, soils, geotechnical factors, drainage, natural hazards and micro-climate.*
>
> and

Land development and major new works will be subject to assessment of geotechnical constraints and land capability.

This document describes how land capability assessment is to be conducted for such developments, and the information that is expected in the assessment. The guidelines have been drafted in order to establish a consistent methodology for land capability assessment in the ACT, and to provide guidance on measures required to address hazards and land use constraints. They are intended to be a simple and practical guide for the assessment of typical development activities in the ACT.

1.4 Background to the guidelines

A number of ACT soils present significant environmental and geotechnical hazards because of erosion susceptibility, soil structure, seasonal waterlogging, poor wet strength and slope instability. These hazards may be increased by the type of urban land use or development solutions adopted. The ACT Government has adopted a policy of planning and managing land to minimise the potential for land degradation. If land is used beyond its capability it is unlikely to sustain a particular form of land use without serious on site or off site consequences. Thus it forms an essential basis for sustainable land use planning.

Land capability assessment is a tool which can be used by planners, engineers and Government Authorities to assist in evaluating alternative practices or general designs that will overcome unfavourable soil or terrain characteristics and minimise off-site effects, such as sedimentation and pollution of waterways.

Land use capability assessment is defined as "the systematic arrangement of land into various categories according to its capability to sustain particular land uses without land degradation. In some cases, these uses may only be sustainable where supplemented by hazard management measures."

The approach involves the identification and interpretation of unique land units with similar climatic, geological, landform and soil characteristics, as the basis for determining erosion risk and other land use constraints and hazards.

This information is used to assess the capability of land to sustain different uses, and to assess the measures required to address erosion, drainage, foundation, and slope stability hazards.

The intention of this material is not to exclude urban development from particular areas, but rather to provide better information about the implications of development decisions, including the identification of hazard control measures and the costs of the hazard management. One possible outcome of this assessment may be that, in the light of the cost and maintenance implications of the hazard reduction measures, the proposed land use is inappropriate.

The methods of surveying soil and assessing land use capability have much in common but capability assessment involves several disciplines that need to be integrated. Soil is only one of these attributes and so soil surveying involves only the single discipline of soil science (Gunn *et al* 1988).

1.5 Why Land Capability Assessment is Necessary

As land is a limited resource and the competition between land use alternatives is complex, a knowledge of physical constraints identified from a land capability assessment, becomes a major consideration in any planning exercise. Building a solution to these constraints or potential problems into the planning phase of a project is generally cheaper than using a band-aid approach afterwards.

If soil and landform characteristics are neglected soil erosion, flooding and slope failure can result as development proceeds. Much of this damage results from disturbance and mismanagement during the construction phase but may continue well after construction has finished in areas of critical erosion risk. Numerous factors contribute to the initiation of erosion during development. These include the destruction of vegetation and disturbance of the ground surface caused by the construction of access roads, disposal of runoff, excavation and land filling. Unsuitable stabilisation techniques also initiate or aggravate erosion and may prolong its effects after the construction phase.

Covering the soil with buildings and paved surfaces, without compensating measures, leads to a rise in flood peaks, extends the areas subject to flooding and increases the potential for larger volumes of sediment downstream. The deposition of sediment and detritus downstream of urban settlements often reduces the value of land and waterways thereby limiting their use. As sedimentation proceeds there may be accompanying damage to scenic assets, biotic resources and aquatic recreation areas.
Erosion risk assessment includes characterisation of soil properties and identification of temporary and permanent conservation practices that may be required. These may be land grading and shaping, terraces, surface and subsurface drains, diversions, berms, sediment basins, waterways, grade stabilisation structures, plant cover on critical sites and mulching.

Land capability assessment comprises an extension of erosion risk to consider the consequences of development on a particular area of land. When the effect of a proposed development is considered in conjunction with the erosion risk, it becomes the erosion hazard. The converse to this is consideration of the soil or slope development constraints that may occur in an area. These two complementary pieces of information provide an assessment of the capability of an area of land to support a particular land use.

Consequently land capability assessment will provide three sorts of information:

1. erosion risk based on existing conditions
2. erosion hazard which factors in how development activities can increase erosion risk
3. constraints on development imposed by natural conditions

For planning of individual large sites the determination of erosion risk will generally provide adequate information. For outline planning exercises it will be necessary to consider also the erosion hazard and the constraints to development.

Land capability should not be confused with land suitability. Land suitability is the assessment of how suitable a particular site is for a particular use, and depends on land capability and a range of other factors such as proximity to centres of population, land tenure, attractiveness of scenery and consumer demand.

1.6 When is land capability assessment required?

Individual Sites
Land capability assessment should be conducted where any of the following are involved:

- the site is > 5 ha in size and a significant proportion of the site will be developed
- road construction is involved
- the average slope of the site is over 10^0 and a significant proportion of the site will be developed

For all these situations an **initial assessment** is required which will involve;

- determining the erosion risk and general soil/slope based limitations

Outline Planning
For all outline planning exercises a more comprehensive assessment (**full assessment**) is required which will involve;

- determining the erosion risk
- determining the impact of the proposal on erosion risk
- determine the engineering risks the proposal may encounter
- determine the mitigation measures required to contain any problems
- assess the cost, land take or other limitations arising from mitigation measures
- review appropriateness of proposed land use in the light of the preceding analysis

The need for land capability assessment, and procedures that should be followed, are discussed in detail in following sections.

2 INITIAL LAND CAPABILITY ASSESSMENT

2.1 Purpose of Land Capability Assessment

Land capability assessment is a process of relating land use activities to erosion risk and other constraints. The initial step in any assessment is an evaluation of the land conditions and the risk erosion on a site. This is termed the **initial assessment** in this document. This section describes how an initial assessment is conducted (see also Figure 1.1).

The second level of land capability assessment (required for outline planning exercises), requires;

- determining the erosion risk
- determining the impact of the proposal on erosion risk
- determine the engineering risks the proposal may encounter
- determine the mitigation measures required to contain any problems
- assess the cost, land take or other limitations arising from mitigation measures
- review appropriateness of proposed land use in the light of the preceding analysis

This second level is termed a **full assessment** and is described in detail in Section 3 (see also Figure 1.1).

2.2 Initial Assessment

Initial land assessment provides sufficient information for individual sites. It comprises three components; identification of homogeneous land units, characterisation of soils in the land unit and calculation of erosion risk in the land unit. These components are elaborated below.

2.3 Homogeneous Land Units

A key approach underpinning land capability assessment is the identification of land units which are homogeneous in respect of their critical spatial attributes. Such land units will then have consistent capability characteristics across their spatial extent. Three factors are used to define land units across the ACT; geology, slope and extent of rock outcrop. Once homogeneous land units have been defined, information on soil characteristics and erosion risk is determined for each land unit.

Land unit attributes and description comprises:

- geology of area - geological units across area
- slope classifications (classes are based upon regular logarithmic intervals; (<1^o, 1-3^o , 3-10^o 10-23^o , 23-37^o , 37-60^o, >60^o)
- rock outcrop - extent of rock outcrop (0 - 10%, 10 - 30%, 30 - 50%, >50%)

The land unit is identified on a map in terms of:

Geological unit / Slope / Rock outcrop
e.g. Silurian rhyodacite / 1-3^o slope / 0 - 10% rock outcrop

Figure 1.1 Flow Chart of the Land Capability Assessment Process

Step 1: Define Homogeneous Land Unit

Define land units (section 2.1)
geology
slope
rock outcrop

⇐ **Geology (Appendix B1, C6)**
Identify geological units

⇐ **Slope**
Measure slope (<1^0, 1-3^0, 3-10^0, 10-23^0, 23-37^0, 37-60^0, >60^0)

⇐ **Rock Outcrop**
Measure area of rock outcrop (0 - 10%, 10 - 30%, 30 - 50%, >50%)

⇓

Initial land unit information
e.g. Silurian rhyodacite / 3-10^0 slope/ 10 - 30% rock outcrop

Step 2: Get soil information and measure erosion risk

Acquire further information
- soil classification
- soil constraints
- erosion risk

⇐ **Soil Classification (Section 2.4, Appendix C4)**
Based on the Great Soil Group and / or Northcote Factual Key

⇐ **Soil constraints (Section 2.4, Appendix C5)**
For example shallow soils, long slopes, or seasonal waterlogging

⇐ **Erosion risk (Section 2.5, Appendix A5, C5)**
Identify erosion risk class **(from Table 1.1)**

⇓

Full land unit information
e.g. Silurian rhyodacite / 3-10^0 slope/ 10 - 30% rock outcrop
e.g. yellow podzolic soil / seasonal waterlogging, salinity / high erosion risk

Initial Assessment completed ⇑
Continue for **Full Assessment** ⇓

Figure 1.1 Flow Chart of the Land Capability Assessment Process (cont)

Continue for **Full Assessment** ⇓

Step 3: Determine impacts of proposal on erosion risk

Identify significant proposed activities, e.g. removing vegetation, excavating, stockpiling **(Section 3.2)**

⇓

Identify effect of activity on erosion risk (erosion hazard) based on: - activity - land unit information e.g. stripping vegetation on low wet strength soils greatly increases erosion risk **(from Table 3.2)**

⇓

Identify mitigation measures and their costs (from section 3.2)

Step 4: Determine site constraints

Identify site constraints on proposed activity based on: - land unit information - activity e.g. road construction on shallow rocky soils will encounter excavation difficulties **(from Tables 3.3, 3.4)**

Step 5: Overall Assessment

Determine viability of land use proposal based on - cost and effectiveness of hazard reduction measures - constraints on proposal imposed by land unit characteristics

2.4 Characterisation of soils

Soils occurring within each of the geology - slope - outcrop land units are examined in order to assign a "typical soil classification" to each land unit.

Soil group classification comprises:

- classification of soils based on the Great Soil Group classifications and/or Northcote Factual Key descriptors.
- identification of soil characteristics that may limit activities on the site. These will include soils that are highly permeable, shallow, erodible, shrink-swell, low wet strength, or are subject to flooding, seasonal waterlogging or mass movement

The soil details are identified on a map in terms of:

Soil group classification / Hazards
e.g. yellow podzolic soil / seasonal waterlogging, salinity

A field survey will commonly be needed to acquire soil information on depth, texture, soil profiles, mottling, salinity, colour and the potential for water logging, mass movement or flooding.

Laboratory testing will be required to ascertain particle grading, plasticity, dispersion, erodibility, wet strength, shrink/swell, permeability.

2.5 Erosion risk assessment

An evaluation of erosion risk is developed for each land unit. For the ACT erosion risk is based on soil loss which is determined using the Universal Soil Loss Equation (USLE). Although the resultant rating is not fully supported by the observed erosion patterns in the ACT because of the idiosyncratic nature of ACT soils, it does provide a clear, objective assessment of erosion risk.

The USLE is a method developed to determine soil loss from agricultural areas and is also applicable to other areas. It focuses entirely on sheet and rill erosion processes. Although it is recognised that in the ACT region the majority of soil exported from catchments is the result of gully, streambed and streambank erosion, land capability assessment deals with soil loss at small spatial and temporal scales. For this purpose the focus on sheet and rill erosion is appropriate.

The USLE approach is based on quantifying the factors that affect sheet and rill erosion; rainfall erosivity (**R**), soil erodibility (**K**), slope length (**L**), slope steepness (**S**), support practice (**P**) and crop management (**C**). The soil loss (**A**) is calculated by multiplying these six factors together. The soil loss equation is;

$$\mathbf{A = R * K * L * S * P * C}$$

The terms in the USLE are explained in more detail in Appendix A.

While there may be some inaccuracy in the erosion risk assessment, this is not as critical in the determination of urban land capability as for non-urban land capability assessment. High erosion potential during construction can be anticipated due to soil disturbance and loss of vegetation. More important are soil stability issues such as gully or tunnel erosion or soil movement which present a need for hazard management rather than temporary containment.

Once the USLE has been applied to calculate erosion soil losses for a site, these losses need to be interpreted in terms of erosion risk. Although our understanding of the importance of a particular level of soil loss is poor, Table 2.1 provides an interpretation.

Table 2.1 Erosion Risk Classes

Erosion Risk (tonnes soil loss ha^{-2} y^{-1})	**Erosion Risk Class**	**Description**
<5	A	Low erosion risk
5-30	B	Moderate erosion risk
30-50	C	High erosion risk
50-200	D	Very high erosion risk
>200	E	Extreme erosion risk

The erosion risk classes described in Table 2.1 should be further qualified by any additional limitations usually indicated by lower case letters. Typical limitations are shown in the Table below.

Table 2.2 Soil / Landform limitations

Usual code	**Soil / landform limitation**
c	very highly permeable soils
d	shallow soils overlying impermeable material
e	erodible soils
v	high shrink-swell potential and plasticity
o	soils with low wet strength
f	flooding
r	rock outcrop
s	slope
t	topographic constraint difficult access
y	long slope lengths or runon hazard
w	seasonal waterlogging
m	mass movement hazard
l	salinity

Elaboration of technical aspects of these factors, and the level at which they become significant, is given in Appendix C5.

3. FULL LAND CAPABILITY ASSESSMENT

A full land capability assessment builds upon an **initial assessment,** described in section 2, to provide the following additional information;

Determine the erosion risk ⇓	From **initial assessment**
Determine the impact of the proposal on erosion risk ⇓	(erosion hazard)
Determine the mitigation measures required to contain any problems ⇓	
Determine the engineering risks the proposal may encounter ⇓	
Review appropriateness of proposed land use in the light of the preceding analysis	

3.1 Impact of land use activities on erosion risk

In the initial evaluation the erosion risk of land units was determined from the conditions of the slope, soil and geology of the land unit. Development of an area has the potential to exacerbate the erosion risk, depending on the land use activities associated with the development. The increase in erosion risk caused by development activities is called erosion hazard. Activities found to increase erosion risk include:

- destruction of vegetation or topsoil by traffic movements;
- excavation of benches associated with building foundations, roads etc;
- excavation of pits and trenches associated with building foundations, services, etc;
- modification to drainage morphology;
- construction of impervious surfaces (can exacerbate peak runoff);
- stock piling of materials.

In order to determine erosion hazard we need firstly to determine the level of soil disturbance. Table 3.1 shows how to determine the level of soil disturbance caused by different activities. For example, if the land use activity involved stripping of vegetation from a site, and the area disturbed were 2 ha, the level of soil disturbance would be **medium**.

Table 3.1 Land use activities and their level of soil disturbance

Land use activity	Implication for erosion risk	Level of soil disturbance
Stripping vegetation/topsoil	Exposure of B horizon - increased rill and sheet erosion risk.	If the area disturbed is; < 0.5 ha = **Low** 0.5-5 ha = **Medium** > 5 ha = **High**
Benching - building foundations, roads	Exposure of B horizon - increased rill and sheet erosion risk increased tunnel erosion risk Drainage modification - increased gully erosion risk	If the area disturbed is; < 0.5 ha = **Low** 0.5-5 ha = **Medium** > 5 ha = **High** If the change in catchment size is; < 10% = **Medium** > 10% = **High**
Pits and trenches - building foundations, services	Exposure of B horizon - instability and tunnel erosion in trench Drainage modification - increased gully erosion risk	**Low** **Low**
Modified drainage	Drainage modification - increased gully erosion risk	If the change in catchment size is; < 10% = **Medium** > 10% = **High**
Impervious areas	Increased peak flows - increased gully erosion risk	If the change in impervious surface is; < 10% = **Medium** > 10% = **High**
Stockpile materials	Loss vegetative cover - increase sheet and rill erosion risk Drainage modification - increased gully erosion risk	If the area disturbed is; < 0.5 ha = **Low** 0.5-5 ha = **Medium** If the change in catchment size is; < 5% = **Low** 5-10 % = **Medium**

The erosion hazard of an activity (Table 3.2) can now be determined by combining the known erosion risk for a particular land unit (A, B, C, etc from Table 2.1), with the level of soil disturbance (low, medium, high etc from Table 3.1) expected with the proposed activity.

For example, if the erosion risk for a land unit is moderate (B), and the level of soil disturbance is medium, then the erosion hazard from the proposed activity will be minor (Table 3.2).

Table 3.2 Erosion Hazard - Determined from erosion risk and disturbance

		Level of Disturbance		
		Low	**Medium**	**High**
Erosion Risk Class	**A - low risk**	Insignificant	Insignificant	Minor
	B - moderate risk	Minor	Minor	Moderate
	C - high risk	Minor	Moderate	Major
	D - very high risk	Moderate	Major	Severe
	E - extreme risk	Major	Severe	Severe

3.2 Mitigation measures

Following is a discussion of the mitigation measures that may need to be considered on different sites. The purpose of this section is to provide guidance in determining how to mitigate erosion and site constraint issues. Where costs of development are high the planner may choose an alternative land use that is more appropriate. Alternatively the planner may adopt the land use knowing that there is a need for sufficient funds to cover the cost of mitigation measures. In the latter case more detailed site investigation is often warranted to obtain a more accurate assessment of the limitations involved and their associated costs.

3.2.1 Erosion and sediment control issues

There is a requirement for erosion and sediment control consideration wherever there is an existing erosion risk, or wherever activities have a potential to exacerbate erosion (loss of vegetative cover, excavation, drainage modification, stockpiling).

Techniques for minimising problems:

- protect vegetative cover, and re-establish cover on disturbed surfaces as soon as possible
- chemically treat dispersive soils
- relocate proposal

Techniques for mitigating impacts:

- use buffer zones, sediment traps and ponds
- flocculate suspended particles

3.2.2 Drainage considerations

There is a requirement for drainage consideration if there is drainage related erosion risk, or flooding/water logging problem, or for activities that may impact on existing drainage lines (physical modification - shape, alignment, grade, changes in discharge volumes, modification to vegetative cover).

Techniques for minimising problems:

- minimise changes in discharge regimes (point source retention techniques, swales in catchment)
- protect/enhance vegetative cover in channels
- relocate activity

Techniques for mitigating impacts:
- stabilise existing channels to reduce erosion risk (vegetative, geo-fabric, rock, concrete)
- increase capacity of existing channel
- modify channel cross-section to limit depth (velocity) of flow
- incorporate open space (e.g. sportsgrounds) in floodplain, and construct retardation basins, to intercept and retard discharge of runoff

3.2.3 Building and foundations excavation

There is a requirement for consideration of building and foundation excavations wherever there is an existing erosion risk or other hazard, or wherever activities have a potential to impact on stability, seepage problems, structural problems, drainage problems or ground stability.

Techniques for minimising problems:
- minimise area of exposed soil and time of exposure
- divert drainage around the excavation
- intercept groundwater seepage into excavation/dewatering of site
- consider alternative foundation arrangement
- consider relocation of proposal

Techniques for mitigating impacts:
- use sub-soil drains to intercept and remove seepage. Types include:
  - mole drains which are made in situ by dragging a torpedo shaped implement through the soil;
  - rubble drains, which are constructed by placing rubble in an excavated trench;
  - perforated pipes
- use stabilisation techniques (mechanical, chemical)
- use bulkheads/bracing/retaining walls to support excavation
- use deep piles to withstand shrink/swell movement
- remove problem soils and backfill with compacted selected materials

3.2.4 Slope stability considerations

There is a requirement for slope stability consideration wherever slope stability is identified as a hazard, or wherever activities have a potential to impact on slope stability as a result of modified drainage regimes or changes in slope profile. In these instances specialist advice should be sought.

Techniques for minimising problems:
- divert runoff from above the site to a stable disposal area.
- establish a stable drainage system through the site before other construction activities have commenced.
- construct sediment retention ponds, sediment traps and other necessary sediment control works

Techniques for mitigating impacts:
- restrict surface disturbance to retain the maximum area of natural vegetative cover.

- strip and stockpile topsoil from disturbed areas, to be respread prior to revegetation.
- establish vegetation as soon as practical on areas where soil has been exposed
- maintain erosion and sediment control structures regularly

3.2.5 Trenching considerations

There is a requirement for trenching consideration wherever trench instability or drainage erosion risks exist, or wherever the activity has the potential to impact on drainage problems.

Techniques for minimising problems:

- minimise area of exposed soil and time of exposure
- divert drainage around the excavation
- intercept groundwater seepage by dewatering of site
- consider relocation of proposal

Techniques for mitigating impacts:

- use sub-soil drains to intercept and remove seepage
- use bulkheads/bracing to support excavation

3.2.6 Waterlogged Soils

There is a requirement to consider waterlogging of soils wherever such conditions may constrain the proposed activity, or wherever the activity has the potential to exacerbate waterlogging.

Techniques for minimising problems:

- use remedial sub-soil drainage.
- intersect all groundwater mounds by drains, in particular point source groundwater flow in surficial aquifers.

Techniques for mitigating impacts:

- use bores and piezometers during and after development to monitor changes to the groundwater

3.3 Constraints on development imposed by the land unit characteristics

Another component of a full assessment is an analysis of the constraints imposed on development by site conditions. For example shallow soil depth may mean that excavation for services will require trenching through rock. An objective approach has been adopted in which the degree of development constraint is based on the single worst factor affecting development. Five distinct levels of constraint are identified (Table 3.3).

Table 3.3 Development Constraint Classes

Constraint Class	Constraint	Type and Degree of Limitation	General Description and Conservation Management
1	None to very slight	Engineering difficulties do not occur or are very slight.	Standard designs and installation techniques and normal site preparation should be satisfactory.
2	Slight	Slight limitations are present in the form of engineering difficulties.	These areas are capable of being used for the proposed use. Careful planning and the use of standard specifications for site preparation are required.
3	Moderate	Moderate engineering difficulties exist	Areas with fair capability for the proposed use. Specialised designs and techniques are required.
4	High	Considerable engineering difficulties exist.	Areas with poor capability for the proposed use. Extensively modified design and installation techniques required.
5	Severe	Severe engineering difficulties which are extremely difficult to overcome with current technology.	Areas with very poor capability for the proposed use.

The constraint class in Table 3.3 that a land unit may impose on a development, can be determined from Table 3.4. To use Table 3.4, the activity proposed for a site should be identified (eg excavation), and the constraint classes identified based on the site characteristics (eg. slope 1.1-2.9^{o}, therefore site has a class 2 constraint). To determine the overall constraint class for a site, the most severe permanent limitation for an activity determines the classification of the entire unit.

Table 3.4 Limiting Site Constraints

PROPOSED ACTIVITY

Building Foundations: STUMPS	**Constraint Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Slope (degrees)	0-2.9	2.9-4.6	4.6-8.5	8.5-19.2	19.2-45
Drainage	Good drainage	Moderate drainage	Moderate drainage	Poor drainage	Very poor drainage
Depth to seas. watertable (cm)	500-120	120-80	80-50	50-30	30-0
Depth to hard rock (cm)	500-120	120-80	80-30	30-0	
Boulders (% of surface area)*	0-0.1	0.1-0.5	0.5-5	5-100	
Rock outcrop (% of surface area)	0-0.05	0.05-0.1	0.1-1	1-5	5-100
B Horizon USCS classification	GW SW SC GM GC	SM CL	MH CH SP GP	ML	PT OH OL
Shrink-Swell (%)	0-4	4-12	12-20	20-30	
Slope failure risk	Nil	Nil	Nil	Low	High

Building Foundations: SLAB	**Constraint Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Slope (degrees)	0-1.1	1.1-2.9	2.9-5.7	5.7-14.0	14.0-45
Drainage	Good drainage	Moderate drainage	Moderate drainage	Poor drainage	Very poor drainage
Depth to seas. watertable (cm)	500-120	120-80	80-50	50-30	30-0
Depth to hard rock (cm)	500-120	120-80	80-30	30-0	
Boulders (% of surface area)*	0-0.2	0.2-1	1-10	10-100	
Rock outcrop (% of surface area)	0-0.05	0.05-0.1	0.1-1	1-5	5-100
B Horizon USCS classification	GW SW SC GM GC SM	CL CH MH	SP GP	ML	PT OH OL
Shrink-Swell (%)	0-12	12-20	20-30		
Slope failure risk	Nil	Nil	Nil	Low	High

Building Foundations: PILES	**Constraint Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Slope (degrees)	0-2.9	2.9-4.6	4.6-8.5	8.5-19.2	19.2-45
Drainage	Good drainage	Moderate drainage	Moderate drainage	Poor drainage	Very poor drainage
Depth to seas. watertable (cm)	500-120	120-80	80-50	50-30	30-0
Depth to hard rock (cm)	500-120	120-80	80-30	30-0	

Boulders (% of surface area)*	0-0.1	0.1-0.5	0.5-5	5-100	
Rock outcrop (% of surface area)	0-0.05	0.05-0.1	0.1-1	1-5	5-100
B Horizon USCS classification	GW SW SC GM GC	SM CL	MH CH SP GP	ML	PT OH OL
Shrink-Swell (%)	0-4	4-12	12-20	20-30	
Slope failure risk	Nil	Nil	Nil	Low	High

Minor access roads	**Constraint Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Slope (degrees)	0-1.1	1.1-2.3	2.3-3.4	3.4-6.8	>6.8
Drainage	Good drainage	Moderate drainage	Moderate drainage	Poor drainage	Very poor drainage
Depth to seas. watertable (cm)	>1000	>1000	1000-500	500-3000	<300
Depth to hard rock (cm)	500-100	100-40	100-40	40-15	<15
Rock outcrop (% of surface area)	0-1	0-1	1-5	1-5	5-100
B Horizon USCS classification	GW GC SC	SM SW GM	SP CL CH MH GP	ML	PT OH OL
Shrink-Swell (%)	0-4	4-12	12-20	20-100	
Slope failure risk	Nil	Nil	Low	Medium	High

Shallow excavation	**Constraint Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Slope (degrees)	0-1.1	1.1-2.9	2.9-5.7	5.7-14.0	14.0-45
Drainage	Good drainage	Moderate drainage	Moderate drainage	Poor drainage	Very poor drainage
Depth to seas. watertable (cm)	1000-200	100-150	150-120	120-90	90-0
Depth to hard rock (cm)	1000-200	200-150	150-120	120-90	<90
Boulders (% of surface area)*	0-0.1	0.1-1	1-5	5-30	30-100
Rock outcrop (% of surface area)	0-0.05	0.05-0.1	0.1-0.2	0.2-1	>1
B Horizon USCS classification	CL GC GM SC	ML SM CL	GW SW	GP SP CH	PT OH OL
Slope failure risk	Nil	Nil	Nil	Low	High

Effluent disposal	**Constraint Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**
Slope (degrees)	0-8.5	0-8.5	0-8.5	8.5-16.7	16.7-45
Drainage	Good drainage	Moderate drainage	Moderate drainage	Poor drainage	Very poor drainage
Depth to seas. watertable (cm)	500-150	150-120	120-90	90-60	<60

Depth to hard rock (cm)	500-150	150-125	125-100	100-75	<75
Shallow permeability (l/m2/day)	3000-1000	1000-300	300-150	150-100	<100
Gravel (% of volume)**	0-5	5-20	20-40	40-75	>75
Boulders (% of surface area)*	0-0.02	0.02-0.2	0.2-2	2-10	>10
Rock outcrop (% of surface area)	0-0.01	0.01-0.1	0.1-1	1-5	>5
Shrink-Swell (%)	0-5	5-15	15-20	20-30	
Slope failure risk	Nil	Nil	Nil	Low	High

* Boulders are defined as isolated rocks >200mm in diameter.

** Gravel is defined as rocks in the size range 2-60mm.

3.4 Worked example

Following is a worked example showing how a full land capability assessment would be conducted for a hypothetical site. It follows the steps outlined in Figure 1.1;

> Proposal: Construction of a high density residential development on a 10 ha site using slab foundations.
>
> Site conditions: Rock type underlying the site is rhyodacite, the mean slope is 5.7^{o} and 2% of the site has rock outcropping. The soils on the site are yellow podzolics which can suffer seasonal waterlogging.
> The proposed development will require removing all vegetation from the site.

Step 1: Define land units on site

Examination of the hypothetical site reveals that the entire site falls into a land unit with the following characteristics;

Land Unit: geology - rhyodacite / mean slope 5.7^{o} / 0 - 10% rock outcrop

Step 2: Get soil information and measure erosion risk

A survey of the site finds that the soils are yellow podzolics which can suffer from seasonal waterlogging. The annual soil loss through erosion is now calculated using the Universal Soil Loss Equation (USLE). For the hypothetical site the annual soil loss is calculated to be 5-30 t/ha/yr. From Table 2.1 we read off the erosion risk class.

Soil classification and hazards: yellow podzolic soil / seasonal waterlogging
Erosion risk class: B - moderate erosion risk

Step 3: Determine impacts of proposal on erosion risk (erosion hazard)

In order to determine the erosion hazard we first need to ascertain level of soil disturbance of the proposed activity. The development will require removing all vegetation off the 10 ha site which could result in increased rill or sheet erosion. We determine the level of soil disturbance by looking up Table 3.1;

Level of soil disturbance: High

We combine the level of soil disturbance (high) and the erosion risk class (moderate) in Table 3.2 to look up the erosion hazard;

Erosion hazard: Moderate

We should also consult section 3.2 which outlines the mitigation measures that may be required to deal with erosion problems and engineering constraints. The more significant the erosion hazard is the more elaborate the mitigation measures are likely to be.

Step 4: Determine site constraints

The site constraints are determined by looking up Table 3.4 to find which of the following characteristics poses the greatest constraint on construction of slab foundations;

- 2% rock outcrop - constraint class 4
- slope 5.7^{o} - constraint class 3
- seasonal watertable 150 cm deep - constraint class1

The rock outcrop is the most severe constraint;

Site Constraint: **Class 4 (Considerable engineering difficulties exist)**

Step 5: Overall assessment

We now have the two major components of a land capability assessment; erosion hazard and site constraints. These elements should be synthesised in light of the cost, land take or other limitations arising from mitigation measures, and consequently the appropriateness of the proposed land use.

4. REQUIREMENT FOR ASSESSMENT

Land capability assessment should be conducted wherever a significant potential exists that a proposed land activity or land use poses a erosion hazard or other hazard, or where the activity is constrained by land unit characteristics. As this may not be known in advance of the assessment the following criteria should be used:

4.1 Individual Sites

Land capability assessment should be conducted where any of the following are involved:

- the site is > 5 ha in size and a significant proportion of the site will be developed
- road construction is involved
- the average slope of the site is over 10^0 and a significant proportion of the site will be developed

For all these situations the following assessment is required:

Initial assessment:

- determine the erosion risk and other limitations (Figure 1.1, section 2.3)

4.2 Outline Planning

For outline planning further assessment is required

Full assessment:

- determine impact of the proposal on erosion risk (Figure 1.1, section 3.2)
- determine the engineering risks the proposal may encounter (Figure 1.1, section 3.3)
- determine the mitigation measures required to contain any problems (Figure 1.1, section 3.2)
- assess the cost, land take or other limitations arising from mitigation measures
- review appropriateness of proposed land use in the light of the preceding analysis

4.3 Information required in an Initial Land Capability Assessment

4.3.1 Site Plan

A site plan of the area must be provided. For individual sites two sorts of information should be shown on the plan;

- details of the proposed development
- contours and soil information

4.3.2 Erosion risk and soil constraints

The assessment must identify land units on the site, and determine their erosion risk and other soil constraints. The schema detailed in section 2 should be followed to arrive at;

- details of the land units on the site.
- erosion risk and other constraints.

Where possible the assessment should include details on mitigation measures that may be applied to reduce erosion.

4.4 Information required in Full Land Capability Assessment

4.4.1 Site Plan

A site plan of the area must be provided with the following information;

- contours and soil information
- details of the proposed land use policies proposed for the area

4.4.2 Erosion risk and soil constraints

The assessment must identify land units on the site, and determine their erosion risk and other soil constraints. The schema detailed in section 2 should be followed to arrive at;

- details of the land units on the site.
- erosion risk and other constraints.

4.4.3 Assessment

The assessment must determine how (if) the proposed activity will worsen erosion risk and mitigation measures that may be needed. It must also determine the site constraints that the land unit characteristics may impose. The schema detailed in section 3 should be followed to arrive at;

- proposed activities that may worsen erosion risk
- proposed mitigation measures and their costs
- site constraints arising from land unit characteristics
- An overall assessment of the viability of the proposal based on mitigation measures and their costs, and the constraints on the proposal imposed by the land unit characteristics.

5 CONCLUSION

These guidelines describe how land capability assessment should be conducted and its importance in planning and management.

The initial step for an assessment is the analysis of basic resource data to identify unique land units. Secondly the erosion risk and physical constraints for each land unit is identified. Finally the impact of the proposed development on land units, and vice versa, is factored into the analysis to arrive at a full land capability assessment.

The benefits of a land capability assessment extend across both planning and land management. For initial planning, land capability assessment brings together the importance of considering natural conditions in the development process. For ongoing management, land capability assessment can alert the Environment Management Authority and other land managers to problem areas and issues that should be addressed to meet their statutory responsibilities.

6 REFERENCES

ADOMEIT, E.M., AUSTIN, M.P., HUTCHINSON, M.F. STEIN, J.L. (1987) Annual Mean Rainfall and Temperature Surfaces and Contour Maps of South Eastern Australia. C.S.I.R.O. Institute of Natural Resources and Environment, Division of Water Research Tech Mem 87/15

ANON (1960) Design of Small Dams U.S. Dept of Interior, Washington

BURCH, G. and GRAETZ, D and NOBLE I. (1987) In: Land Degradation (ed A. Chisholm and R.Dumsday) Cambridge University Press

BURROUGH P.A. (1986) Principles of Geographical Information Systems Oxford Science Publications; Monographs on Soil and Resources Survey

CHARMAN P.E.V, (1978) Soils of New South Wales - Their Characterisation, Classification and Conservation

EMERY K.A.,(1975) Identification of Soil Erosion from Aerial Photographs. J. Soil Cons N.S.W. 31(4)

EMERY K.A. (1981) Joint Shires Study Soil Conservation Service of N.S.W.

FAO (1983) Guidelines; Land Evaluation for Rainfed Agriculture. Soil Bull. No 52.

GOLDMAN S.J., JACKSON K, BURSZTYNSKY, P.E. (1986) Erosion and Sediment Control Handbook

GIBBONS, F.R., (1976) A Study of Overseas Land Capability Ratings, S.C.A. limited circulation report

GUNN, R.H., BEATTIE, R.E., REID, R.E. van de GRAAFF R.H.M., (1988) Australian Soil and Land Survey Handbook Inkata Press.

HANNAM I.D., HICKS R.W.,(1980) Soil Conservation and Urban Land Use Planning J. Soil Conservation Service N.S.W. 36(3).

HIRD, C. (1988) Land Resources of the Paddy's River Catchment A.C.T. Administration Landcare Unpubl.

LINDSAY A., ROWE,.K (in press) Land Evaluation- the Victorian Land Capability Approach Proceedings of the Ecological Society of Australia's 16th Biennial Conference.

McDONALD, R.C., ISBELL, R.F., SPEIGHT, J.G., WALKER, J. HOPKINS, M.S. (1984) Australian Soil and Land Survey Field Handbook. Inkata Press

MINISTRY ARTS SPORT AND ENVIRONMENT. Notes on Greenhouse 88 Canberra Regional Conference Workshop 4.

NORTHCOTE, K.H. (1979) A Factual Key for the Recognition of Australian Soils Rellim Technical Publications.

PASCALL, D. (1985) Land Resources Study Gungahlin.

ROSEWELL, C.J., EDWARDS K (1988) Soiloss A program to assist in the Selection of Management Practices to Reduce Erosion

SCOTT AND FURPHY (1988) Design Manual for Urban Erosion and Sediment Control

SOIL CONSERVATION SERVICE OF N.S.W. (1978) Urban Erosion and Sediment Control Technical Handbook No 2.

UNITED STATES DEPT OF AGRICULTURE (1976) Soil Survey of the District of Columbia

WISCHMEIER W.H. SMITH D.D. (1978) Predicting Rainfall Erosion Losses A Guide to Conservation Planning Agriculture Handbook no 282, U.S. Dept of Agriculture, Washington D.C.

7. GLOSSARY OF TERMS

A HORIZON
The original top layer of mineral soil. It may consist of the A1 and A2 horizons.

A1 HORIZON
The surface soil. Relative to other horizons it has a high content of organic matter a dark colour and maximum biological activity. This is the most useful part of the soil for vegetation and plant growth.

A2 HORIZON
A layer of soil which may occur below the A1 horizon which is similar in texture to the latter but is paler in colour poorer in structure and less fertile.

AERIAL PHOTO INTERPRETATION
A technique for obtaining information from aerial photographs using stereoscopic viewing of the photographs. This method enables the evaluation of terrain in three dimensions. It also involves the establishment of ground truth by field examination and the study of available maps and reports.

AGGRADATION
The process of building up of surfaces, such as stream beds or floodplains, by the deposition of sediment and or colluvium.

ALLUVIAL
Describes material deposited by, or in transit in, flowing water.

ALLUVIAL SOIL
A soil developed in recently deposited alluvium normally characterised by little or no modification of the deposited material by soil-forming processes particularly with respect to soil horizon development.

B HORIZON
Layer of soil below the A horizon. It is usually finer in texture (i.e. more clayey) denser and stronger in colour. It may consist of more than one layer.

BULK DENSITY
The mass of dry soil per unit bulk volume.

C HORIZON
Layers below the A horizon which may be weathered consolidated or unconsolidated parent material little affected by biological soil forming processes.

CATCHMENT
That area determined by topographic features within which rainfall will contribute to runoff at a particular point under consideration.

CLAY
Soil material consisting of mineral particles less than 0.002 mm in equivalent diameter. When used as a soil texture group such soil contains at least 35% clay and no more than 40% silt.

CLAY LOAM
A soil texture group representing a well-graded soil composed of approximately equal parts by weight of clay, silt and sand.

COLLECTOR AND MINOR ACCESS ROADS
These typically have an all weather surface that can carry light to medium traffic all year. They consist of a subgrade of under lying soil material; a base of gravel or crushed rock fragments or soil material stabilised with lime or cement an a flexible rigid surface, commonly asphalt or concrete. The roads are graded with soil material at hand and most cuts and fill are less than 2m deep.

The load supporting capacity and the stability of the soil as well as the fill material available are important in design and construction of roads and streets. The U.S.C.S. of the soil and the soil texture, density, shrink-swell potential are indicators of the traffic supporting capacity used in making the rankings. Soil wetness, flooding, slope, depth to hard rock or very compact layers and content of large stones all affect stability and ease of excavation are also considered in table

COLLUVIUM
Unconsolidated rock material, moved largely by gravity deposited on lower slopes and/or at the base of a slope.

CREEP
A general term used to describe more or less imperceptible transportation of soil particles under the influence of various erosive agents.

DISPERSIBLE SOIL
A structurally unstable soil which readily disperses into its constituent particles (clay, silt and sand). Highly dispersible soils are normally highly erodible.

DISTURBED TERRAIN
An area of land in which the components have been permanently altered from their original state as a result of human activities. It includes mining and quarrying areas as well as construction sites.

DRAINAGE
The interception and removal of excess surface and/or subsurface water from land, using artificial or natural means.

DRAINAGE PLAIN
A longitudinally extensive level or gently inclined area of sediment adjacent to a drainage line built up by alluvial deposition during the current regime of the drainage line. Such areas are subject to periodic overland flow of water and may be subject to seasonal waterlogging.

DUPLEX SOIL
A soil in which there is a sharp change in soil texture between the A and B horizons (e.g. loam overlying clay).

EFFLUENT
The fluids discharged from domestic, industrial and municipal waste collection systems or other treatment facilities.

EFFLUENT DISPOSAL
Favourable soil properties are needed for the proper functioning of septic tank absorption fields, sewage lagoons and sanitary landfills.

Properties and features that affect the absorption of effluent are permeability, depth to seasonal high water table, depth to bedrock and susceptibility to flooding. Stones, boulders and shallow depth to bedrock interfere with installation. Excessive slope may cause lateral seepage and surfacing in downslope areas. Also soil erosion and soil slippage are hazards where absorption fields are installed on sloping soils.

Some soils are underlain by loose sand and gravel or fractured depth to bedrock at a depth of less than a metre. In these soils the absorption field does not adequately filter the effluent and as a result groundwater supplies may be contaminated.

ERODIBILITY
Susceptibility to erosion.

ERODIBLE
Susceptible to erosion. The term is typically applied to soils.

EROSION
The wearing away of the land by running water, rainfall, wind, ice or other geological agents.

EROSION CONTROL MEASURES
Those activities based on structural works, vegetation management, tillage operations and/or other farm management options designed primarily to achieve control of soil erosion.

EROSION HAZARD
The susceptibility of a parcel of land to the prevailing agents of erosion. It is dependent on a combination of climate, landform, soil, land use and land management factors. The qualitative categories of erosion hazard are often expressed as low, moderate, high, very high and extreme. (A-E)

EROSION RISK
The intrinsic susceptibility of a parcel of land to the prevailing agents of erosion. It is dependent on a combination of climate, landform and soil factors.

Determination of erosion risk differs from the determination of erosion hazard in that land management factors are ignored. Thus the relative difference between various parcels of land is less susceptible to change due to technological improvements in land management practices.

EROSIVITY
Potential ability to cause erosion. The amount of erosion on a site is dependent on the erosivity of the eroding agent - rainfall, running water etc. The term is commonly applied to rainfall.

ESCARPMENT
A steep to precipitous landform comprising a linearly extensive, straight or sinuous inclined surface which separates terrains at different altitudes. The upper margins are commonly marked by a precipitous face, revealing the exposed geological strata, below which talus or scree occurs.

FLOODPLAIN
A large flat area adjacent to a watercourse, characterised by frequently active erosion and aggradation by channelled or overbank stream flow. Such areas result from, and are subject to, inundation by floodwaters.

FLUTING
A process of lateral gully erosion whereby a series of vertically elongated grooves, called flutes, is created by rill erosion of gully sides, particularly in dispersible soils.

FOOTSLOPE
A moderate to gently sloping landform at the lower end of a slope, resulting from aggradation or erosion by sheet flow, earth flow or creep.

FOUNDATIONS
These refer to foundations of buildings no more than 3 storeys high. Large house or commercial buildings would need separate analysis.

For such structures soils should be sufficiently stable that cracking and subsidence should not occur. Shrink-swell, compressibility and shear strength (from the U.S.C.S. classification) are evaluated. Soil texture, plasticity and depth to seasonal water table are also considered in addition to bedrock, large stones. Flooding is considered a serious limitation.

GRADATIONAL SOIL
A soil where there is a gradual change in soil texture between the A1 and A2 horizons (e.g. loam over clay loam over light clay). The soil is dominated by the mineral fraction and shows more clayey texture grades on passing down the solum of such an order that the texture of each successive horizon changes gradually to that of the one below.

GREAT SOIL GROUP
A soil classification category in which soils are classified according to their mode of formation as reflected in major morphological characteristics and profile form.

The grouping depends on an appraisal and interpretation of features such as the colour, texture, structure and consistency of soil material, the various horizons in the soil profile and the nature of the boundary between the horizons

GULLY EROSION
A process whereby the removal of soil is characterised by large incised channels (>30 cm deep) in the landscape.

Minor and moderate gully erosion are related to the density of gullies within the primary drainage lines. With minor gully erosion, gullies are discontinuous and with moderate they are continuous. When branching of the gullies away from the primary drainage line occurs the severe categories are used.

Gully erosion processes may include;
- Removal of soil from the land surface by concentrated runoff with sufficient volume and velocity to cut channels.
- Dispersion of unstable subsoils due to seepage followed by the collapse of soil into the void so formed.

HARDSETTING
The condition of a dry surface soil when a compact, hard and apparently apedal condition prevails. Such soils tend to give rise to high rates of runoff compared with better structured soils.

HORIZON
A general term used to describe individual layers within a soil.

INCISED DRAINAGE CHANNEL
A channel in the land surface having distinct bed and banks and which carries perennial or ephemeral water flows.

LAND CAPABILITY
The ability of land to accept a type and intensity of use permanently, or for specified periods under specific management, without permanent damage. It is an expression of the effect of biophysical land resources, including climate, on the ability of land to sustain use without damage. Land capability involves consideration of;
- the various land resource attributes
- the proposed land use
- the activities or inputs required to achieve the desired land use
- the risks of damage to the land, on-site or off-site, resulting from those activities
- the inter-relations of the above

If the land is used beyond its capability it ultimately loses its productive capacity. Therefore land capability forms an essential basis for land use planning.

LAND CAPABILITY CLASSIFICATION
The systematic arrangement of land into various categories according to their capability for particular land uses and the treatment required to sustain those uses without land degradation.

In a soil conservation context, land capability classification is based on a balance between usage and conservation measures which allow the most intensive use of the land without soil erosion and with a permanently sustained level of usage. It relates to the degree of hazards and limitations in managing the land and thus the classification is primarily concerned with erosion risk.

LAND SUITABILITY
The potential uses of the land based upon the consideration of physical, technical and socioeconomic conditions prevailing. Full suitability evaluation involves a multi-disciplinary approach to land evaluation and includes a basic inventory of land resource data, an understanding of the ecological requirements of the land use contemplated, basic data on the economics of land use, land improvement, new technologies, marketing and transport, and a knowledge of the attitudes and goals of people affected by proposed changes

LAND UNIT
An area of common landform, geology and soils occurring repeatedly at similar points in the landscape over a defined region.

LOAM
A medium-textured soil of approximate composition 1 to 25% clay, 25 to 50% silt, and less than 50% sand.

MASS MOVEMENT
A general term encompassing 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 materials to dislodgement. When the gravitational stress exceeds this resistance, mass movement occurs. The occurrence of mass movement depends upon the interaction of various factors including landform, lithology, soil type, rainfall intensity and duration, drainage characteristics, vegetal cover and human intervention.

MOTTLED
The presence of more than one soil colour in the same soil horizon, not including different nodule colours. The subdominant colours normally occur as scattered blobs or blotches, which have definable differences in hue, value or chroma from the dominant colour. Mottling is often an indicator of slow internal drainage, but may also be a result of parent material weathering.

pH
A measure of the acidity or alkalinity of a soil. A pH of 7 denotes neutrality, higher values indicate alkalinity and lower values acidity. Soil pH is measured in the field by a colorimetric method using Raupach's indicator.

OUTCROP
The exposure of rock that is inferred to be continuous with underlying bedrock

PARENT MATERIAL
The geologic material from which a soil profile develops. It may be bedrock or unconsolidated materials including alluvium, colluvium or other sediments.

PEDOLOGY
The study of soils, particularly their formation, morphology, distribution and classification.

PHYSICAL LIMITATIONS
These are physical characteristics of landscape units that are capable of being measured and which adversely affect either the erosion hazard associated with the development of a site or cause costly modifications in engineering design for a particular form of urban use.

Such limitations include:

- c very highly permeable soils
- d shallow soils
- e erodible soils
- g soils with low wet strength
- l saline soils
- p soils with poor permeability
- x extraction/disposal site
- f flooding
- m mass movement
- r rock outcrop
- s slope gradient
- t topographic feature
- w seasonal waterlogging
- v high shrink-swell potential
- y slope length

PRINCIPAL PROFILE FORM
The end point of the Factual Key (Northcote 1974) soil classification system. A principal profile form code such as Dy3.41 describes the soil profile to such an extent that it will be possible to make a reasonably concise statement concerning the soils belonging to it.

RAINFALL INTENSITY
The rate of rainfall for any given time interval, usually expressed in millimetres per hour.

REGOLITH
The layer of loose, noncohesive or cohesive rock material of whatever origin, that nearly everywhere forms the surface of the land and rests on bedrock.

REMOTE SENSING
The collection of information about an object or phenomenon by the use of sensing devices not in physical or intimate contact with the subject under investigation. Devices range from cameras to various scanners and radiometers.

REVEGETATION
The reestablishment of plants on an area of ground that is depleted or devoid of vegetation, in order to provide protection against erosive agents. It is an integral part of erosion control and vegetation.

RILL EROSION
The removal of soil by runoff from the land surface whereby numerous small channels, generally up to 30 cm deep are formed.

RUNON
Surface water flowing onto an area as a result of runoff occurring from a higher slope. A contributing factor to increased erosion risk.

SALINITY OR SALTING
The accumulation of free salts in part of a landscape to an extent which causes degradation of vegetation and/or soils.

SAND
A soil separate consisting of particles between 0.02 and 2.0 mm in equivalent diameter.

SEDIMENTATION
Deposition of sediment. In a soil conservation sense sedimentation is the end point of the erosion process, with transported soil material being deposited in locations such as a channel, along a fence line, in a gully, creek or dam.

SHALLOW EXCAVATIONS
Shallow excavations are used for pipelines, sewerage, telephone and power transmission lines, basements open ditches and cemeteries. Such digging or trenching is influenced by the soil wetness of a high seasonal water table, the texture and consistency of soils, the tendency of soils to cave in or slough and the presence of very firm, dense soil layers, bedrock or large stones. In addition excavations are affected by the slope of the soil and the probability of flooding. Ratings do not apply to material below 2m.

SHEET EROSION
The removal of a fairly uniform layer of soil from the land surface by raindrop splash and/or runoff. No perceptible channels are formed.

SHRINK-SWELL POTENTIAL
The capacity of the soil material to change volume with changes in moisture content. Can give rise to problems in earth foundations and some soil conservation structures.

SIDESLOPE
The section of hillslope which comprises the middle and upper slopes where soil processes are usually transportational. It lies between the hillcrest and footslope supplying depositional material to the latter.

SILT
A soil separate consisting of particles between 0.002 and 0.02 mm in equivalent diameter.

SOIL
Soil is defined as "a three-dimensional body of inorganic and organic materials of varying proportions, that has developed as a result of interactions between parent material, and climatic, physiographic and biotic factors over time". A soil is generally organised into horizons, more or less parallel to the earth's surface as a result of various physical, chemical and biological processes and is the natural medium for the growth of plants.

SOIL COMPLEX
A soil mapping unit in which two or more soil taxonomic units occur together in an undefined or complex pattern. The soils are intimately mixed and it is impractical to delineate them at the scale of the map.

SOIL CONSERVATION
The prevention mitigation or control of soil erosion and degradation through the application to land of cultural, vegetative, structural and land management measures, either singly or in combination, which enable stability and productivity to be maintained for future generations.

SOIL PROFILE
A vertical cross-section exposure of soil extending downwards from the soil surface to the parent material.

SOIL REACTION TREND
The change in pH with depth in a soil profile from surface soil to deep subsoil. Three such trends have been defined (Northcote 1974) strongly acid, neutral and alkaline.

SOIL STRUCTURE

The combination or spatial arrangement of primary soil particles (clay, silt, sand, gravel) into aggregates such as peds or clods and their stability to deformation.

Well structured soils are usually more resistant to erosion due to their ability to absorb water and their resistance to detachment by rainfall. Poorly structured soils have unstable aggregates and low infiltration rates. They break down quickly under heavy rainfall and surface sealing occurs.

SOIL SURVEY
The systematic examination, description classification and mapping of soils with the aim of categorising soil distribution in an area.

SOIL TEXTURE
The coarseness or fineness of soil material as it affects the behaviour of a moist ball of soil when pressed between thumb and forefinger. It is generally related to the proportion of soil particles of differing sizes (sand, silt, clay, gravel) in a soil, but it is also influenced by organic matter content, clay type and degree of structural development in the soil.

STABILISATION
The provision of adequate measures, vegetative, structural and/or mechanical, to prevent or control erosion.

STREAMBANK EROSION
The removal of soil from streambanks by the direct action of stream flow.

SUBSOIL
Subsurface soil material comprising the A horizons of soils with distinct profiles. Alternatively the soil below the topsoil.

SWAMP
A vegetated depression with a seasonal or permanent water table at or slightly above the floor of the depression.

TERRAIN
A tract of land having particular physical features.

TEXTURE CONTRAST SOIL
See DUPLEX SOIL

TOPSOIL
That part of the soil profile, typically the A1 horizon, containing material which is usually more fertile and better structured than underlying layers. It is the material which is retained for revegetation of batters and earthworks for rehabilitation purposes.

URBAN CAPABILITY CLASSIFICATION
A method of land capability classification which ranks land according to various intensities of urban use on the basis of physical constraints applying to it. The classification does not consider development costs, social implications, aesthetics or other factors relating to ecology and the environment. It is based on erosion hazard (and engineering limitations) of the site in question together with the level of management needed to support a particular urban use.

WATER HOLDING CAPACITY
The amount of water in the soil generally available to plants that can be held between field capacity and the moisture content at which plant growth ceases.

WATER TABLE
The upper surface of unconfined groundwater below which the pores of the rock or soil are saturated.

USCS
Unified soil clsssification system. A system used by engineers to describe the engineering properties of soil.

APPENDIX A. BASIC CONCEPTS

A1 Land Capability Assessment

Two concepts are central to practical land capability assessment. The first is the land unit which can be described by several attributes or "land features". These features may include specific engineering constraints.

The second concept concerns the inter-relatedness of land features, land use and the effects of use (impacts) on the land. This embodies the concept of erosion hazard. A conceptual model developed by Gibbons (1976) illustrates these interactions. It proposes that land use should be considered in terms of both management and production. In an urban sense production refers to the "type" of development (housing, recreational use etc.) and intensity or "degree" of development (medium density housing versus standard residential). Management refers to the construction procedures and controls that are put in place to minimise the effects of erosion hazard or (for example) overcome the adverse effects of a highly plastic and swelling clay material. The "type" of management will refer to the techniques or works used whereas the "degree" of management will refer to the number or intensity of implementation of these works.

"Land features" and "impact" (or hazard) also vary in type and degree - for example, the land feature "type" may be the erosion potential or "erodibility" of the soil which can vary in degree from low to very high. The impact "type" may be sheet erosion and the degree will be the expected rate of soil loss.

These emphasise that change to one variable will lead to compensating changes in one or more of the other variables. Where changes are undesirable, management inputs are required to compensate for, or overcome these changes. Given sufficient management inputs it is possible to imagine any land being used for any form of production. The restriction then becomes one of cost.

Because of the complexity of the system, it is usual to consider interactions between two variables, while the other two are held constant. For example the management required to achieve a certain type of urban subdivision may be given on the assumption that soil erosion (impact) will be confined below a certain specified limit (a management rating). Alternatively the erosion loss which could be expected from a given standard of subdivision management may be assessed (a hazard rating). This would allow judgement to be made as to whether the predicted soil loss would be within tolerable limits or whether changes to management "degree" or production "type" should be made to reduce the hazard.

There is currently method that has been adopted across Australia for integrating bio-physical or land unit attributes into capability assessment. Different methods are discussed in detail by Van de Graaff in Gunn et al., (1988). The Limitations approach used by the Victorian Land Protection Division offers the most objective approach. This approach considers separately the limits imposed by various land features on a particular land use. The overall capability is determined by the most limiting factor. However, distinction is not made between those land features which are permanently limiting or costly to overcome (such as slope and soil texture) and those which may be temporary such as poor drainage. In addition it does not provide a means for separately considering the problem of erosion risk. The latter is an important consideration in determining the appropriate level of sediment and erosion control works in new developments.

A2 Land Resource Survey

Variations in climate, geology, landform, hydrology, vegetation, fauna and soil, and complex interactions between these attributes give rise to a wide range of environments within a survey area. There is therefore a need to classify land in terms of its inherent attributes into mappable and readily identifiable units as a prerequisite to evaluation and planning.

A2.1 Identification of homogeneous land units

Land units are areas of land that are either more homogeneous than the whole area or have special features that separate them from the rest.

A land unit may be defined as an area of land which has a sufficiently consistent association of land features to respond uniformly and predictable to a particular use. The land features considered when mapping such land units can include all the biophysical aspects of the environment - climate, soil, geology, topography, hydrology and vegetation. The potential of the land for sustained use and its susceptibility to degradation depends on an interplay of all these factors.

Because of the inter-relatedness of land features it can be assumed that land units may be defined in terms of a smaller number of features (eg. landform and parent material).

In this Guideline, homogeneous areas have been accepted as a practical and appropriate approach for land capability assessment and land use planning.

A2.2 Soil

Soil is the natural medium for the growth of plants, supplying water, air, plant nutrients and support to plant roots. It can also provide a faunal habitat and engineering material. Interactions with other landscape attributes control the physical, chemical and biological processes that determine the kinds of soil profiles that develop and hence their suitability for various purposes. Soil depth, texture, thickness of horizons, structure, bulk density and mineralogy are the more important physical properties of soils. Combined with chemical properties such as soil reaction, trace elements and organic matter, these properties together form the pedological environment. Variations in these properties affect the productivity, susceptibility to degradation and the ease or otherwise of modification and management of soils for specific uses.

A3 Erosion Processes in Urban Development

The particular form of erosion that is likely to occur in developing urban areas is dependent on both the management practices during development, as well as the nature of the terrain and soil type. Erosion hazards likely to result from urban construction activities are discussed in detail in Scott and Furphy (1988). Forms of erosion which affect urban lands are discussed below.

A3.1 Raindrop Erosion

When vegetative cover is stripped away the soil surface is exposed to raindrop impact. The energy imparted from the rain drop cause particles to move both upwards and downslope. Some splashed particles may rise as high as 0.6m (Goldman et al 1986). If the soil is on a slope the splashed particles move downhill.

In addition soil aggregates are broken down separating the fine particles and organic matter from the heavier particles. This action causes destruction of soil structure and a hard crust may form when the soil dries inhibiting water infiltration and plant establishment as well as increasing runoff and erosion potential.

This process is likely to occur where areas are bared of vegetative cover and is more severe during high intensity storms. In addition, some soils are more susceptible than others - this idea is embodied in the concept of soil erodibility.

A3.2 Sheet Erosion

When water flows, it is initially as "sheets" over the soil surface. These flows transport soil particles that have been detached by raindrop erosion. This is the dominant form of erosion during the urban development stage. Sheet erosion is more severe on steep slopes and where water can flow unchecked over long slopes.

Sheet erosion is considered minor when less than 10% of the ground cover is bare; moderate when between 10 and 30% is exposed; severe when between 30 and 50 % is exposed and very severe when more than 50% of the ground is exposed.

A3.3 Rill Erosion

Rill erosion begins when shallow surface flows start to concentrate in low spots in the soil surface. As the flow changes from sheet flow to deeper flow the velocity and turbulence increases. The energy of this flow is able to both detach and transport soil particles. This action begins to cut tiny channels called rills.

This kind of erosion is likely to occur in developing urban areas where large areas of land have been bared at any one time or where bare areas occur on lower slopes.

Rill erosion is considered minor when rills cover less than 5% of the landscape; moderate when they cover between 5 and 15% of the landscape; severe when they cover between 15 and 30% of the landscape and very severe when rilling is more frequent than this or when some convergence is evident.

A3.4 Gully Erosion

Gully erosion is a more complex process. Some gullies are formed when runoff cuts rills deeper and wider or when the flows from several rills come together to form a bigger channel. Gullies can enlarge both uphill and downhill. Water flowing over the headwall of the gully causes undercutting. As a consequence, large chunks of soil can fall from a gully headwall in the process known as mass wasting. This soil is later carried away by stormwater runoff.

Gullies can also be initiated beneath the ground surface through a process known as "tunnelling". In this process unstable or "dispersable" subsoils form tunnels underneath the ground surface. Eventually the topsoil caves in and a new gully is initiated.

Hence the relative "erodibility" of both topsoil and subsoil is critical in the process of gully erosion.

Heavy rain can transform a small rill into a gully overnight. Once a gully is created it is difficult and expensive to stop it growing. During urban development, any structure or landform (e.g., drainage redirection) which causes water to concentrate may initiate gully erosion. Tunnel erosion is less landform dependent and may occur where ever unstable subsoils are present.

Gully erosion is considered minor if the incision is small and does not show signs of active fluting of sidewalls or headwall extension. Usually there is some vegetation growth to stabilise the bank walls.

Moderate gully erosion occurs when the incision is still relatively narrow, but headwall extension is active and some minor fluting is apparent. Little or no vegetation is present to stabilise the gully.

Severe gully erosion implies active headwall extension and fluting in addition to some "fingering" or lateral extensions to the gully.

Very severe gully erosion involves extensive fingering of the gully.

A3.5 Channel or Streambank Erosion

Channel erosion occurs when streambank vegetation is disturbed or when the volume of flow in a stream is increased. Natural streams have adjusted over time to the quantity and velocity of runoff that normally occur in a watershed. When a watershed is altered by removing vegetation, by increasing the amount of impervious surfaces or by paving tributaries, streamflows are changed. Typical changes are an increase in peak flow during storms and an increase in stream velocity. Either of these changes can destroy the equilibrium of the streambed and cause channel erosion to begin.

A3.6 Salting or Dryland Salinity

This is a process whereby salts accumulate, usually in drainage lines or lower footslopes, to the extent that most vegetation species cease to thrive and the area thus becomes more susceptible to sheet and gully erosion.

Dryland salinity usually occurs as a result of a rise in the natural water table usually brought about by clearing of timber and overgrazing of pasture. It is more likely to occur when the parent rock materials are already high in natural salts, such as marine sediments.

A3.7 Wind Erosion

Wind erosion involves the movement of soil particles as a result of energy generated by wind. It becomes a major problem when unvegetated ground, typical in developing urban areas, dries out.

A3.8 Landslip Erosion or Mass Movement

Mass movement refers to the displacement of soil and regolith on slopes, in which the centre of gravity of the unstable mass moves down slope.

The major types of mass movement can be broadly classified into two groups - slides and flows. In the slide process movement results from shear failure along several surfaces. In the flow process the displaced material behaves more like a viscous fluid. The material is unconsolidated at the time of flow but may consist of rock fragments in addition to plastic clays.

The failure usually occurs within the soil material rather than bedrock, hence soil data provides a valuable means of analysing the physical behaviour of a slope. Usually steep slopes are involved.

Mass movement is an example of an urban erosion process that can continue well after the development phase and result in extensive damage to structures. In addition to certain types of soils and landforms being pre-disposed to mass movement, it may also occur as a result of changes in the landform hydrology brought about by the process of development.

A4 Erosion Risk

Erosion risk is the intrinsic susceptibility of a parcel of land to the prevailing agents of erosion. It is dependent on a combination of climate, landform and soil factors. Attempts at classifying erosion risk involve interpretation and weighting of attributes of land units.

There is no widely accepted "objective" method for mapping erosion risk classes. As a rule, erosion risk is considered along with other physical or engineering constraints in capability classification systems, such as the N.S.W. or Victorian systems. (Hannam and Hicks 1978, Lindsay in press)

However, in this material, erosion risk is separately identified from the other concepts of physical or engineering limitations, and land capability. Erosion risk for land units occurring within erosional landscapes, has been determined from an interpretation of the Universal Soil Loss Equation (USLE, Wischmeier and Smith 1978).

For landscapes which can be described as both erosional and depositional, e.g., pediments of hills or drainage plains, the concept of erosion risk becomes blurred in the interaction of processes involving both erosion and sedimentation. In addition, models such as the USLE are poor in handling the erosive effect of run off where the run off water is flowing across several changes in slope gradient. Also the types of erosion processes change with position on a hillslope. In part these problems can be reduced by choosing land units that contain only one form of erosion.

The USLE has been adopted for use in the ACT Land Capability Guidelines for, despite its shortcomings, it still remains the most objective technique available to quantify erosion risk.

A4.1 USLE

The USLE approach is based on quantifying the factors that affect sheet and rill erosion; rainfall erosivity (**R**), soil erodibility (**K**), slope length (**L**), slope steepness(**S**), support practice (**P**) and crop management (**C**). The soil loss (**A**) is calculated by multiplying these six factors together.

The soil loss equation is
A = R * K * L * S * P * C

Where,

A, is the calculated soil loss per unit area, expressed in the units selected for **K** and for the period selected for **R**. Traditionally these have been selected so that **A** is in tons per acre per year, but other units can be selected. Accepted SI units are now tonnes per hectare per year.

R, the rainfall factor: more appropriately called the erosivity index; it is a statistic calculated from the annual summation of rainfall energy in every storm (correlates with raindrop size) times its maximum 30-minute intensity. Empirically, this "EI-Index" was found to have the highest correlation with soil erosion from experimental plots. As expected, it varies geographically, but its seasonal distribution is also important to calculate **C**-values. Units now used are MJ.mm/(ha.h.y).

K, the soil erodibility factor: This factor quantifies the cohesive character of a soil type and its resistance to dislodging and transport due to raindrop impact and overland flow shear forces. It is measured as the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 22.1 m length of uniform 5^{o} slope maintained in continuous clean-tilled fallow. Units are t.ha.h/(ha.MJ.mm). It is possible to estimate **K** knowing certain soil properties.

L, the slope length factor, is the ratio of soil loss from the field slope length to that from a 22.1 m length under otherwise identical conditions.

S, the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that from a 5^{o} slope under identical conditions. Both **L** and **S** result in increased erosion potential, but in a non-linear manner. For convenience **L** and **S** are frequently lumped into a single term.

C, the cover and management factor: This factor is the ratio of soil loss from land under specified cover and management conditions to corresponding loss under tilled, continuous fallow conditions. This is the most computationally complicated of USLE factors, it incorporates effects of: tillage management (dates and types), crop, seasonal change in **R**, cropping history (rotation), and crop yield level (organic matter production potential).

P, the conservation practice factor: This factor is the ratio of soil loss with a specified practice like contouring or strip cropping to that with straight-row farming up and down the slope. Practices included in this term are contouring, strip cropping (alternate crops on a given slope established on the contour), and terracing. As a rule of thumb, contouring reduces to one-half the soil loss caused by up-and-down hill farming, strip cropping to one-half that of contouring, and terracing to one-half that of strip cropping**.**

A5 Land use and erosion hazard

Determination of erosion risk differs from the determination of erosion hazard. With erosion risk land use or land management factors are ignored. Erosion hazard is defined as "the susceptibility of a parcel of land to the prevailing agents of erosion". It is dependent on erosion risk plus land use and land management factors.

A6 Engineering Constraints

In addition to identifying erosion risks, engineering constraints based on soils and terrain types can be identified. Areas may have soils with high shrink-swell potential, with low wet strength, with shallow depth to hard rock, or with seasonal or permanently high water tables. Identification of constraints of this nature is an integral part of land capability assessment and is a key component of a comprehensive planning approach.

APPENDIX B LAND RESOURCE DATA AVAILABLE WITHIN THE ACT

This appendix lists basic resource data for the ACT which relates to land capability. In addition there is discussion on the nature and quality of the data for this purpose. Note that vegetation data is not included.

B1 Geology

There is a considerable amount of geology and engineering geology mapping within the ACT. However only the 1:250 000 and 1:100 000 maps described below cover the whole of the ACT. The larger scale maps are most suited to urban soil survey and land unit mapping which is generally mapped at scales of 1:10 000 or better for urban land capability assessment.

It is important to realise that for soil surveys and land capability assessment, the upper 1 to 2 m of material is generally the most important. In many cases, particularly on lower slopes, drainage lines and floodplains, the upper 1 or 2 m is composed of transported material, geologically described as colluvium and alluvium. Whilst all geology maps available in the ACT contain areas identified as alluvium, only the 1:10 000 series contain mapped areas of colluvium.

Geological map units in all cases are made up of stratigraphic units which indicate the time of deposition of rocks. Hence each map unit may include a broad range of different rock types. Rock type or "lithologic" maps are preferred for land unit and soil mapping. Only the 1:10 000 series contains lithologic map units.

Maps units on geological maps are always represented by symbols. The first symbol in capital letters always indicates the geological period (O for Ordovician, S for Silurian etc) when the rocks were laid down. The second letter symbol (lower case) indicates membership of a group of formations laid down at the same time. The third symbol may be a letter or a number and usually refers to the formation name (if it has one). Sometimes the third letter symbol is followed by a number to indicate the particular facet of a formation.

Unfortunately there is no consistency between different geological maps in terms of symbols, resulting in for example, four different symbols being used for the same geological formation where it appears on four different maps. This is a particular problem when maps of a different scale are used.

B1.1 Availability of maps

1:250 000 Geology

Best, J.G., D'Addario, G.W., Walpole, B.P. and Rose, G. 1964. Canberra, A.C.T. and N.S.W. 1-250 000 Geological Series. Bureau of Mineral Resources, Australia. Sheet SI 55-16 (2nd edition)

Strusz, D.L., Canberra, A.C.T. and N.S.W. - 1:250 000 Geological Series. Bureau of Mineral Resources Explanatory Notes SI/55-16

1:100 000 Geology

Richardson, S.J., 1979 - Geology of the Michelago 1:100 000 Sheet 8726. Geological Survey of N.S.W. Sydney.

Michelago 1:100 000 Geological Sheet 8726 (1977) Geological Survey of N.S.W.

Tantangara 1:100 000 Geological Sheet 8626 Geological Survey of N.S.W.

Brindabella 1:100 000 Geological Sheet 8627 Geological Survey of N.S.W.

Canberra 1:100 000 Geological Sheet 8626 (provisional only)

1:50 000 Geology

Henderson G.A.M. 1979 The Geology of the Canberra-Queanbeyan 1:50 000 Map Area. B.M.R. Record 1979/87

Henderson G.A.M. 1981. Notes to accompany the 1980 1:50 000 geological map of Canberra, Queanbeyan and Environs.

1:10 000 Geology

Henderson G.A.M. 1986 Central Canberra 1:10 000 Engineering Geology Sheet B.M.R. Report No 267

Henderson G.A.M. 1886 Coppins Crossing 1;10 000 Engineering Geology Sheet B.M.R.

In addition maps are available in draft only format of Belconnen, Woden, Weston Creek, North and South Canberra. Copies may be obtained by formal application to the BMR.

The 1:10 000 series contain specific comments on nature of the weathering regolith, suitability for foundations and ease of excavation.

B2 Soils

1:100 000 Soils

The Canberra Region has been mapped at 1:100 000 by Sleeman and Walker in 1979. The southern part of the ACT is not included. The scale of this mapping is too small for incorporation into land capability mapping. Comments on erodibility and engineering qualities of individual map units are not present. However some general comments are made in this respect for individual Great Soil Groups.

1:25 000 Soils

The Australian Geological Survey Office (AGSO) have produced several soil/engineering geology maps at scales of 1:25 000 for various areas within the ACT. These include surface mapping of geology and soils, an assessment of groundwater conditions and an auguring and drilling program.

Excavation characteristics of the underlying lithology are described as well as the thickness and Unified Soil Classification (U.S.C.S.) for major soil types. Terrain features at landform pattern level are described for each soil mapping unit. In addition cross-sections are given showing relationships between landform, soils and drainage characteristics.

Specific engineering characteristics of the soil such as shrink-swell potential, permeability and wet strength would have to be interpreted from the U.S.C.S. classifications.

The following publications exist as unpublished records and may be borrowed through the AGSO library.

Hohnen P.D. Engineering geology of the proposed Halls Creek urban development area, Gungahlin District ACT.

Hohnen P.D. Engineering Geology of the Gungahlin Urban Development Area, ACT 1974/186

Hohnen P.D. Engineering Geology and Environmental Factors of the Proposed Jerrabomberra Industrial Estate, ACT 1975/36

Jacobsen, G., Kellett, J.R., Saltet J.A. and Vanden Broek, P.H. 1975 Urban Geology of Tuggeranong

Kellet J.R., Soil Survey Division of Watson, Canberra ACT 1970 1971/3

"Environmental Geology for Urban development- Tuggeranong, A.C.T. is published in BMR Journal of Australian Geology and Geophysics Vol 1 1976.

1:10 000 Soils

Since 1985 soils and terrain mapping have been undertaken for large sections of the "open space" lands within the ACT. This project is being funded by the National Soil Conservation Program (N.S.C.P.).

B3 Landform

The authors are not aware of any specialist landform mapping within the ACT other than within the N.S.C.P. program.

B4 Terrain Classification

In 1976 K. Grant wrote a "Terrain Classification and Evaluation for Engineering Purposes of the Canberra Area, ACT and NSW". It is published by CSIRO, Australia, Division of Applied Geomechanics, Technical Paper No 22. It contains maps based on a scheme known as PUCE (Pattern-Unit-Component-Evaluation) program.

The basis of the program is "that any area of land can be uniquely defined in terms of its topography, i.e., slope characteristics, underlying lithologic and structural (tectonic) characteristics and soil and vegetation characteristics; by defining intervals in these terrain characteristics at suitable significant levels, valid naturalistic terrain classes may be erected" (Grant 1976). Included in the discussion of map units are U.S.C.S. classifications. Limitation tables (flooding, steepness, rockiness) are prepared for each map unit and include an assessment of urban development potential. Building foundations, road formation, borrow pits are also discussed.

The map is presented at a scale of 1:100 000. It is the small scale of mapping that is the main limitation to the incorporation of this otherwise comprehensive piece of work being incorporated into a land capability assessment program.

B5 Land Capability Mapping

From 1985 to approximately 1993 there was a program funded by the National Soil Conservation Program, (N.S.C.P.) to conduct capability mapping for "non-urban" lands of the ACT.

This involved the collection of landform, existing land use, existing erosion and soils data at scales of between 1:10 000 and 1:25 000 using air photo-interpretation, field survey and laboratory methods. A digital elevation model was used to determine slope classes for some of the study areas.

One of the aims of the program was to present the data in a format that can be readily used by various land planning organisations within the ACT. To this end erosion hazard and land capability maps for a range of alternate land uses were developed. The incorporation of the data collected into a geographical information system (GIS) is under way (Table B1).

Table B1 ACT Land capability studies

Area	Date	Author	Hard copy available?	Digital map available?
Gungahlin	1984	Dennis Pascal		In progress
Bulgar Creek	?			
West Belconnen	1985	Cathy Hird	Yes	Yes
Pine Ridge	1986	Cathy Hird	Yes	Yes
Woolshed Creek	1986	Cathy Hird	Yes	
Woden Creek	1987	Cathy Hird	Yes	Yes
Paddy's River	1988	Cathy Hird	Yes	Yes

Jerrabomberra	1989	Cathy Hird	Yes	
Dairy Flat	1989	Cathy Hird	Yes	
CSIRO Lands	1990	Cathy Hird	Yes	Yes
Stromlo Forest	1990	Cathy Hird		
Huntley	1991	Cathy Hird	Yes	
Guises Creek	1993	Applied Ecol Res. Grp.	Yes	

The NSW system (Hannam and Hicks 1980) or a modified version has been used in some of the earlier studies. Later studies follow the procedures outlined in this document.

APPENDIX C BASIC TECHNIQUES

C1 Land Capability Assessment

In assessing the capability of the land both the erosion hazard of a particular land use and other physical or engineering constraints are considered. For example gently undulating plains have little or no erosion hazard for many land uses, yet if they are characterised by highly swelling soils, the capability of that site is downgraded for land use activities involving the construction of buildings. In this case the extent of the downgrading depends on the extent of the shrink-swell problem.

C1.1 N.S.W. Land Capability System

The N.S.W. capability system uses an empirical approach, i.e. "the effect of all or several land attributes is not stated explicitly and in a quantitative manner and their combined effect on capability can only be assessed by an expert with local experience" van de Graaff in Gunn et. al. (1988).

Note that Table 2.1 of the Guidelines is derived from the NSW empirical approach in which the severity of a particular annual soil loss has been converted into an erosion risk class.

C1.2 Victorian Land Capability System

An objective approach to capability classification has been developed by the Victorian Department of Conservation, Lands and Forests. They use a single worst factor model. In this approach a continuum of values for any land characteristic or quality is segmented into 5 ranges, each range being allotted a capability class. The single most severe permanent limitation for any one attribute for the land use under consideration determines the classification of the unit, ignoring the effects of all other attributes.

This system has been adopted for ACT conditions and is shown in Tables 3.3 and 3.4. The capability rankings ascribed to different sets of conditions still depend in part on the experience of the consultants who conducted the original land capability work in the ACT, Cathy Hird and Associates. There is as yet no wholly objective set of criteria to determine land capability.

C2 Land Resource Survey

This section outlines the techniques and procedures used to carry out a land resource survey. It will also provide some background for users of land resource data. More detail on these techniques is found in Gunn et al., (1988).

C2.1 Choosing a suitable scale

Reid in Gunn et al., (1988) suggests that mapping scales of 1:5 000 to 1:10 000 are suitable for soil and land unit mapping for urban development, waste disposal, highway planning and engineering uses. The particular scale chosen should permit separation of land unit bodies that may behave differently and require different management.

The scale chosen also dictates the smallest area that can be shown on the map. At scales of 1:10 000 or less this usually approximates to between 1 and 2 m^2 of land.

C2.2 Aerial photo-interpretation

Aerial photo-interpretation is a form of remote sensing using a stereoscope to view stereo pairs of air photographs.

The use of remotely sensed imagery in mapping is based on the premise that similar kinds of land reflect similar patterns in aerial photographs or imagery. The principle factors causing differences in patterns are changes in landform and vegetation. Landforms generally reflect the nature of underlying rocks or materials and the history of weathering, erosion and deposition. Landforms are identified by stereoscopic examination by means of their relative relief, structural form and drainage networks and relationships to other landforms. Together with geological information, landforms indicate the nature and mode of formation of soil parent materials and hence the kind of soils present.

Where the land is not largely cleared it is often necessary to identify boundaries from undisturbed native communities which generally reflect differences in the complex environmental conditions of a survey area.

The scale of the air photograph is determined by the focal length of the camera lens and the height above the general ground level at which the photograph is taken. In the ACT most photographs are at a scale of approximately 1:10 000.

Users of the photographs should be aware that image distortion increases radially from the centre of the photograph so that only the central area is true to scale to the degree necessary to delineate boundaries and location of sampling sites. In addition, it is necessary to have a 60% overlap in order to see in stereo.

Most soils/ landform maps are prepared using only simple optical stereoscopes. Where large scale aerial photographs are available (as in the ACT) it is not necessary to magnify the photographs. This allows the viewer to be aware of the whole landform pattern in order to accurately classify individual elements of the landform pattern. Accuracy is not as critical as for example in contour mapping because in practice it is often impossible to specify the exact position where a hillcrest becomes a sideslope, a footslope a drainage plain or the boundary between two distinct plant communities. Magnification becomes appropriate when the available air photos are at a smaller scale.

Boundaries identified on air photographs are usually transferred by hand onto topographic maps, preferably at a similar scale. It is best to assume that the contour lines on the topographic map are accurate and to place boundaries according to the appropriate configuration of contour lines.

It is important to have a set of codes for each feature to be identified on the air photo. Boundaries of map units can be made up of unique configurations of several features including relative relief, terrain type, land use, existing erosion, amount of surface rock outcrop and so on.

The cost of analytical stereoscopes, and associated software and hardware is coming down considerably. In the near future it may be feasible to utilise the available technology associated with automatic digitising and transformation of map unit boundaries and attributes.

Sophisticated techniques for remote sensing have not as yet been appropriate to land resource mapping in the ACT since they were initially developed for the relatively large scale LANDSAT imagery. However the advent of the SPOT satellite which yields much larger resolution satellite imagery and digital enhancement techniques for photographic images, may mean their use will become appropriate in the near future.

C3 Digital Elevation Models

Digital elevation models (DEM) are a digital representation of the continuous variation of relief over a specified area. Digital elevation data points are available on a 40 m grid within the ACT and are available from AUSLIG. These can be used to compute slope and aspect maps to assist in the recognition of land units.

A study described in Hird (1988) suggested that a slope map obtained from this data was more reliable than obtaining slope classes from aerial photo and topographic map interpretation.

Using digital elevation models any slope class can be specified by the user.

C4 Field and Soil Survey

Field surveys provides a means to both check the validity of existing data and add specific information about the soil.

C4.1 Selecting sites to describe and sample

Soils from each unique land unit map should be described and sampled for laboratory analysis. Each land unit should be sampled in at least three different geographical places. Where significant soil variation is found within any one unique unit, extra sampling should be taken with a view to creating a new land unit or describing the soil unit as a "complex" of different soil types.

Soils are sampled using a 10 cm auger except where a cutting or gully exposure is available. An attempt is made to strip 30 cm of soil from the side of the exposure before the soil is described (Northcote 1979). Where samples are taken for laboratory analysis the depths at which samples are taken for laboratory analysis are based on the appearance of discernible layers identified in the soil profile.

Sampling depths do not exceed 1 metre where a hand auger is used. However up to 2 metres may be described when cuttings or gullies are available, or if mechanical auguring techniques can be utilised.

C4.2 Soil Mapping Units

Usually in undertaking soil surveys for land capability mapping it is necessary to construct practical groupings of soils that occur together in the soil landscape. It is often the case that soils with very different characteristics in terms of influence on land capability may still belong to the same unit.

For example erodibility, shrink-swell potential, and even permeability are not necessarily incorporated into the design of soil units commonly used in Australia. Soil taxonomic units have been based more on degree of so called profile development than on their inherent properties.

Soil mapping units are usually not homogeneous, nor are the boundaries very sharp. The boundaries in soil maps usually indicate the mid-point of a more or less gradual transition. Nevertheless if the mapping has been done competently, the mapping units should normally be sufficiently homogeneous and boundaries precise enough to satisfy practical management needs.

Where different soils occur repeatedly at short intervals or in a pattern such that their mapping as individuals would require a much larger scale, the component soils should be recorded and the area mapped as a "complex".

C4.3 Soil Classification Systems

At present there are two widely accepted classification schemes for soils. These are the Great Soil Group System as described in Stace et al., (1968) and the Principal Profile Form as described in a Factual Key for Australian Soils.

C4.4 The Great Soil Group System

The Great Soil Groups are determined from an appraisal and interpretation of features found in the soil. The principal features considered are colour, texture, structure and consistency of the various horizons or layers found in the soil profile and the nature of the boundaries. The presence and form of various soil inclusion, such as parent material, are noted. The groups are presented in Stace (1968) in an order such that they represent overall the progressive increase in the degree of profile development and degree of leaching. Both field and laboratory analyses are required to determine the precise classification of the soil.

C4.5 The Northcote Factual Key

The Northcote Factual Key system (Northcote 1979) depends on the recognition of a number of features of the soil profile - this being done either by observation, handling, or simple chemical tests that can be carried out in the field. Because of this the identification of a soil is made almost completely objective, as definitions used to describe each feature have been precisely set out in a comprehensive glossary. The method is essentially a field one. Soils are coded according to various properties. A complete set of codes for one soil is known as a Principal Profile Form (P.P.F.).

C4.6 The Unified Soil Classification System

The Unified Soil Classification System (USCS) is used by engineers to describe the engineering properties of the soil material. It can be assessed in the field or as a result of laboratory tests.

The classifications are not based on the "soil profile" but on soil materials. Usually many different soil materials are present in one profile often equating to different soil horizons. However, the unique land unit concept can be used to describe the spatial occurrence of these materials. Usually the B horizon materials are considered the most important. The Unified Soil Classification System is considered important because many engineering properties of the soil have been correlated with it.

C4.7 Soil Data Cards

Soil data cards provide a means for recording field descriptions in a consistent and simple manner. They allow for a permanent memorandum of field data and supply a ready means of comparison of sites from different surveys. The cards should be formatted so that information can be easily entered into a computer.

In the last few years soil data cards have been developed by various organisations. The current recommended card for the ACT is the CSIRO card.

C5 Soil Problems

C5.1 c - very highly permeable soils

Soils with very high permeability are difficult to revegetate as they have very low nutrient and water holding capacities. Where these soils need to be revegetated they will require additions of fertiliser and organic matter.

These soils also rapidly transmit water nutrients (or pollutants) into the groundwater. In addition they may not be suitable as materials in sediment control structures. Soils classified has having a high permeability are those with textures sandier than loam.

C5.2 d - shallow soils overlying impermeable material

Where the depth of soil to bedrock is likely to be less than 50 cm a depth constraint is indicated. Bedrock close to the soil surface severely increases the difficulty of excavation. These soils also increase the erosion risk and pollution hazard since water holding capacity is reduced thereby increasing potential runoff. They are not suitable for septic tanks.

C5.3 e - erodible soils

Erodibility constraints are listed for all soils with high subsoil erodibility ratings. Topsoil erodibility is not included in urban capability assessment as in most cases topsoil is removed. Erodibility is measured from the Emerson Aggregate Test (E.A.T.) values and particle size analysis.

Structures designed to contain sediment must be provided downstream of sites with these soil types. In addition structures built from highly erodible soils will need to be surface mulched and seeded as erosion on batter walls will be more severe.

C5.4 v - high shrink-swell potential and plasticity.

Swelling soils change their volume in both horizontal and vertical planes with changes in moisture content. Slight changes in moisture content may cause significant shrinking and swelling. This property can be detrimental to such structures as rigid walls roads and buildings unless precautions are taken to allow for soil movement.

Shrink-swell is measured in the B horizon or subsoil. Soils with linear shrinkages of greater than 12% are classified as having a moderately significant shrink -swell potential and those with linear shrinkage greater than 19% have a high shrink-swell potential.

In the A.C.T. it is rare to find soils with a high shrink-swell potential.

Plastic soils have low bearing strength when saturated and are often slippery causing machinery to bog. Soils with U.S.C.S. classifications CH are placed in this category.

C5.4 o - soils with low wet strength.

Some soils have layers (often discontinuous) which have a very low wet strength when saturated. These are typically fine sandy or silty loams and clay loams with a plasticity index (the difference between plastic limit and liquid limit See Section 4.6) approaching zero. USCS classifications are SM, or ML.

Typically they are deep A2 horizons of sideslopes or footslope soils or they may occur to even greater depths in drainage lines. Where they occur, they usually must be removed as they are unsuitable foundation material. In addition construction machinery is likely to become bogged in these materials.

These soil materials are usually found associated with seasonal or perched water tables.

C5.5 f - flooding

These areas may be subject to periodic flooding and to waterlogging during periods of extended rainfall. All terrain units classified as floodplain and some drainage plains are considered to have a flood hazard. Within the ACT building is not allowed within the 100 year flood zone. Note that the flood hazard identified here does not necessarily equate with this zone.

C5.6 r - rock outcrop

The presence of significant amounts of rock outcrop increases the difficulty of clearing the land, locating services and in some cases the siting of buildings. It also increases the erosion hazard of an area by increasing runoff potential. Areas with greater than 5% surface rock outcrop are included in this category.

C5.7 s - slope

Slope gradient acts as a limitation to development by increasing the land disturbance when building structures, roads or installing services.

The interaction of increasing slope gradient with soil properties such as erodibility and depth leads to increases in erosion risk. In addition there is an increase in land slip hazards associated with site modification.

This limitation is assigned where average slopes exceed 3^{o}. The slope is also used in calculating the erosion risk class.

C5.8 t - topographic constraint difficult access

This constraint is used to identify areas with potential for urban development but access is through areas considered unsuitable for development.

C5.9 y - long slope lengths or runon hazard

This classification applies to areas of long slope lengths where a considerable amount of runon water following prolonged periods of rain is likely. All footslopes of hills with local relief greater than 10 m should be classified in this way.

C5.9 w - seasonal waterlogging

This classification applies to areas known to be seasonally waterlogged. In addition, soils with extensive A2 horizon development or mottled B horizons are likely to be seasonally waterlogged. In these soils water infiltrating the profile usually reaches a barrier at the more heavily textured A horizon causing waterlogging and lateral flow in the A2. In the Canberra region this is most likely to occur in late winter or spring.

Construction activities need to be timed for summer or autumn in areas affected by seasonal waterlogging. In addition special vegetative techniques are required to stabilise these soils.

Improved drainage, subsoil drains and sand backfilling of services will decrease the undesirable effects of waterlogging.

C5.10 m - mass movement hazard

This hazard is generally recognised wherever slope gradients exceed 1.7^{o}. At these slope gradients both rock and soil movements may occur if land is disturbed. Mass movement is also indicated wherever slumping or "terracetting" is evident.

C5.11 l - Salinity

Identification of saline soils is necessary for revegetation programs. Saline soils are those which have electrical conductivity values of greater than 4 millisiemens per centimetre measured in a saturation extract.

C6 Geology and Surface Rock Outcrop

C6.1 Geology

Lithology is one of the principal factors governing type distribution of soils and land units. Geology is therefore of prime importance in soil and land resource mapping. However, since the hard geological material rarely influences land capability (see comments below) it is not considered necessary for an original geological survey to be carried out as part of a land capability mapping program. In most cases available geological data is sufficient.

The availability of geological information is discussed in Appendix B

Rock material in the landscape includes bedrock and regolith. Regolith is a mantle of less coherent material that overlies the coherent bedrock. It is on this material that soil is formed. It may either be saprolite or sediment. Saprolite is rock material disaggregated in place by weathering; sediment has been deposited after transport and often has no relationship with the underlying rock. Sediment may be further divided into alluvium and colluvium.

Geological units obtained from the best available geological map (see Appendix B) should be used in the identification of unique land units.

In addition colluvium and alluvium can be identified easily from aerial photographs when 1:10 000 geological maps are not available. All footslopes can be thought of as colluvium and all drainage plains and floodplains as alluvium.

Geological symbols from the available geological map should be used. Where colluvium is separately identified this is labelled Qc. In addition it may be useful to identify the geological material from which the colluvial material is derived. To avoid too many different units being created the geological material can be more broadly grouped.

The correct mapping of lithology is an important aid in grouping soil types, however for land capability mapping it is important to characterise the particular features of the rock only when hardrock lies close to the surface. In this case runoff potential may increase and hence erosion risk is also increased. In addition, hardrock imposes engineering constraints for foundation designs, excavations and absorption of effluent. Other constraints are associated with particular rock types;

- heavily cleaved or fractured rocks (slates, shales phyllites) may cause failure of excavations.
- rocks which can dissolve (e.g. limestone). In this case special foundations are required.

C6.2 Surface Rock Outcrop

The incidence of surface rock outcrop and large surface aggregates can be assessed from aerial photographs. Surface rock outcrop should be reported as a percentage of the ground surface.

C7 Landform

Landform pattern can be described and differentiated on the basis of relief, modal slope gradient, mode of geomorphological activity and component land form elements. This description is consistent with McDonald et al 1984.

Relative relief is defined as the difference in elevation between the high and low points of a land surface. Relative relief is considered an important component in assessing erosion risk or hazard as in combination with modal slope class it gives some indication of the length of slope over which runoff will occur. Relief is ascertained using interpretation of contour maps or a digital elevation model.

Table C1 Land Disturbance generated by different Land Uses

Category	Land Use	Level of Disturbance
1	Nature reserve	No disturbance to less than 10% of ground area disturbed at any one time
2	Parks	Less than 50% of ground disturbed, no significant levelling or cut and fill. Completely stabilised following construction.
3	Pine Plantations	Up to 100% of land disturbed. No significant cut and fill. Almost stabilised after trees established.
4	Playing Fields	Up to 100% of ground disturbed. Special requirement for flat land. Completely stabilised following construction.
5	Public Utility	Less than 30% of ground disturbed. Minor cut and fill. Completely stabilised following construction.
6	Rural Residential	Less than 50% of ground disturbed, minor cut and fill. Some levelling. Flexible site selection. Almost completely stabilised after construction.
7	Recreation Facility	Up to 80% of ground disturbed. Not necessarily stable following construction.
8	Standard Residential	Up to 80% of ground disturbed, minor cut and fill and levelling. Almost completely stabilised after construction.
9	Medium to Multiple Unit	Up to 80% of ground disturbed. Significant cut, fill and levelling. Almost completely stabilised after construction.
10	Industrial and commercial areas	Up to 100% ground disturbed. Requirement for extensive leveling or cut and fill on sloping lands. Almost completely stabilised following construction.

Modal slope is described as the common class of slope occurring in a landform pattern. These values can ascertained from digital elevation models or by interpretation of aerial photographs and available contour maps.

C8 Existing Soil Erosion

Soil erosion is mapped to show the extent of degradation of the soil resources and to give some indication as to the erodibility of each soil type. Erosion processes are discussed in Appendix A.

The techniques for mapping existing soil erosion from aerial photographs are described by Emery (1975). For land unit mapping only severe gully/streambank erosion and salinity can be incorporated into the identification of unique land units. However it is useful to measure other types as they may indicate some cause effect relationships. The description of existing erosion requires a determination of the form of the erosion and its severity.

On slopes with gradients generally exceeding 25% soil creep, sheet erosion, rill erosion and minor gully erosion may be all apparent. As not all forms of erosion can be mapped, soil creep is generally recorded except when the sheet, rill or gully erosion is moderate to severe. In this case the most severe erosion is recorded.

C9 Laboratory Procedures

Collection of soil specimens and their laboratory analysis is relatively costly. Hence when designing a particular survey this aspect should be investigated in detail.

Specimen collection for laboratory analysis is undertaken for two reasons;

- general characterisation of soil profile classes/map units
- examination of selected attributes such as salinity and shrink-swell potential which are difficult to assess from field data alone.

A minimum of 2 profiles should be sampled for each unique land unit. In addition, each different horizon or layer identified in the profile should be sampled separately.

Details of the analytical procedures are given in the following table. These tests provide a verification of field site analyses as well as providing additional information on the engineering qualities and erosion susceptibility of the soils.

Apart from pH, the information does not provide the nutritional status of the soil. Nutritional status is hard to predict on a land unit basis, since the former is highly dependent on land management.