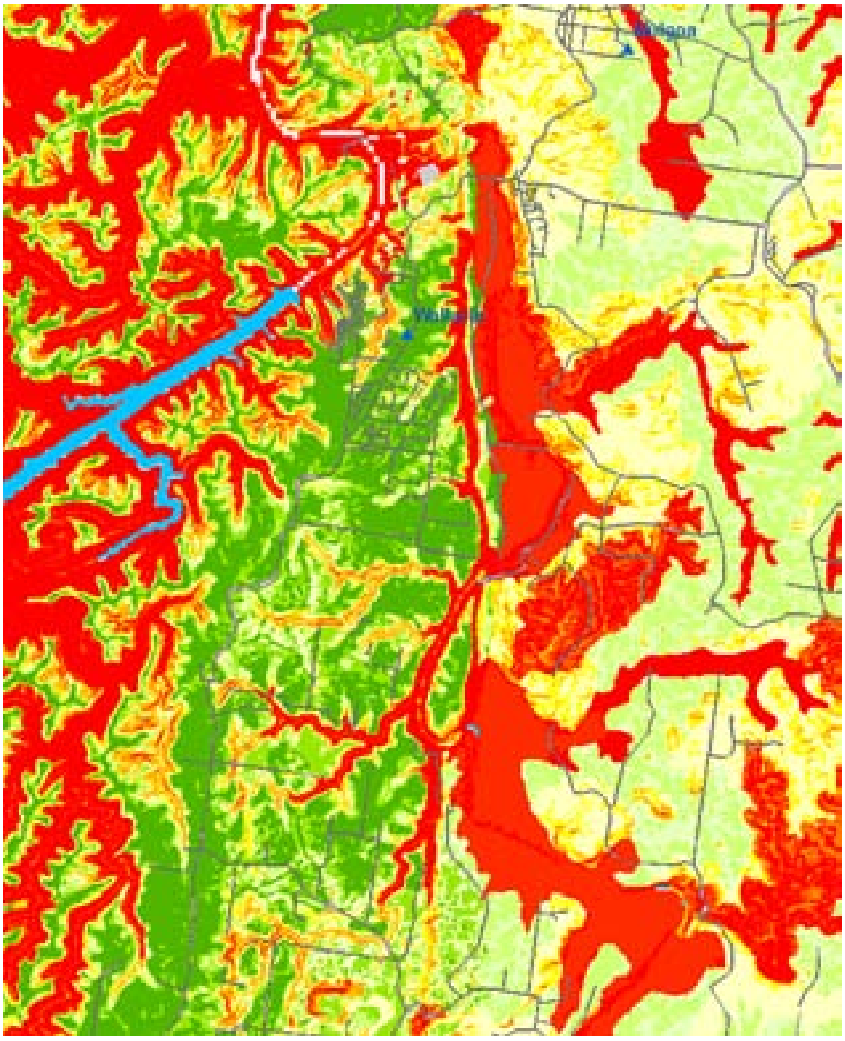
NSW GOVERNMENT | Environment, Climate Change & Water

Soil and land constraint assessment for urban and regional planning



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Front cover: Constraint map for standard residential development, SW Sydney region (DECCW)

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Abstract

A new approach to land capability assessment, termed soil and land constraint assessment, has been developed. The system allows for the generation of detailed soil and land constraint maps that portray the physical potential of the land to support a range of land uses. The results provide an estimate of the potential financial costs of ameliorating site constraints to a level of acceptable risks. Both on- and off-site risks are considered. Land uses considered range from standard residential development to agricultural cropping and domestic wastewater disposal.

The process is based around the application of constraint assessment tables prepared for each specific land use. Data are derived from 1:100 000 soil landscape maps and reports, digital elevation models, acid sulfate soil risk mapping and erosion hazard modelling. Outputs are digital maps on a 25 m x 25 m raster basis, with details on the overall level and nature of constraints included for each pixel. Results are considered reliable to a scale of 1:25 000 but for finer than this local site investigations are required.

The results can be readily interpreted by land-use planners and land managers and should contribute to environmentally sustainable land-use decision making. Twenty of the 34 standard land use zones used in local environmental plans in New South Wales are effectively covered.

1 Introduction

The effective and sustainable use of land involves matching site conditions with the specific requirements and potential impacts of different land uses. Significant costs to the environment and society in general may result where land is used for purposes that it is not physically capable of supporting. It is the responsibility of land-use planners and land managers to ensure that all land is used within its physical potential or capability.

Land capability may be defined as the inherent physical potential of land to safely and effectively sustain use without degradation to land and water resources. Failing to use land within its capability may have serious consequences. Common environmental impacts on- and off-site include soil erosion and sedimentation, contamination or other degradation of water resources (both surface water and groundwater), release of acid solutions from acid sulfate soils and other forms of land degradation. The long-term safety and effectiveness of a land use may be threatened by factors such as failure of building foundations, mass movement, flooding and restricted plant growth.

Land capability assessment provides information on:

- the land uses most physically suited to an area, that is, the uses with the best match between the physical requirements of the use and the physical qualities of the land
- the potential hazards and limitations associated with specific uses of a site
- the inputs and management requirements associated with specific land uses.

Such information is valuable for land-use planners at both the state and local government levels. The information assists in the initial urban and regional planning processes including the preparation of planning instruments such as local environmental plans (LEPs) and regional environmental plans (REPs). It also aids in decisions relating to granting of consent to development applications and applying accompanying conditions. The information will assist land managers and advisers, including local government bodies, catchment management authorities and farmers to identify appropriate specific uses (for example, type of agricultural product) and intensity of use. It will also assist development proponents and consultants in determining project feasibility, appropriate design and necessary environmental impact control measures.

The importance of land capability assessment in protecting New South Wales soils and other natural resources is recognised in the NSW Total Catchment Management Policy 1987 which commits the NSW Government to ‘ensuring that land within the state’s catchments is used within its capability and on a sustained basis‘. Likewise, the NSW State Soils Policy 1987 states that the ‘use of the state’s soils for any purpose should not lead to their loss or degradation and must therefore be within the bounds of their inherent capability to ensure continued utility, stability [and] productivity’. It also states that ‘land capability and land suitability assessments which take full account of soil characteristics and limitations are essential prerequisites to determination of the best use of the state’s lands and associated soils’.

Various approaches to land capability assessment have been practised in Australia. The Department of Environment, Climate Change and Water NSW (DECCW) has recently developed a new approach, termed soil and land constraint assessment, primarily for urban and regional planning applications. This involves a semi-quantitative analysis of soil-landscape constraints using the concepts of risk management, including an indication of potential costs in real dollar terms necessary to overcome these constraints. It is considered to be easily understood and interpreted by planners and other land-use decision makers, and more readily incorporated into the decision-making process than most standard land capability assessment outputs.

The approach is being used to progressively generate broadscale land constraint assessment maps with comprehensive supporting data for a wide range of land uses (for example, standard residential development and cropping) and land qualities (for example, domestic wastewater disposal). These maps and data are proposed to be made readily available to all potential users. The approach can also be applied over individual sites by the application of specific data collected for that site.

The aim of this report is to:

- present the soil and land constraint assessment process
- facilitate the interpretation of existing constraint maps and explain their potential use in the planning process
- provide guidance on the generation of new constraint maps over regions or single sites.

Background information on land capability schemes in general and on the constraint assessment process methodology is provided in sections 2 and 3. Potential sources of information are outlined in section 4. A description of the major soil-landscape constraints that impact on different land uses is provided in section 5. The general application of the constraint tables is discussed in section 6. The specific land constraint assessment tables developed for each land use are presented in the Appendices. These include:

- development – standard residential, medium density, high density and rural residential
- agriculture – cropping and grazing
- wastewater disposal – surface irrigation, trench absorption and pump-out methods.

The process is envisaged to have most application to urban and regional land-use planning in NSW. It is not intended to supersede the recently adopted Land and Soil Capability (LSC) scheme (Murphy et al. 2006, 2008) for the assessment of agricultural land in NSW, but rather provide a supporting and complementary assessment method for this land use.

The application of the soil and land constraint assessment maps and supporting data to land-use planning processes in NSW should assist in the effective and environmentally sustainable use of land resources in the state.

2 Background to land capability schemes

2.1 Overview

Land capability is a measure of the inherent physical potential of the land to fulfil a certain use in an effective and environmentally sustainable manner. It involves a comparison of the requirements of different uses with the resources offered by the land (Dent and Young 1981; McRae and Burnham 1981). For land to be used within its capability, there should be no significant degradation to land and water resources, either on or off site, in both the short and long term. Capability has been equated with 'ecological carrying capacity' of the land (Duggin 1992).

The concept generally considers only physical factors relating to soil and landscape conditions; it does not deal with socioeconomic factors such as prevailing market conditions or access to urban centres. Likewise, ecological, heritage or aesthetic factors such as the presence of endangered species, archaeological remains or scenic values are not normally considered within capability.

A simple conceptual model for land capability evaluation illustrating the combination of land-use requirements and land-unit characteristics is presented in Figure 1.

2.2 Development of land capability schemes

The first formal land capability rating system was devised in the early 1950s by the Soil Conservation Service of the US Department of Agriculture (USDA). It was mainly intended for farm planning and led to the publishing of the handbook *Land capability classification* (Klingebiel and Montgomery 1961). This scheme referred to the potential of the land for broad agricultural use, with or without specified soil conservation practices. It allocated land into one of eight classes based on the severity of various limitations, assuming a moderately high level of management. In its original form, the scheme has been criticised for being too generalised and subjective (Johnson and Cramb 1992). The USDA later developed other capability schemes for non-agricultural uses (USDA 1971, 1983).

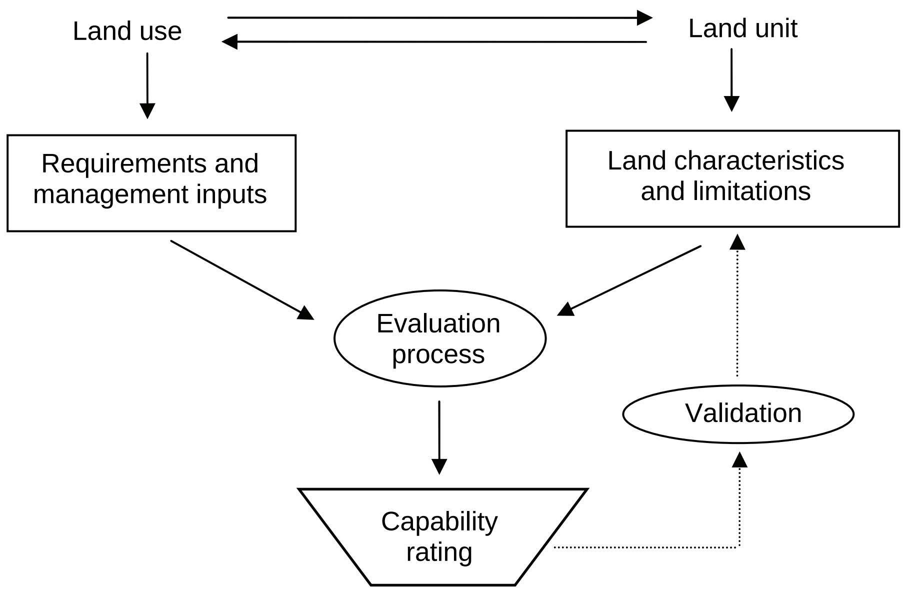


Figure 1: Main components of land capability assessment

Source: Modified from Baja et al. (2001)

Land evaluation processes were further developed by the United Nations Food and Agriculture Organization (FAO) in the early 1970s. This led to the publication of *A Framework for Land Evaluation* (FAO 1976) which formed the basis of several more specific schemes such as those relating to rain-fed agriculture (FAO 1983) and forestry (FAO 1984). These schemes were particularly intended for use in developing countries and did not automatically assume a certain level of management. They are described as suitability classification schemes and are used to allocate land into one of five suitability classes (S1, S2, S3, N1 and N2) based on limiting factors. They went further than assessing purely physical features of the land by also considering economic factors. Another new concept introduced was the 'land utilisation type' defining the technical specifications for a land use and the physical, economic and social setting (Johnson and Cramb 1992).

In later years several new entirely quantitative land evaluation systems were developed. These have been variously termed 'arithmetic', 'integrated' or 'parametric' systems. Most of these are either 'additive', involving a summing of factors to derive a final score, 'multiplicative', involving a multiplying of factors, or 'complex' involving a combination of those methods (van de Graaff 1988; Shields et al. 1996). With enhanced computer technology and increased availability of quantitative data, these schemes may be expected to gain more widespread use.

In Australia, different approaches to land evaluation are adopted in each state, but most systems in frequent use are based on one or both of the USDA capability and FAO suitability schemes. Most are empirical in nature, being based on experience and intuitive judgement. They are typically primarily qualitative with broad descriptive capability or suitability class definitions. However, quantitative criteria are increasingly being used to identify class limits, notably in systems used in Victoria (Rowe et al. 1988) and Western Australia (van Gool et al. 2005). Most are also limitations-based, relying on negative qualities to classify the land. Various arithmetic schemes are being developed and implemented around the country, for example Johnson and Cramb (1992) and Baja et al. (2001). There is commonly an emphasis on agricultural potential, with less treatment of other land uses. Accounts of the main contemporary schemes used in each state are provided by Shields et al. (1996).

In NSW, two broad systems have been widely used to evaluate agricultural potential of land: the rural land capability system developed by the former NSW Soil Conservation Service (SCS) (Emery 1985), and agriculture suitability system (NSW Department of Agriculture 1983). The SCS capability system has eight classes and is similar to the original USDA system. It is empirical and qualitative in nature, emphasising soil conservation aspects and the ease of maintaining the stability of land under cropping, grazing and timber. Most of eastern and central NSW has been mapped using the scheme at a scale of 1:100 000. The NSW Agriculture suitability system has five classes and identifies the agricultural productivity of the land (from better quality cropping land to poorer quality grazing land), mainly through qualitative descriptions. Unlike the SCS system it also considers social and economic parameters.

The SCS rural capability system has recently been revised to produce the *land and soil capability* (LSC) scheme (Murphy et al. 2006, 2008). It was developed for the NSW property vegetation planning program under the *Native Vegetation Act 2003* and further upgraded for the NSW Monitoring Evaluation and Reporting program. It retains the eight classes of the earlier system but places additional emphasis on soil limitations and their management. It comprises separate detailed ratings for a range of soil and land hazards, for example, sheet erosion, structure decline and acidification.

An *urban capability scheme* for NSW was also devised by the SCS (Hannam and Hicks 1980). This essentially qualitative scheme assessed the capability of land for urban and associated uses in relation to soil erosion and other site hazards. Ratings were allocated on the basis of single limiting factors. Urban capability studies using the scheme were carried out over numerous expanding urban areas around the state in the 1970s and 1980s. Chapman et al. (1992) and the related work of Morse et al. (1992) proposed a more detailed approach to urban land-use capability assessment that involved examination of individual constraints. This approach, combined with residual risk management and relative costings, formed the basis of the constraint assessment scheme presented in this report.

The current *soil and land constraint assessment process* described in this report was developed by the former NSW Department of Natural Resources (now incorporated into DECCW) as part of the NSW Comprehensive Coastal Assessment process (DNR 2006; DoP 2007). This risk management based, semi-quantitative approach provided outputs that could be readily linked with other planning information for use in urban and regional planning processes. Although constraint tables for agricultural use have been included, it is envisaged that these will provide only a supporting and complementary role to the LSC scheme in relation to agricultural land-use management.

Table 1 lists published Australian and overseas land evaluation schemes developed for the main land-use categories.

Table 1: Published capability tables for various land-use categories

Land-use category	Publication
Development	Hannam and Hicks (1980), McRae and Burnham (1981), Rowe et al. (1988), Morse et al. (1992), USDA (1993), van Gool et al. (2005)
Agriculture	Klingebiel and Montgomery (1961), Hilchey (1970), Rosser et al. (1974), McRae and Burnham (1981), NSW Department of Agriculture (1983), FAO (1983, 1985, 1991), Emery (1985), Rowe et al. (1988), Wells and King (1989), Johnson and Cramb (1992), van Gool et al. (2005), Murphy et al. (2006, 2008)
Waste disposal	USDA (1993), EPA (1996), van Gool et al. (2005), DLG et al. (1998)
Forestry*	McRae and Burnham (1981), FAO (1984), Rowe et al. (1988), USDA (1993), Cocks et al. (1995), Laffan (1997)

* This category is not dealt with in this report.

3 The soil and land constraint assessment scheme

The soil and land constraint assessment scheme builds on previous capability systems applied in NSW. It provides an indication of the physical potential of land to sustainably support a particular land use without degradation to land and water resources, taking into account the cost of ameliorating site constraints and the remaining risks.

Unlike many standard capability systems, the land constraint assessment system gives semi-quantitative outputs from the combined effect of all constraints, not just the most limiting constraint. The system determines rankings on the basis that ameliorative measures will be applied to overcome constraints, which again differs from standard capability systems. The assessment provides an indication of the costs in meaningful financial terms of overcoming constraints to the point where acceptable conditions prevail for different land uses. This means the information becomes more meaningful and readily accepted by many planners, land managers and developers. The quantitative nature of the outputs facilitates integration with other quantitative natural resource and socioeconomic datasets increasingly being used in land-use planning and land management studies.

The constraint assessment approach presented here is as outlined in DNR (2006), Chapman et al. (2006), Gray and Chapman (2005), Yang et al. (2008), among others. In some of these publications the process is referred to as 'feasibility assessment'.

3.1 Land constraint assessment concepts

The assessment process involves evaluating the combined effects of a number of key soil and landscape attributes. Two key principles behind the approach are:

- risk management – the risk assessment framework in the Australian and New Zealand Standards AS/NZS 4360:1999 was adopted. To quote this standard: *'Risk assessment is based on the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood.'* Residual risk management is also considered, being defined in the Standard as *'the remaining level of risk after risk treatment measures have been taken'.* For example, large residual risks may remain on very steep sites with erodible soils even after intense erosion control measures have been implemented.
- quantitative costings – the approximate costs of amelioration required to reach an acceptable level of risk for each constraint are estimated, facilitating the comparison of potential costs associated with different land-use scenarios. Further detail on the costings process is given below.

Five classes of constraint, ranging from 1 (very low) to 5 (very high), applying to individual attributes are defined, as shown in Table 2.

Table 2: Constraint classes of individual attributes

Constraint class of attribute	Description
1 Very low	Very low constraint; low treatment costs; straightforward or no maintenance; associated with negligible financial, environmental or social site costs; very low residual risk.
2 Low	Low constraint; associated with minor financial, environmental or social site costs; straightforward or low maintenance; low residual risk.
3 Moderate	Moderate constraint; moderate financial, environmental or social costs beyond the standard; frequent maintenance required; moderate residual risk; marginally acceptable to society – other factors may intervene.
4 High	High constraint; high financial, environmental or social costs beyond the standard; special mitigating measures are required; regular specialist maintenance; moderate to high residual risks and costs.
5 Very high	Very high constraint; risks very difficult to control even with site-specific investigation and design; very high financial, environmental or social costs beyond the standard; regular specialist maintenance may be mandatory; high residual risk; generally not acceptable to society.

Each of the five constraint classes is assigned a particular number of constraint points representing the degree of associated financial, environmental and social costs. Classes 1 and 2 do not attract any constraint points as these represent standard desirable conditions. Classes 3, 4 and 5 attract 1, 3 and 6 points respectively indicating increasingly detrimental conditions associated with higher costs. Widespread flooding falls into Class 5 but is considered a special case and attracts 9 constraint points.

Specific quantitative costings are brought into the process by assigning a relative cost to a constraint point. Each constraint point may be considered to represent an approximate additional cost of 5% of a benchmark cost as shown in Table 3. The more constraint points associated with a hazard, the more costly it is to overcome.

Table 3: Scoring and costing of constraint classes applicable to individual attributes

	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint
Constraint points	0	0	1	3	6*
Additional cost to land use (relative to benchmark cost)	0	0	1 x 5% = 5%	3 x 5% = 15%	6 x 5% = 30%

* Widespread flooding attracts 9 points (45% of benchmark cost).

The benchmark costs vary for different land uses. For development uses (such as standard residential or medium density development) the benchmark costs are the estimated initial construction costs, including associated infrastructure (such as roads and sewerage). For example, the benchmark cost for standard residential development is taken as $200 000 (2009 dollars), being a very approximate cost for a standard residence with associated infrastructure. Potential costs may accumulate over the life of the development (nominally 100 years). For agriculture, the benchmark cost is the estimated value of annual production. For domestic wastewater disposal, the benchmark cost is the estimated cost of establishing a reliable surface irrigation disposal system, valued at approximately $12 000.

The constraint points applied to individual attributes are added to give a total score for a particular site. The total constraint score allows a comparison of the costs associated with the land-use change at different sites. The higher the total score, the more costly and inappropriate the proposed land-use change. Specific examples of the scoring system are given in the section 3.2.

Costs associated with a particular constraint may be attributed to:

- direct financial expenses for on-site actions including detailed site investigations, additional design work, special construction and impact mitigating measures, ongoing maintenance, and for major repair work that may be required, and/or
- indirect environmental and social (external) costs converted to an equivalent financial cost, which may be required if the special design and mitigating measures are not properly applied or fail. These may be based on the costs necessary to return conditions to pre-impact state, for example the cost of neutralising the effect of acid conditions following disturbance of acid sulfate soils (ASS), or an estimate of the loss of public amenity.

The derived costings are approximate. Further development of the process will yield more precise estimates of the costs associated with different constraints. While some cost estimates for treatments are relatively easy to obtain (such as those that relate directly to commonly used building foundation types), there are others that are problematic (for example, treatment of disturbed ASSs). This may be due to a large number of variables, a wide range of available treatment methods or the uncertainty of treatment success.

3.2 The assessment process

The assessment process may be applied over broad areas using existing regional data or over specific sites using field data collected from that site. It involves the application of constraint assessment tables as described in the following sections.

3.2.1 Constraint assessment tables

The constraint assessment tables synthesise the soil and landscape data relating to a range of potential constraints attributes for each land use or quality. They are used to determine a single constraint score for each area under study. A worked example for standard residential development is shown in Table 4, with the other tables in Appendix 2. The broad components of each table are:

Land-use description – a brief description of the land use or quality, including the main elements and associated actions and processes is provided above each table

Attributes – soil and land features relating to key constraints that potentially influence each land use are listed in the left-hand column of each table. Specific attributes or those derived from different data sources may be listed under each constraint. For example, under the shrink-swell constraint in Table 4, two attributes are listed: the broad limitation as identified by a soil surveyor and a volume expansion percentage derived from laboratory data, as reported in the relevant soil-landscape report. All constraints and attributes are described in section 5.

Constraint classes – five constraint classes are included in the next five columns. These range from Class 1, very low constraint, to Class 5, very high constraint, as defined in section 3.1. Within each class, each constraint or attribute is prescribed a range of values; for example, volume expansion is less than 5% for Class1, and 5–15% for Class 2. Less serious constraints or attributes may only extend to Class 4 or even Class 3 because of the relatively low costs associated with their amelioration.

Constraint rationale – this column gives a brief description of the potential consequences arising from each constraint.

Data source – this column indicates the source of data for each constraint or attribute. The entries that appear in the current tables represent the data source currently relied upon by DECCW. The intention should always be to use the most reliable data source available, so these entries will vary from study to study.

Certainty levels – the last two columns provide an estimate of the level of certainty associated with each constraint or attribute rating. One column refers to the theoretical certainty of the relationship between attribute values and the constraint class, the other the certainty of the rating using the available data source, that is, the confidence one has in the data being applied. Four certainty ratings are defined below, with the applied rating being the lowest from either column.

certain: no doubt as to the theoretical relationships in the ratings – a very reliable data source

confident: sound observed and theoretical reasons to expect rating relationships – mostly reliable data

probable: rating relationships are based on findings from other aspects of soil science – data is of moderate reliability, and may be of moderate variability within the soil-landscape unit

uncertain: rating relationships are untested – data is of questionable reliability, and may be of significant variability within the soil-landscape unit.

3.2.2 Generating results

For an individual unit or a specific site the constraint assessment tables are used to derive a constraint score as follows.

1. Data for each of the required constraints and attributes listed in each table is acquired. The data sources currently used by DECCW are given in the table, and those with the highest level of certainty are used.
2. Relevant values for each attribute are applied to the table, and are ranked into one of the five constraint classes.
3. An individual score is applied to each constraint, based on the worst rated attribute associated with that constraint. As shown in Table 3, Class 3 constraints attract 1 point, Class 4 constraints attract 3 points and Class 5 constraints attracts 6 points (or 9 for widespread flooding).

Table 4: Soil and land constraint assessment table for standard residential development with worked examples

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data source	Theoretical correlation	Correlation using data source
Slope (%)	<4 **A, C**	4–8	8–15	15–35	>35	Increases complexity of construction and long-term access	DEM	Certain	Certain
Erosion hazard (tonnes/ha/year)	<3	3–8 **A, C**	8–40 **B**	40–135	>135	Loss of soil, degrades water quality, sedimentation of waterways	Soil erosion hazard map	Certain	Confident
Wave erosion hazard	Not recorded **A, B, C**	–	–	Localised	Widespread	Unstable ground, damage by waves and water	Landscapes limitations table	Confident	Confident
Flood hazard	**A, B**				**C**				
Probablity (%)	Nil	–	<1 events less frequent than 1 in 100 years	1–2 1 event in 50 to 100 years	>2 1 event in <50 years	Flooding poses a large potential threat to human life and built structures	From flood risk maps	Certain	Certain
General occurrence	Not observed	–	–	Localised	Widespread	As above	Landscapes limitations table	Certain	Confident
Terrain unit	Hill slope units (excluding footslopes)	–	Low footslopes, plains (excluding floodplains)	High floodplains	Middle and lower floodplains, drainage depressions, stream channels	As above	Multi-attribute mapping, soil landscape descriptions, topographic maps	Certain	Confident
Mass movement hazard	Not observed **A, C**	–	Localised & slope <15%	Widespread & slope <15% Localised & slope >15% **B**	Widespread & slope >15%	Potential failure of ground and structures	Landscape limitations table and slope estimate	Certain	Confident
Acid sulfate soil risk	No occurrence **A, B**	LP > 4 m	HP > 4m LP 2–4m **C**	HP 2–4m LP <2m	HP <2m	Potential acid corrosion	ASS risk maps	Confident	Confident
Shrink-swell potential	**A, B**			**C**					
Shrink-swell limitation	Not recorded	–	Widespread over minority of materials	Widespread over majority of materials	–	Ground movement, potential cracking	Soil material limitations table	Certain	Confident
Volume expansion (%) *(worst soil material)*	<5	5–15	15–30	>30	–	As above	Type profile lab data		Confident
Soil strength	**A, B**		**C**						
Plasticity	Not recorded	Widespread over minority of materials	Widespread over majority of materials	–	–	Potential subsidence and cracking of structure	Soil material limitations table	Confident	Probable
Low wet bearing strength *(average of soil materials)*	Very high	High, mod	Low, very low	–	–	As above	Soil material data	Confident	Probable
Organic soils	Not recorded	Widespread over <70% of materials	Widespread over >70% of materials	–	–	As above	Soil material limitations table	Confident	Confident
Unified soil classification system *(worst soil material)*	All others	CL	ML, MH, CH, OL	OH	Pt	As above	Type profile lab data	Confident	Confident
Salinity	**A, B, C**								
Saline soil materials	Not recorded	Widespread over minority of materials	Widespread over majority of materials	–	–	Potential corrosion and salt attack	Soil material limitations table	Confident	Confident
Saline landscapes	Not recorded	Localised	Widespread	–	–	As above	Landscapes limitations table		Confident
ECe (dS/m) *(worst soil material)*	<0.1	0.1–2.0	>2.0	–	–	As above	Type profile lab data	Confident	Confident
Waterlogging	**A, B**		**C**						
Seasonal waterlogging	Not recorded	–	Localised	Widespread	–	Water weakens foundations, promotes corrosion & rising damp	Landscapes limitations table	Confident	Confident
Permanently high watertable	Not recorded	–	Localised	Widespread	–	As above	Landscapes limitations table	Confident	Probable
General foundation hazard	Not recorded	–	Localised	Widespread	–	Overall hazard perceived	Landscapes limitations table	Certain	Confident
Rock outcrop	Not recorded **A, C**	Localised **B**	Widespread	–	–	Impedes construction	Landscapes limitations table	Confident	Confident
Total constraint score	**Site A: 0**	**Site B: 7**	**Site C: 12**	*(derived by adding sub-scores from each column. Attributes in Moderate column: 1 point; High column: 3 points; Very High column: 6 points)*					

4 The total of the individual constraint scores are added to give the total constraint score for the unit or site. These scores typically range from 0 (very low constraints, very high capability) to 12 or greater (very high constraints, very low capability).

5 The score is converted to a proportion of the relevant benchmark cost, with each point being equivalent to 5–10% of the benchmark; for example, a constraint score of 6 for standard residential development is equivalent to approximately 30% of the initial construction costs (including associated infrastructure).

The process is illustrated by the following examples of three sites, A, B and C, being considered for standard suburban residential development.

Site A: current residential area, very gentle slope (2% gradient), low erosion hazard, all other attributes have nil or minor constraints.

Site B: current woodland, moderate to steep slopes (25% gradient), high erosion hazard, localised mass movement hazard, all other attributes have nil or minor constraints

Site C: current pasture land, very gently inclined site (2% gradient), high flood hazard (approximately 2% probability), slight acid sulfate soil risk, clay-rich soils with high shrink-swell potential and high plasticity, local seasonal waterlogging, all other attributes have nil or minor constraints.

Table 4 presents the standard residential constraint assessment table with constraint ratings applied to the various attributes for the three example sites. Table 5 gives a summary of the constraint scoring.

The tables show that Site A has a low constraint score of 0, with no constraints that cannot be easily overcome. Site B has high constraints (score of 7), indicating additional potential costs amounting to approximately 35% of original construction costs (including associated infrastructure) and high residual risks remaining. Site C has very high constraints (score of 12), indicating additional potential costs amounting to approximately 60% of original construction costs and high residual risks remaining.

Table 5: Example of constraint scores at three sites

Attribute (or group of attributes)	Site A	Site B	Site C
1 Slope	0	3	0
2 Erosion hazard	0	1	0
3 Wave erosion hazard	0	0	0
4 Flood hazard	0	0	6
5 Mass movement hazard	0	3	0
6 Acid sulfate soils	0	0	1
7 Shrink-swell potential	0	0	3
8 Soil strength	0	0	1
9 Salinity	0	0	0
10 Waterlogging	0	0	1
11 Rock outcrop	0	0	0
Total constraint score	**0**	**7**	**12**

The process of generating constraint assessment results over broad areas involves incorporating rules from the tables into queries to allow interrogation of databases containing the regional soil landscape data. DECCW uses Hyperion® (formerly Brioquery) as the query program to extract preliminary results from MS Access databases called SLADE (Soil Landscape Access Database Environment).

These results are further sorted and analysed using MS Excel to derive intermediate results for each soil landscape unit. These intermediate results are imported into ArcGIS and linked with spatial coverage for each unit. Digital elevation models and rules derived from the soil landscape descriptions were used to delineate subcomponents, also termed facets, of many of the soil landscapes at 1:25 000 scale (Yang et al. 2007). Finally, the influence of acid sulfate soils, slope and erosion hazard are added to a 25 m x 25 m pixel basis to produce the final results. Further details on the process are provided in DoP (2007) and Yang et al. (2007, 2008).

3.3 Presentation of results

The results of the land constraint assessment process may be presented as a series of hard copy and digital derivative maps for the range of land uses and qualities being considered. These identify levels of constraint associated with each use throughout the study area.

An example of a constraint map produced for the Coastal Comprehensive Assessment process is shown in Figure 2. The maps are best viewed in electronic format using GIS technology, allowing access to the comprehensive supporting data contained within the digital maps.

The maps are prepared on a 25 m x 25 m raster basis with constraint scores and associated data being allocated to each cell. Figure 3 shows an example of a screen image of a constraint map with supporting data for a particular point. The key data presented for each pixel includes:

- **constraint score** – ranges between 0 (nil constraint) and 12 (extreme constraint), with a green to yellow to red colour ramping representing the increasing scores. Although some locations actually have scores higher than 12, these are brought back to the maximum 12 score, which is effectively limiting to any land use. As described above, each point of the score represents approximately 5–10% of a benchmark cost relating to the land use in question
- **constraint code** – this presents the ratings applied to all constraints and attributes considered in the assessment process. The code begins with the rating of the most limiting factor. For example, the code shown in Figure 3a (5_fh5_mm1_ss3_pl2…) indicates a limiting factor rating of 5, with a flood hazard rating of 5, mass movement rating of 1, shrink-swell rating of 3, etc.). A full listing of abbreviations of all attributes used in the assessment process is given in Appendix 1. Some units contain the letters DF (dominant facet) in the code, indicating that the following part of the code relates only to the most widespread facet in that landscape, which may differ slightly from the landscape as a whole.
- **confidence rating** – this gives the level of certainty associated with each constraint score, as described in section 3.2.1.
- **unit identifier** – soil-landscape code and facet name to which each pixel belongs is provided. For example, in Figure 3a, spz_footslope refers to the Seconds Pond Creek landscape, footslope facet. In some cases, the four-digit 1:100 000 topographic map code may be included before the landscape code.

Further description of the soil landscape unit may be obtained by referring to the relevant published soil-landscape report.

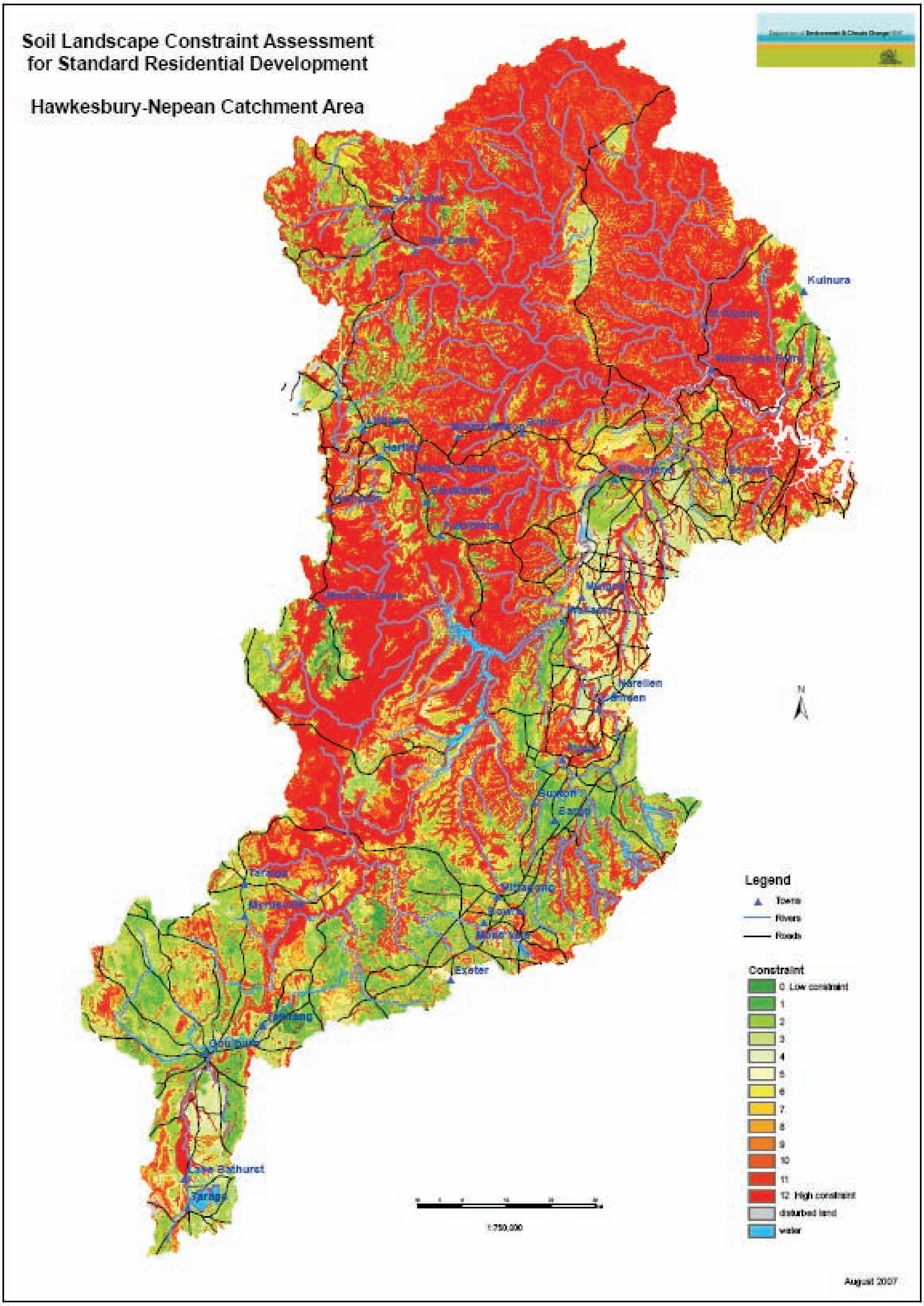
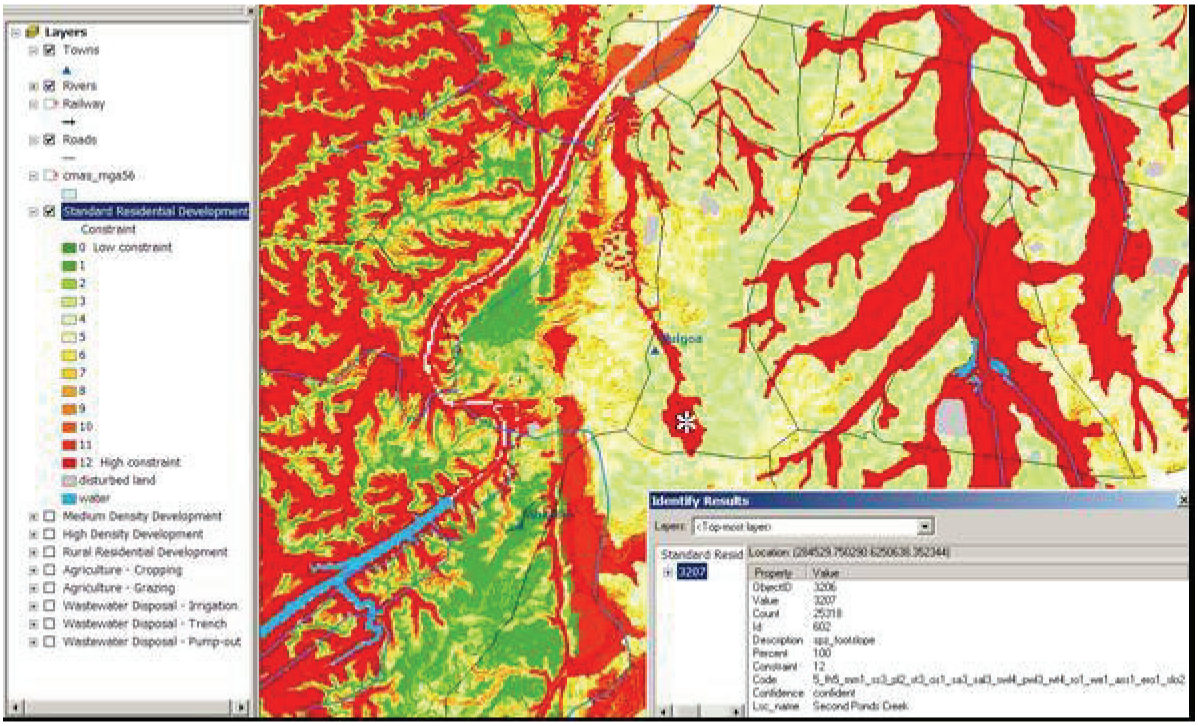
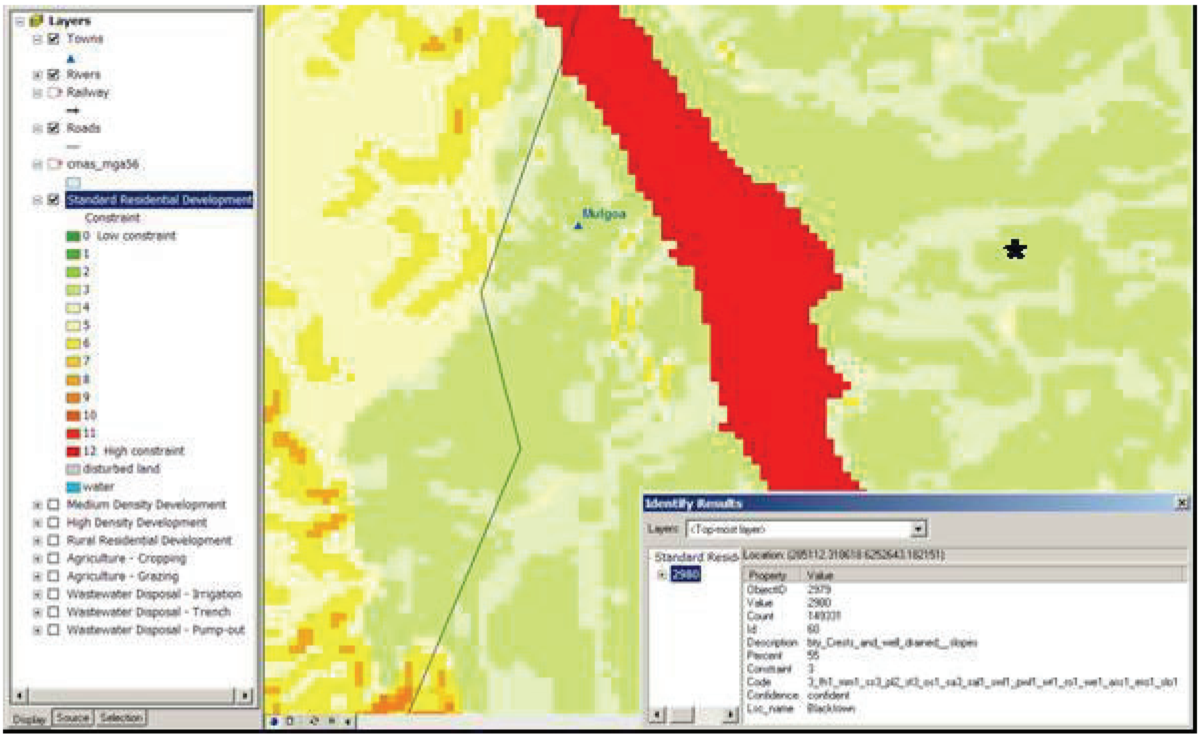


Figure 2: **Preliminary soil and landscape constraint assessment map for standard residential development for the Hawkesbury–Nepean catchment**



a) Approximately 1:100 000 scale



b) Approximately 1:10 000 scale

Figure 3: Screenshots of standard residential constraint draft maps for western Sydney area, with information box for a selected pixel

Note appearance of pixilation in the finer scale map, where the selected pixel is marked by *.

4 Sources of information

The main data sources available for use in the constraint assessment process are described below and are referred to in the assessment tables.

4.1 Soil landscape mapping

The results of the mapping program provide the major source of data for the assessment process. The maps and accompanying reports present detailed information on soil-landscape units which are areas of land with relatively uniform soil types and landscape characteristics (such as slope, terrain and geology). Each unit is expected to have broadly similar qualities, limitations and land management requirements (Chapman and Atkinson 2007).

Soil landscape mapping at 1:100 000 scale is available for much of eastern NSW and at 1:250 000 scale for much of central NSW. The current status of mapping is shown in Figures 4 and 5. Recent published reports include King (2009) and Morand (2001). These maps have been enhanced by DECCW by subdividing the soil landscape units into subunits (facets), generally based on distinguishable topographic elements (such as crests and side slopes).

Three levels of information are available:

- **soil landscape limitations** are broad limitations (constraints) applying across the entire landscape unit or facet. They include flood, mass movement, salinity or high water table hazards and are identified by the soil surveyor on the basis of all landscape observations, soil profile and site descriptions. The data is generally summarised in a table in the report
- **soil material limitations** are limitations (constraints) applying to the dominant soil layers identified by a soil surveyor. They include constraints such as shrink-swell, low wet strength, low fertility, highly acidic and saline soils. The data is generally summarised in a single table in the report. Laboratory results assist in the identification of the limitations.
- **laboratory results** include a range of physical and chemical laboratory results which are available for most soil materials and presented in tables in the reports. DECCW applies these results cautiously across entire landscapes in the assessment process.

Further detail on the NSW Government's soil survey program is available on its website,[1] and soil profile data can be accessed through the SPADE tool.[2]

4.2 Other soil data

Acid sulfate soil risk maps identify areas at risk of containing these hazardous soils. Areas are mapped as having either high or low probability of containing the soils at different elevations (0–1 m, 1–2 m, 2–4 m or >4 m Australian Height Datum – AHD) or with no known occurrence. Maps have been completed around all estuarine systems of NSW to an elevation of 10 m and are available through the NSW Government's natural resource agency (see Naylor et al. 1998).

Erosion hazard maps have been developed to show data on sophisticated erosion hazard modelling which combines topographic data from digital elevation models (DEMs) with soil erosivity and rainfall erosivity data (Yang et al. 2006).

[1] www.environment.nsw.gov.au/soils/survey.htm
[2] www.environment.nsw.gov.au/soils/data.htm

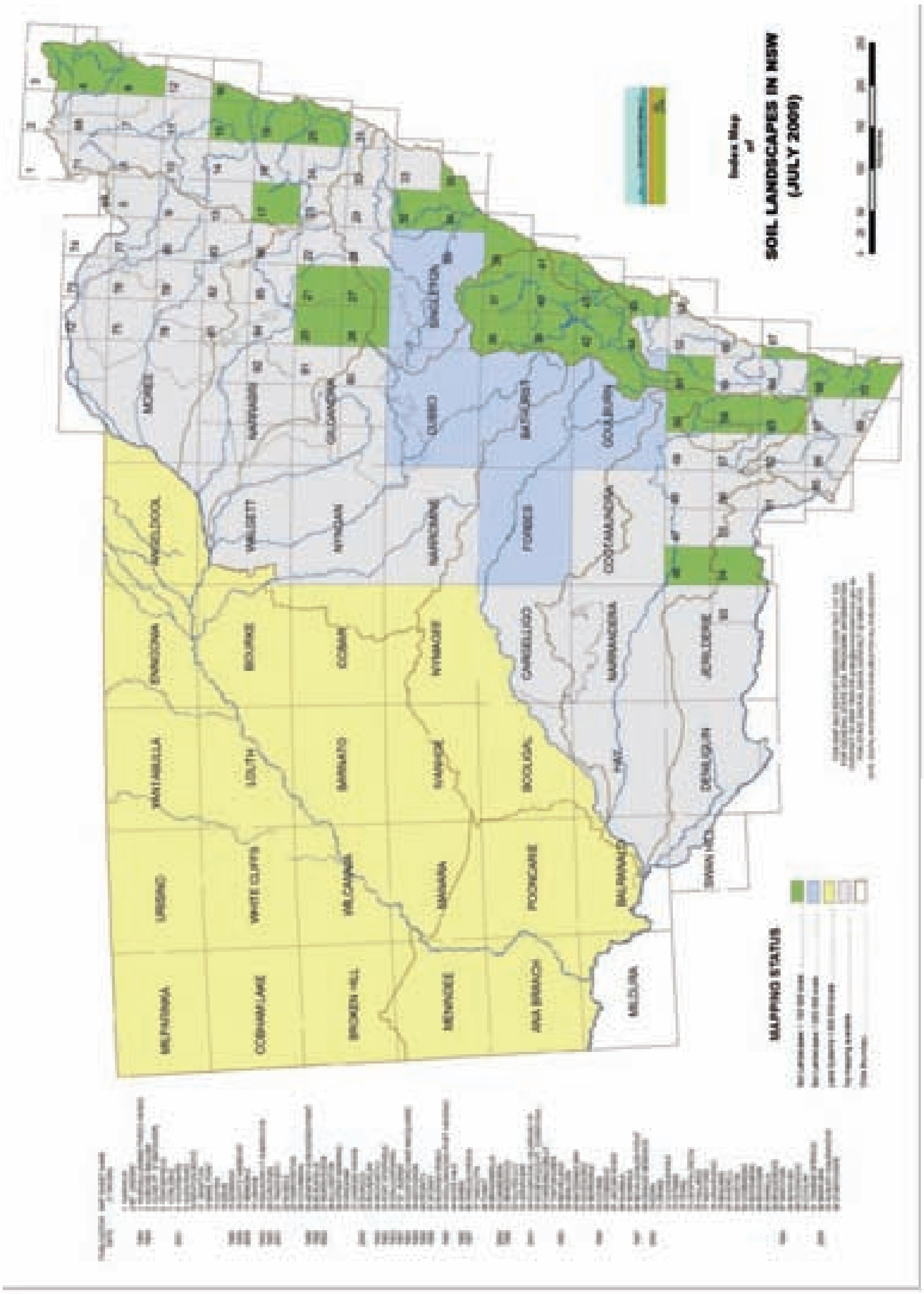


Figure 4: Soil-landscape maps, July 2009

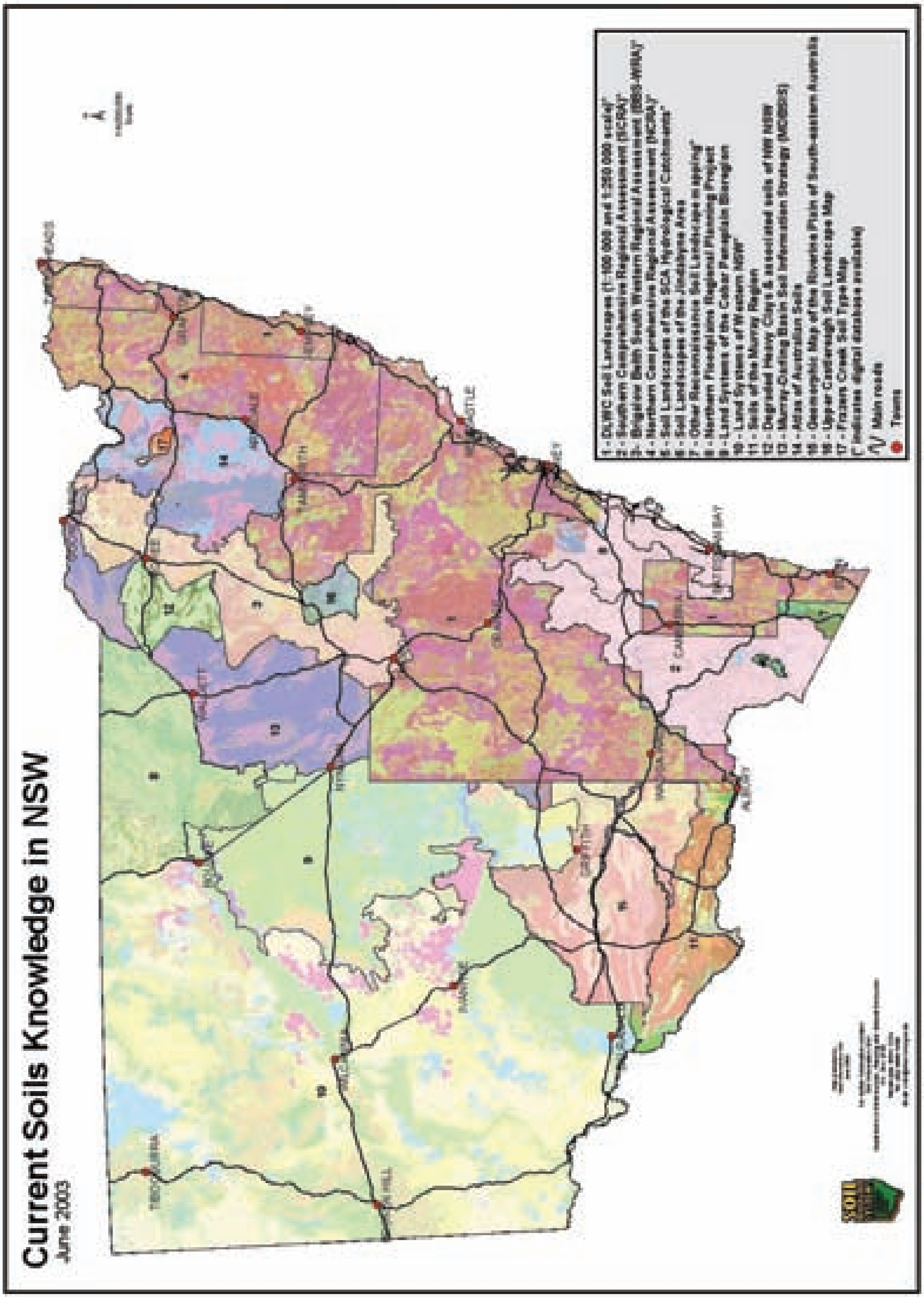


Figure 5: Soils knowledge map of NSW, June 2003

Land resource maps, also termed multi-attribute maps, identify areas of uniform terrain and land-use character, usually at a scale of 1:25 000. They have been prepared over selected areas of eastern NSW and may be accessed through the NSW Government natural resource agency.

Soil regolith stability maps reveal the soil-regolith stability class of land, giving an indication of the combined soil and substrate erodibility and sediment delivery potential. Mapping has been completed over all state forests of eastern NSW (Murphy et al. 1998) and other secondary maps are being derived from soil-landscape mapping.

Comprehensive resource assessment maps are regional reconnaissance soil maps at scales of 1:100 000 and greater, carried out as part of comprehensive resource assessment projects for south-east NSW, north-east NSW and western NSW (southern Brigalow) to help inform nature conservation and forestry land-use allocation (Figure 5). The omission of many relevant soil and landscape attributes and lack of laboratory testing limit the maps' usefulness for other land uses.

Land systems mapping in western NSW covers broadscale (1:250 000) land units with information on landform, geology, vegetation and soils (Walker 1991; Figure 5). The broad scale and lack of detail on many important attributes limit the use of these maps for capability assessment.

4.3 Other natural resource data

Flood hazard maps indicate the probability of flooding in areas surrounding many of the state's major watercourses. The maps are usually held by state government agencies dealing with water resources and local government bodies.

Groundwater vulnerability maps indicate the vulnerability to pollution of potable groundwater reserves. The maps are currently available over selected regions of the state and may be accessed through state government agencies dealing with water resources.

Land and soil capability maps are statewide digital maps recently produced by DECCW based on 1:100 000 and 1:250 000 scale soil-landscape mapping. The maps provide capability data on a number of specific soil and land hazards of relevance to rural land uses, such as sheet erosion, structure decline and acidification. More detailed urban capability maps are available over specific urban areas. Although these maps do not provide specific data required for the capability assessment process presented here, they do provide useful supporting information.

Topographic maps provide data on landscape features such as slope, terrain and relation to watercourses (giving potential for flooding). Maps at a scale of 1:25 000 are available for most of the eastern part of the state with 1:50 000 or 1:100 000 scale maps over the remainder

Digital elevation models (DEMs) provide spatial elevation data in digital format and give rise to a digital representation of the landscape. They consist of a raster (or regular grid) of spot heights. In NSW, models are available at different resolutions, with ground resolution of 25 m and vertical resolution of 1 m over much of eastern NSW. SRTM DEMs at 90 m ground resolution are available for western parts of the state and LiDAR DEMs at 1 m or finer ground resolution are available over selected areas, such as the Hunter, Central Coast, Sydney and Shoalhaven regions. They can also be used to identify topographic features such as slope gradients and lengths and various advanced topographic indices such as CTI (compound topographic index) or FLAG Upness index.

5 Soil landscape constraints

A wide range of soil landscape constraints is considered in the land constraint assessment process, with each land use subject to a subset of these constraints. This section briefly describes each constraint, with advice on their broad influence on land uses and the data sources relied on in the assessment tables. They are grouped into broad landscape constraints, soil physical constraints and soil chemical constraints, as shown in Table 6.

5.1 Landscape constraints

5.1.1 Steep slopes

Land gradient generally has a major influence on many land uses and qualities. Almost all land-use operations become increasingly difficult as slope increases, particularly above moderately inclined levels (>20%).

The greater the slope (gradient), the greater the potential for erosion due to the increased surface water velocity (thus erosive power), increased water runoff compared to infiltration and the increased gravitational force on the soil particles. Steeper slopes mean access is more difficult and cumbersome, especially where heavy machinery is required or heavy loads are being transported. Site preparation for construction work is more difficult, requiring greater cut and fill operations.

Slope data for use in the tables is acquired through the use of digital elevation models, contour separation on topographic maps, aerial photos using stereo dip comparators or from field measurement with a clinometer.

5.1.2 Water erosion hazard

Water erosion, which is of concern to most land uses, results in the removal of soil and its deposition elsewhere by the action of water. Water erosion may take the form of sheet, rill or gully erosion.

The impacts of water erosion occur at the site of erosion, in transporting water or at the site of deposition. Impacts at the site of erosion include loss of valuable soil needed for plant growth and damage to roads, access tracks and building foundations. Impacts in transporting water include a reduction in water quality arising from high turbidity, high nutrient levels or other contaminants, leading to degradation of aquatic ecosystems, blue-green algae outbreaks, contamination of human water supplies and loss of aesthetic and recreational value. Build-up of sediment at sites of deposition result in a loss of flow capacity in river and stream channels, thus increasing the risk of flooding, and decreasing depth of water bodies with associated loss of dam storage capacity, navigability and recreational amenity.

The magnitude of water erosion is dependent on a number of factors:

- soil erodibility – the inherent susceptibility of the soil to erosion, dependant on factors such as soil texture, structure, dispersible character, permeability, organic content and stone content
- slope factors – slope gradient and slope length
- rainfall erosivity – the intensity and duration of rainfall events
- ground cover – the degree of protection provided by vegetation, mulch, stones or other surface cover
- land management practices, such as presence of erosion and sediment controls, contour ploughing.

Table 6: Constraints relevant to key land uses

Attribute/Constraint	Development				Agriculture		Wastewater Disposal		
	Standard Res.	Medium Density	High Density	Rural Res.	Cropping	Grazing	Surface Irrigat'n	Trench Absorp'n	Pump-out
Landscape Constraints									
Steep slopes	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water erosion hazard	✓	✓	✓	✓	✓	✓			
Flood hazard	✓	✓	✓	✓	✓	✓	✓	✓	✓
Acid sulfate soils	✓	✓	✓	✓	✓				
Mass movement	✓	✓	✓	✓			✓	✓	✓
Wave attack	✓	✓	✓	✓					
Poor site drainage/ waterlogging	✓	✓	✓	✓	✓	✓	✓	✓	✓
General foundation hazard	✓	✓	✓	✓					
Shallow soils					✓	✓	✓	✓	✓
Rock outcrop	✓	✓	✓	✓	✓	✓			
Soil Physical Constraints									
Shrink-swell potential	✓	✓		✓			✓	✓	✓
Low soil strength	✓			✓					
Low or high permeability							✓	✓	✓
Plant available water holding capacity					✓	✓			
Stoniness					✓	✓	✓	✓	✓
Soil Chemical Constraints									
Salinity	✓	✓		✓	✓	✓	✓	✓	✓
Acid and alkaline soils	✓	✓		✓	✓	✓	✓	✓	✓
Sodicity					✓	✓	✓	✓	✓
Low fertility/nutrient availability					✓	✓			
Low phosphorus sorption							✓	✓	✓

DECCW uses a newly developed erosion hazard modelling system that combines the above factors to provide estimates of potential soil loss in different locations (Yang et al. 2006). It is based on the revised universal soil loss equation (RUSLE) (Rosewell 1993).

5.1.3 Flood hazard

Flooding, a major constraint to many land uses, can damage or destroy buildings and their contents, infrastructure, crops and other assets. It can also be a threat to human life. Even a low probability of flooding at a site will restrict or prevent the establishment of most forms of development. It may take the form of:

- flash floods – the rapid build up of water flow in narrow and confined valleys, typically in hilly or mountainous areas (Cluny 1991)
- riverine floods – the more extensive inundation of floodplains adjacent to rivers following heavy rains in the catchment (NSW Government 2001)
- coastal floods – the inundation of low lying coastal lands by ocean or estuarine waters, resulting from severe storm events and/or unusually high tides (NSW Government 1990).

In the constraint tables, the potential for flooding may be indicated by one of three different data sources:

1. percentage probability per year is the most reliable data and should be used wherever available; it can be acquired from flood maps or other data records available from local councils or the NSW natural resources agency
2. general occurrence is the susceptibility of an area to flooding and is recorded in landscape limitation data from the soil landscape mapping program as not observed, localised or widespread
3. terrain unit is by definition inherently more flood-prone than other areas. River channel and floodplains are high risk areas, while side slopes and crests are generally immune from risk. Terrain information is readily available from DECCW in the form of land-resource, soil-landscape or topographic maps, or aerial photos. This data is used where neither of the above sources is available.

5.1.4 Acid sulfate soils

ASSs are highly hazardous soils which are usually associated with estuarine margins. They are a potential constraint to all land uses involving excavation or the disturbance of soils, such as most forms of development and intensive cropping (cultivation).

Potential ASSs contain pyrite (FeS_2) which reacts with atmospheric oxygen to form sulfuric acid (H_2SO_4) on exposure to air through drainage, excavation or dredging. Consequently very highly acidic solutions, with pH values as low as 2, may find their way into waterways. These acidic conditions cause the release of other toxic materials such as concentrated aluminium and heavy metals. The soils are often also highly saline.

The disturbance of these soils has the potential to cause severe problems, both on and off site, including:

- degradation of aquatic ecosystems
- corrosion of iron, steel, other metal alloys and concrete leading to extensive damage to foundations and underground services
- inhibition or prevention of plant growth, thus threatening native vegetation, agricultural lands and revegetation programs during site rehabilitation/landscaping
- increased soil erosion.

For further information on ASSs refer to Stone et al. (1998) and DECCW's website.[3] The primary source of information for the constraint tables is the ASS risk maps referred to in section 4.2. Ratings are based on the probability of occurrence of ASSs at different elevations in the landscape (<1 m, 1–2 m, 2–4 m, >4 m AHD).

5.1.5 Mass movement

Mass movement includes landslides, earth slumps and rock falls and is a serious threat to many land uses. It may involve the collapse of a slope at one point and the accumulation of the failed material further downslope. The most serious consequences are damage or destruction of buildings and other infrastructure and injury or loss of life.

Mass movement occurs when the weight of slope material exceeds the materials restraining capacity. It frequently occurs during periods of rainfall when the weight of the ground material has increased and the internal friction has been reduced. Construction, particularly cuttings into slope bases, may exacerbate this hazard (Rosewell et al. 2007; DLWC 2000).

Data in the constraint tables is derived from the soil landscape limitation tables (indicating not observed, localised or widespread) in combination with slope values (<15% or >15%) derived from DEM or soil landscape descriptions.

5.1.6 Wave erosion

Beaches and foredunes are subject to wave attack, particularly during large storms, where the sand may be reworked or entirely removed. Areas subject to this hazard are highly unstable and thus have extreme constraints for most land uses, particularly those involving buildings or other infrastructure.

The constraint assessment tables use data on the extent of wave erosion hazard (not observed, localised or widespread) from landscape limitation data.

5.1.7 Poor site drainage or waterlogging

Poor site drainage associated with extended periods of saturated ground conditions pose a threat to foundations. Corrosion, accelerated weathering and general weakening of buried structures may be promoted, particularly if other undesirable conditions are present, such as highly acid or saline conditions. The soil mass will have reduced strength and load supporting capacity. Most crop and pasture species suffer under waterlogged conditions; exceptions include rice and sugar cane. Wastewater disposal is severely impeded under these conditions. There may be groundwater contamination in areas with high water tables.

Five related attributes are considered in the constraint tables.

1 Seasonal waterlogging refers to extended periods of waterlogging; derived from data on the extent of this limitation (not observed, localised or widespread) from landscape limitation tables
2 High watertables are sites where the watertable is permanently within 2 m of the surface, and data is derived from the extent of this limitation over the landscape unit
3 Poor drainage is on sites which are susceptible to extended periods of saturation; derived from data on the extent of this limitation over the landscape unit
4 Groundwater pollution hazard is normally associated with areas with high water tables, high permeability and low nutrient retention ability; derived from data on the extent of this limitation over the landscape unit

[3] www.environment.nsw.gov.au/acidsulfatesoil/index.htm

5 Profile drainage considers the drainage of the soil and site in terms of six drainage classes, very poorly drained to rapidly drained (from McDonald et al. 1990) as recorded in soil type profile data. It should only be applied where one is confident of the representativeness of the type soil profile.

5.1.8 General foundation hazard

The stability of foundations is important for all land uses involving construction works, including buildings, roads and other infrastructure (above and below ground). Ground instability, soil weakness, potential chemical attack or other limitations of the foundation material may lead to partial or complete failure of a structure or facility.

General foundation hazard as applied in the constraint assessment tables represents a broad assessment by a soil surveyor of the degree of foundation hazards affecting an area, considering all potential soil and landscape constraints. It is provided in the landscape limitation tables. Note that in the constraint assessment process this limitation attracts a lower score than other constraints and is not applied at all where soil material data is available. This is to avoid an effective duplication with other related constraints and consequent over-rating.

5.1.9 Shallow soils

Shallow soils have firm weathered bedrock or a hard pan near the surface, being material effectively restricting crop root penetration. They pose a constraint to several land uses, particularly agricultural uses and waste water disposal. Plant growth is restricted by the limit to root depth and the lower volume of soil available to supply nutrients and moisture. Wastewater treatment is hindered by the low soil volume available for the uptake of nutrients and water in the waste supply. There may be insufficient depth to allow emplacement of trenches in the trench absorption systems. Shallow soils can also hinder excavation and the installation of underground services, but they are not directly considered in the current constraint assessment tables for development uses.

The attributes considered in the assessment tables include:

- shallow soils which are less than 0.5 m deep; derived from data on the extent of this limitation over the landscape unit
- depth to hard layer are soil depth derived from soil type profile data; only when one is confident of the representativeness of the results.

5.1.10 Rock outcrop

Rock outcrop is a significant impediment to workability. It impedes excavation associated with developments, road building and extraction operations and the cultivation of land for cropping and plantation forestry. Minor unsealed roads and access tracks may need to be re-routed to avoid outcrops. It may be a restriction for some recreational uses, particularly sporting fields. Rock outcrop takes the place of soil material on a site, thus there is less potential for plant growth per unit area. There will be less yield of crop or pasture per hectare of land. It often becomes a significant limitation where it covers over 20% of the land surface.

The constraint tables use data on the extent of rock outcrop limitation (not observed, localised or widespread) as provided in landscape limitation tables.

5.2 Soil physical constraints

5.2.1 Shrink-swell potential

This attribute relates to the soil's potential to change in volume as moisture content changes. Volume changes may exceed 40% in the most expansive soils. It is primarily dependent on the content of certain clays that are subject to swelling behaviour, most notably the smectite (montmorillonite) group of clays. The repeated expansion and contraction of these soils can lead to serious damage to building foundations, roads, underground infrastructure, dams and other structures. Appropriate design and mitigating measures must be implemented to avoid problems.

Data used in the constraint tables is derived from the soil material limitation tables. Laboratory data relating to volume expansion may also be applied where there is confidence of its representation over the whole unit. Volume expansion levels over 30% are considered detrimental to most building and underground infrastructure operations.

5.2.2 Low soil strength

This attribute provides an indication of the ability of the soil to support loads. Low strength soils represent a constraint to many building foundations, roads and other infrastructure. The rating applied is taken as the most limiting (worst) of the following four attributes:

- plasticity describes highly plastic soils which are unsuitable for foundations and road materials. They are typically clay rich and easily deformed under stress in wet conditions, meaning that they have low wet-bearing strength and do not support high loads. They can be sticky and have poor trafficability. The constraint tables use the extent of 'high plasticity' limitation from soil material limitation data.
- low wet bearing strength describes soils which have a low ability to support loads when wet. They may be highly plastic clay-rich soils, but also poorly graded sands and silts (that is, limited range of particle sizes), such as 'quicksand'. Data on the extent of this constraint is derived from soil material limitation data.
- organic soils are soils with large amounts of organic carbon (generally >12%) such as peats or peaty soils. They have low wet-bearing strength and may be subject to contraction and other changes as the organic material decays. Soil material limitation data is again the main source of data.
- the Unified Soil Classification System (USCS), which is a widely used, relatively simple classification of soil materials for low level engineering purposes. It takes into account the engineering properties of the soil, including permeability, shear strength and compaction characteristics. It is based on the amounts of different particle sizes and the characteristics of the very fine particles. Although it cannot substitute for specific engineering tests, it can be a useful guide to soil behaviour in various engineering applications such as building and road foundations and small dam construction.

  The 15 classes in the USCS are:

  GW well graded gravels, gravel-sand mixtures, little or no fines
  GP poorly graded gravels, gravel-sand mixtures, little or no fines
  GM silty gravels, poorly graded gravels-sand-silt mixtures
  GC clayey gravels, poorly graded gravels-sand-clay mixtures
  SW well graded sands, gravelly sands, little or no fines
  SP poorly graded sands, gravelly sands, little or no fines
  SM silty sands, poorly graded sand-silt mixtures
  SC clayey sands, poorly graded sand-clay mixtures

ML inorganic silts and very fine sands, silty or clayey fine sands with slight plasticity
CL inorganic clays of low to medium plasticity
OL organic silts and organic silt-clays of low plasticity
MH inorganic silts, elastic silts
CH inorganic clays of high plasticity, fat clays
OH organic clays of medium to high plasticity
Pt peat and other highly organic soils.

Hicks (2007) gives an overview of USCS. Soil materials with USCS classes Pt, OH, CH, MH, OL, ML and possibly CL may present limitations for stable building foundations (Finlayson 1982). USCS ratings are provided in the laboratory results for most soil materials in the soil landscape reports and may be applied for where one is confident of the representativeness of the type soil profile.

5.2.3 Low or high permeability

Permeability provides a measure of the soil's potential to transmit water and is determined by soil attributes such as structure, texture, porosity and shrink-swell behaviour. It is independent of topographic and climate controls. Low permeability is an important factor contributing to poor drainage and waterlogging. Excessively high or low permeability can hinder most forms of agriculture and wastewater disposal.

Two attributes are considered in the constraint tables:

1. permeability ranking, which is derived from soil material data; a five class ranking from very low to very high is applied, which extends the four class system of very low to very high of McDonald et al. (1990)
2. saturated hydraulic conductivity (Ksat) estimates are derived from laboratory data associated with type profiles, and are only applied in wastewater disposal tables, when there is confidence of the representativeness of the results.

5.2.4 Low plant available water-holding capacity

Plant available waterholding capacity (PAWC) is an important attribute for agriculture. It is a measure of the amount of water that can be stored by soil that is available to plants between rainfall or irrigation episodes. It represents the difference in water content between the soil when it stops draining (field capacity) to when the soil becomes too dry to support plant growth (the permanent wilting point). It influences the length of time a plant will survive without rewatering and varies between different plants.

Soil texture and structure both influence PAWC but the relationships are not straightforward, as revealed in Geeves et al. (2007) and Hazelton and Murphy (2007). While fine textured soils such as clays have higher water storing potential (field capacity) due to their greater surface area and absorptive capacity, it is more difficult for plants to extract this water, and as a consequence they have higher wilting points. Loams and clay loams generally have the highest PAWC while sands and medium–heavy clays (non-self mulching) tend to have lower values. Values under 10% are considered low while values over 20% are considered high.

The attributes considered in the constraint tables are:

- PAWC rating, which is derived from soil material data and comprises a five-class rating from very low to very high
- laboratory PAWC (in mm/m) derived from data associated with type profiles and only used where there is confidence of the representativeness of the results.

5.2.5 Stoniness

This limitation refers to high proportions of rock fragments such as gravel, stone and cobbles. These materials occupy soil volume but do not provide or retain nutrients and moisture. They thus detract from a soils agricultural productivity and effectiveness for wastewater treatment. They can also reduce the workability of a soil, hindering cultivation.

Data on stoniness used in the constraint tables includes:

- stoniness limitation which considers the extent (not observed, localised or widespread) in soil materials from the soil material limitation data
- coarse fragment percentage, which is a volumetric proportion, derived from type profile data, only used where there is confidence inthe representativeness of the results.

5.3 Soil chemical constraints

5.3.1 Salinity

Saline soils constrain many land uses. Salt, which has an adverse effect on plant growth, increases the:

- osmotic pressure of the soil solution, which increases the difficulty with which plants can extract water from the soil
- soil content of specific ions, particularly sodium, chloride and bicarbonate ions, that can be toxic to crops at high concentrations
- quantity of sodium in the soil's exchange complex, leading to a breakdown in soil structure, reduced permeability and associated problems.

Plants have differing tolerances to saline conditions, but levels above 8 dS/m restrict all but salt tolerant plants and above 16 dS/m even salt tolerant plants suffer (Charman and Wooldridge 2007).

Salt is a corrosive agent that is of serious concern to many engineering applications. It can attack metals, concrete and other building materials, causing damage or ultimate failure of building foundations, underground infrastructure or other assets. The level of salinity that may impact on underground assets will vary according to site conditions, such as salt type, seasonal moisture and groundwater level fluctuations, so conservative ranking levels are applied in the constraint tables. A series of 10 booklets on urban salinity produced under the local government salinity initiative provide comprehensive information on this issue (DIPNR 2003a).

The constraint tables apply the most limiting of the following three attributes:

- landscape salinity hazard – considers the extent (not observed, localised or widespread) from landscape limitation data
- saline soil material – considers the extent in soil materials from soil material limitation data
- ECe (effective electrical conductivity) – derived from the laboratory results of type soil profiles; only used where one is confident of the representativeness of the results.

5.3.2 Acid and alkaline soils

Acidity and alkalinity are indicated by pH, which is a measure of the effective concentration of the hydrogen ion. pH greatly influences soil chemical conditions, including the availability of most plant macro- and micronutrients, presence of toxic elements and soil microbe populations. For example, in highly acidic soil with pH

(CaCl) below 4.5, aluminium and many heavy metals will be released into solution and nitrogen, phosphorus, potassium and other nutrients will become virtually unavailable. Different plants have different tolerances to acidity and alkalinity, but most plants thrive at pH (CaCl) levels between 6.0 and 7.5. Levels below 4.5 or above 8.5 present significant limitations for most plant growth (Fenton and Helyar 2007; Hazelton and Murphy 2007).

Highly acidic or alkaline soils are thus detrimental to agriculture. They are also detrimental to wastewater management by impeding plant growth in irrigation methods and by interfering with necessary microbial activity. Very acidic soils, such as those associated with ASSs (section 5.1.4), can lead to corrosion of untreated underground infrastructure, such as metal pipes and concrete foundations.

The constraint tables consider the following attributes, in addition to the ASS attribute:

- acidity limitation – uses the extent of this limitation over component soil materials from the soil material data
- alkalinity limitation – as above
- aluminium toxicity limitation – as above
- pH – uses laboratory derived measurements from the type soil profile data; only used where one is confident of the representativeness of the results.

5.3.3 Sodicity

Sodic soils are a significant constraint for agriculture and wastewater disposal. They are associated with poor soil structure, may be hard-setting when dry and often form surface crusts. They thus restrict water and air infiltration and plant growth. Sodic soils are also highly dispersible, meaning that they are prone to erosion and may have low wet bearing strengths, thus contributing to other constraints referred to in Table 6.

The constraint tables apply data from the:

- sodicity limitation which considers the extent of this limitation over the component soil materials from the soil material data
- exchangeable sodium percentage which derives from laboratory data for type profiles and is only used where one is confident of the representativeness of the results.

5.3.4 Low fertility and nutrient availability

Soils with low chemical fertility are a constraint to agricultural land uses. These soils have low levels of nutrients required for plant growth, such as P, N, K, Ca, Mg and a range of trace elements. Organic matter is typically low. These soils are usually characterised by a low ability to retain nutrients, as indicated by a low cation exchange capacity (CEC).

The agriculture constraint tables use the following data:

- fertility ranking – uses the fertility rankings (very low to very high) from soil material data
- nutrient availability – applies laboratory data from type profiles on P (Bray, mg/kg), organic matter (%) and CEC (me/100g); only used where one is confident of the representativeness of the results.

5.3.5 Low phosphorus sorption

This attribute refers to the capacity of the soil to adsorb phosphorus. It generally depends on the extent of phosphate fixing to iron, aluminium or calcium compounds as well as certain organic clay complexes. It often gives an indication of a soil's anion exchange capacity, which is its ability to adsorb a range of negatively charged ions. Phosphate sorption by the soil normally occurs only up to half of the theoretical phosphate sorption capacity. Beyond this, leaching of the phosphate will occur if it is not taken up by plant growth (as in irrigation treatment methods) (DLG et al. 1998). Phosphate sorption is normally considered very low at levels less than 125 mg/kg and very high at levels greater than 600 mg/kg (Morand 2001). It is usually low in light coloured sandy soils and high in dark clay soils.

The attribute is considered in the wastewater treatment tables. It is derived from laboratory analysis for type soil profiles (only used where one is confident of the representativeness of the results).

6 Discussion

The maps and supporting information prepared through the soil and land constraint assessment process present a clear indication of the nature and degree of soil and land constraints affecting various land uses at different locations over a subject coastal area. They provide an indication of the consequences and approximate economic costs of proceeding with different land-use scenarios. The presentation of constraints in terms of estimated monetary costs, such as proportions of initial development costs, facilitates interpretation by land-use planners and land managers. They will also be meaningful to development proponents and the wider community.

6.1 Uses of constraint maps

Constraint maps can be used for:

1. planning by state and local government planners to:
   - assist urban and regional planning processes including the preparation of planning instruments such as LEPs and REPs
   - inform decisions relating to granting of consent to development applications and applying accompanying conditions.
2. land management by government natural resource management agencies, local government bodies, catchment management authorities, farmers and other land holders to:
   - identify appropriate specific uses and intensity of land use, such as the intensity and type of cropping
   - identify the constraints that need to be overcome for sustainable land management
   - identify areas to be excluded from particular land uses or land management
   - identify areas requiring careful monitoring and maintenance, such as for potential failure of wastewater disposal systems.
3. project development by development proponents and consultants to:
   - determine project feasibility, appropriate design and likely environmental impact control measures at a particular site
   - help to place developments where they are most environmentally sustainable.

Constraint assessment maps have been prepared over an extensive area of NSW with high land-use pressure. They cover most NSW coastal local government areas, with the exception of the Greater Sydney – Newcastle – Wollongong metropolitan areas, and were carried out under the NSW Comprehensive Coastal Assessment program (DoP 2007). The entire Hawkesbury–Nepean catchment area has been assessed. It is envisaged that other parts of the state will be covered as resources and new regional soil-landscape datasets become available.

Specific land uses include:

- development – standard residential, medium density, high density and rural residential
- agriculture – cropping and grazing
- wastewater disposal – surface irrigation, trench absorption and pump-out methods.

The program could be expanded to include other land uses or land-use functions, for example specific types of cropping or unsealed road construction.

It is not intended that the process will supersede the Land and Soil Capability scheme for the assessment of agricultural land in NSW, particularly for property vegetation planning requirements under the *Native Vegetation Act 2003* (DNR 2006) or NSW Monitoring and Evaluation requirements (Murphy et al. 2006). Rather, it will provide a supporting and complementary assessment process to the LSC scheme.

The quantitative nature of the constraint assessment outputs allows the combination of the soil-landscape constraint information with other natural resource and socioeconomic assessment data in planning and land-management processes. The outputs are suitable for advanced GIS applications, as they can be readily integrated with other data layers. They may be easily added into multi-criteria analysis techniques such as those described in BRS (2007) or James (2001), which was used in the NSW Comprehensive Coastal Assessment process.

The NSW natural resource and planning agencies are collaborating with local government to facilitate the use of the constraint assessment products. From a physical capability viewpoint, the constraint maps and associated data could be used for 20 of the 34 standard land-use zonings as listed in Standard Instrument (Local Environmental Plans) Order 2006.[4] Table 7 shows how the constraint maps, or combinations of them, could be applied for this purpose. The products may therefore directly assist in the preparation of LEPs.

6.2 Interpretation

The modelled constraint assessment outputs are suitable only for broadscale planning and land-management purposes. They cannot be relied upon with certainty for land-use and management decisions at the local site level. This is because the information depends on the original soil-landscape data which is normally collected at a 1:100 000 scale in eastern NSW. Inevitably, many locations will vary from the standard conditions assessed for a particular soil-landscape unit; thus higher or lower constraints than those indicated by the output maps may be present.

With the application of facet-level information and topographic detail provided by digital elevation models the maps are generally considered reliable at a 1:25 000 scale. This suggests that when using the maps to identify constraint conditions it is necessary to consider the average conditions over the immediately surrounding area (with a radius generally of the order of 200 m). They can be used at finer scales where they are applied with specific local knowledge, for example knowledge of the presence or absence of waterlogging or a high rock outcrop. Where decisions are being made at a local site level, it will be necessary to undertake more specific site investigations.

Although the results are presented on a scale of 0 to 12 constraint points, for many purposes it may be more appropriate to group the scores into three broad classes:

1. 0–3: low constraint, high capability
2. 4–7: moderate constraint, moderate capability
3. 8–12: high constraint, low capability.

The results do not directly indicate areas to be excluded from particular land uses. A high constraint score does not automatically exclude a land use, but rather it indicates the large amount of resources that would have to be expended in order to make the land use viable. In practice, scores higher than 8, which represent 40% of the benchmark cost, will exclude a land use from further consideration. In some cases, however, it will be deemed desirable to allocate the necessary resources, such as in high value residences with scenic views in high constraint, steeply sloping urban

[4] www.planning.nsw.gov.au/planning_reforms/p/2006-155.pdf

Table 7: Standard land use zones for LEPs and equivalent physical constraint methods

Standard instrument (LEP) land uses	Matching physical constraint assessment products
Zone RU5 Village Zone R1 General Residential Zone R2 Low Density Residential	Standard residential development
Zone R3 Medium Density Residential Zone B1 Neighbourhood Centre Zone B2 Local Centre Zone IN2 Light Industrial Zone B4 Mixed Use Zone IN4 Working Waterfront Zone SP3 Tourist	Medium density residential development
Zone R4 High Density Residential	High density residential development
Zone B5 Business Development Zone B3 Commercial Core Zone B6 Enterprise Corridor Zone B7 Business Park Zone IN1 General Industrial Zone IN3 Heavy Industrial	High density development (revised version of high density residential product
Zone R5 Large Lot Residential Zone RU6 Transition	Rural residential
Zone RU1 Primary Production	Agriculture – cropping (cultivation)
Zone RU1 Primary Production	Agriculture – grazing
	Wastewater dIsposal
Zone RU4 Rural Small Holdings	Rural residential and wastewater disposal combined
Zone RU3 Forestry Zone SP2 Infrastructure	New tables required
Zone RU2 Rural Landscape Zone SP1 Special Activities Zone RE1 Public Recreation Zone RE2 Private Recreation Zone E1 National Parks and Nature Reserves Zone E2 Environmental Conservation Zone E3 Environmental Management Zone E4 Environmental Living Zone W1 Natural Waterways Zone W2 Recreational Waterways Zone W3 Working Waterways	No tables proposed, land constraint assessment does not apply

lands. Approval for any land use must always be on the basis that all site constraints are properly addressed.

It should be noted that constraint scores between different land uses are not directly comparable. It is apparent that some land uses have resulted in relatively lower (better) scores than other land uses; For example, scores for high density development are typically lower than for standard residential development. This is largely because constraint scores depend on the relative budget and economics of various land uses, with the costs of overcoming constraints being based on a percentage of initial development costs (or similar factor for non-development uses). For example, the costs of overcoming constraints such as erosion hazard are proportionally smaller for high density development than for standard residential development.

In some cases, the constraint score is averaged over a whole soil-landscape unit, rather than identifying differing levels of constraint in different components or facets. For example, if part of a soil-landscape unit is prone to flooding, with an associated extreme constraint level, but that facet could not be modelled, then the entire unit may be accorded a moderate constraint score. Thus, the non-flood prone areas of that unit will be accorded a slightly higher score than would be expected. This is an issue to be wary of in those units that could not be modelled, indicated by the letters CM (cannot be modelled) in the facet code and DF (dominant facet) in the constraint code.

6.3 Review and further development

A rigorous process of testing and review has been undertaken, including comparing results against existing capability ratings, review by soil surveyors familiar with different areas and by field checking. Field testing of 149 sites throughout the north coast region and Hawkesbury–Nepean catchment indicated that for standard residential development the predicted constraint score fell within 1 constraint point of the observed score in 75% of sample sites, and within 2 constraint points in 86% of sites. For cropping land use, 65% of predictions fell within 1 point and 76% fell within 2 points of observed scores. For wastewater disposal (irrigation method) 73% of predictions fell within 1 point and 82% within 2 points of observed scores.

The testing process indicated that the outputs have a moderately high degree of reliability, bearing in mind the scale of the data upon which they are based. The process tends to give a conservative assessment, with the modelling tool being designed to give a cautious treatment of the identified soil landscape constraints; thus, predicted constraint scores tend to be slightly higher than actual constraints. The testing led to the identification of errors and weaknesses in the process and allowed for its improvement. The process is still subject to ongoing development and a further increase in reliability of results is anticipated.

Further information is needed to improve the costing information included with the process. While some cost estimates for treatments are relatively easy to obtain (such as those that relate directly to commonly used foundation types), others are more problematic. This may be due to the large number of variables, wide range of treatment methods and uncertainty of treatment success, for example in the treatment of disturbed acid sulfate soils. Information concerning the degree of the cost of dealing with various landscape constraints, known as site costs in the construction industry, is difficult to obtain and requires further investigation. Where possible, assessments of cost have been made (Chapman et al. 2004). The value of each constraint score point being equal to 5% of a standard benchmark cost is broad and arbitrary but allows for convenient calculation and spread of cost increments over the five constraint classes. A higher or lower cost unit may be more appropriate and further research is needed to confirm these cost estimates.

In conclusion, the soil and land constraint assessment process is a new form of capability assessment that portrays soil and landscape constraints at high levels of resolution. Detailed constraint maps, with comprehensive supporting data for a wide range of land uses, can be readily viewed and interpreted by land-use planners and land managers. The products should assist in environmentally sustainable land-use planning and land-management decision making throughout much of NSW.

Appendix 1: Abbreviations used in constraint codes

Code	Description
ac	acid soil hazard
acc	access
al	alkaline soil
ass	acid sulfate soil (ASS)
at	potential aluminium toxicity
awf	available water-holding capacity (field)
de	depth to hard layer
dp	depth to hard layer
dr	profile drainage
dz	discharge
eh	erosion hazard
fe	fertility of soil materials
fel	fertility of landscape
fh	flood hazard
fou	foundation hazard (excluding mass movement and ASS)
gen	general foundation hazard from surveyor
gp	groundwater pollution hazard
gph	groundwater pollution hazard
hw	high watertable
mm	mass movement hazard
os	organic soils
pd	poor drainage hazard
pd	profile drainage (wastewater maps)
pdh	poor drainage hazard (wastewater maps)
pl	plasticity
pm	poor moisture availability
pp	permeability
prod	agricultural productivity
pwl	permanent waterlogging
ro	rock outcrop
rz	recharge
sa	salinity (soil layers)
sal	salinity (landscape facets)
sh	shallow soils
slo	slope
so	sodic soil
ss	shrink swell potential
st	stony
sw	seasonal waterlogging
wbs	wet bearing strength
we	wave erosion hazard
wl	seasonal waterlogging
work	agriculture workability
wt	high watertable

Appendix 2: Soil and land constraint assessment tables

Constraint tables for foundations (small and medium) as applied in the Coastal Comprehensive Assessment project are presented in DNR (2006).

1 Standard Residential Development Constraint Rating

Version 2.04.07

This use refers to standard suburban residential developments as might be established on new residential estates. Such residential areas would include:
- standard housing up to two storeys with either pier or concrete slab foundations and generally no basement
- sealed roads with kerb and gutters
- underground infrastructure including plumbing, stormwater, power and telecommunication services.

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data source	Theoretical correlation[1]	Correlation using data source[1]
Slope (%)	<4	4–8	8–15	15–35	>35	Increases complexity of construction and long-term access	DEM	Certain	Certain
Erosion hazard (tonnes/ha/year)	<3	3–8	8–40	40–135	>135	Loss of soil, degrades water quality, sedimentation of waterways	Soil erosion hazard map	Certain	Confident
Wave erosion hazard	Not recorded	–	–	Localised	Widespread	Unstable ground, damage by waves and water	Landscape limitations table	Confident	Confident
Flood hazard									
Probablity (%)	Nil	–	<1 events less frequent than 1 in 100 years	1–2 1 event in 50 to 100 years	>2 1 event in <50 years	Flooding poses a large potential threat to human life and built structures	From flood risk maps	Certain	Certain
General occurrence	Not observed	–	–	Localised	Widespread	As above	Landscape limitations table	Certain	Confident
Terrain unit	Hill slope units (excluding footslopes)	–	Low footslopes, plains (excluding floodplains)	High floodplains	Middle and lower floodplains, drainage depressions, stream channels	As above	Multi-attribute mapping, soil landscape descriptions, topographic maps	Certain	Confident
Mass movement hazard	Not observed	–	Localised & slope <15%	Widespread & slope <15% Localised & slope >15%	Widespread & slope >15%	Potential failure of ground and structures	Landscape limitations table and slope estimate	Certain	Confident
Acid sulfate soil risk	No occurrence	LP > 4 m	HP > 4m LP 2–4m	HP 2–4m LP <2m	HP <2m	Potential acid corrosion	ASS risk maps	Confident	Confident
Shrink-swell potential									
Shrink-swell limitation	Not recorded	–	Widespread over minority of materials	Widespread over majority of materials	–	Ground movement, potential cracking	Soil material limitations table	Certain	Confident
Volume expansion (%) *(worst soil material)*	<5	5–15	15–30	>30	–	As above	Type profile lab data		Confident
Soil strength									
Plasticity	Not recorded	Widespread over minority of materials	Widespread over majority of materials	–	–	Potential subsidence and cracking of structure	Soil material limitations table	Confident	Probable
Low wet bearing strength *(average of soil materials)*	Very high	High, mod	Low, very low	–	–	As above	Soil material data	Confident	Probable
Organic soils	Not recorded	Widespread over <70% of materials	Widespread over >70% of materials	–	–	As above	Soil material limitations table	Confident	Confident
Unified soil classification system *(worst soil material)*	All others	CL	ML, MH, CH, OL	OH	Pt	As above	Type profile lab data	Confident	Confident

Salinity									
Saline soil materials	Not recorded	Widespread over minority of materials	Widespread over majority of materials	–	–	Potential corrosion and salt attack	Soil material limitations table	Confident	Confident
Saline landscapes	Not recorded	Localised	Widespread	–	–	As above	Landscape limitations table		Confident
ECe (dS/m) *(worst soil material)*	<0.1	0.1–2.0	>2.0	–	–	As above	Type profile lab data	Confident	Confident
Waterlogging									
Seasonal waterlogging	Not recorded	–	Localised	Widespread	–	Water weakens foundations, promotes corrosion and rising damp	Landscape limitations table	Confident	Confident
Permanently high watertable	Not recorded	–	Localised	Widespread	–	As above	Landscape limitations table	Confident	Probable
General foundation hazard	Not recorded	–	Localised	Widespread	–	Overall hazard perceived	Landscape limitations table	Certain	Confident
Rock outcrop	Not recorded	Localised	Widespread	–	–	Impedes construction	Landscape limitations table	Confident	Confident
Constraint sub-scores[2]									
Total constraint score[3]									

[1] Certainty of correlation of attribute to ranking: The lowest ranking of certainty for any applicable limiting factor is applied to the entire table.

Certain	No doubt as to the relationship with hazard, very reliable data source
Confident	Confident relationship with hazard, sound observed and theoretical reasons to expect relationship, mostly reliable data
Probable	Relationship with hazard is based on findings from other aspects of soil science, data is of moderate reliability, may be moderate variability within the soil-landscape or facet
Uncertain	Relationship with hazard is theoretical, data is of questionable reliability may be significant variability within the soil-landscape or facet .

[2] Constraint sub-score: Score 1 point for each attribute group that falls in Moderate column, 3 points for each attribute group that falls in High column, and 6 points for each attribute group that falls in the Very high column. Exceptions are for erosion hazard which attract lower scores of 1, 2 and 3 points respectively, to avoid duplication with slope constraint, and flood hazard (Very high) attracts 9 points.

[3] Total constraint score: Add sub-scores from Moderate, High and Very high columns.

2 Medium Density Residential Development Constraint Rating

Version 2.04.07

This use refers to medium density residential as might be established as part expanding metrolpolitan areas. Such developments would include:

- buildings such as villa complexes and small sized residential apartment blocks. These are assumed to be 1–3 storeys with all types of foundations, involving excavations to several metres depth, typically into solid bedrock
- sealed roads with kerbs and gutters, sealed parking areas and paved footpaths
- extensive above and below ground infrastructure including plumbing, stormwater, power and telecommunication services.

Relative to residential development capability, there are two important considerations that need to be borne in mind. As medium density development is associated with a greater intensity of use and greater site disturbance, some limitations are potentially more serious, e.g. flooding, mass movement and disturbance of acid sulfate soils, thus requiring more favourable conditions than residential development. On the other hand, the greater economic value of the development means there is more funding to overcome adverse site conditions. Also, the construction typically extends down into solid bedrock meaning soil constraints are less important. Thus, some site and soil features can be be of less desirable character than for residential development, e.g. soil strength, shrink-swell character and erosion hazard.

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data source	Theoretical correlation[1]	Correlation using data source[1]
Slope (%)	<4	4–8	8–15	15–35	>35	Increases complexity of construction and long-term access	DEM	Certain	Certain
Erosion hazard (tonnes/ha/year)	<5	5–10	10–80	80–170	>170	Loss of soil, degrades water quality, sedimentation of waterways	Soil erosion hazard map	Certain	Confident
Wave erosion hazard	Not recorded	–	–	Localised	Widespread	Unstable ground, damage by waves and water	Landscape limitations table	Confident	Confident
Flood hazard									
Probablity (%)	nil	–	<1 events less frequent than 1 in 100 years	1–2 1 event in 50 to 100 years	>2 1 event in <50 years	Flooding poses a large potential threat to human life and built structures	From flood risk maps	Certain	Certain
General occurrence	Not observed	–	–	Localised	Widespread	As above	Landscape limitations table	Certain	Confident
Terrain unit	Hill slope units (excluding footslopes)	–	Low footslopes, plains (excluding floodplains)	High floodplains	Middle and lower floodplains, drainage depressions, stream channels	As above	Multi-attribute mapping, soil landscape descriptions, topographic maps	Certain	Confident
Mass movement hazard	Not observed	–	Localised & slope <15%	Widespread & slope <15% Localised & slope >15%	Widespread & slope >15%	Potential failure of ground and structures	Landscape limitations table and slope estimate	Certain	Confident
Acid sulfate soil risk	No occurrence	–	LP >4m	HP >4m LP <4m	HP <4m	Potential acid corrosion	ASS risk maps	Confident	Confident
Shrink-swell potential									
Shrink-swell limitation	Not recorded	Widespread over minority of materials	Widespread over majority of materials	–	–	Ground movement, potential cracking	Soil material limitations table	Certain	Confident
Volume expansion (%) *(worst soil material)*	<10	10–20	>20	–	–	As above	Type profile lab data		Confident

Salinity									
Saline soil materials	Not recorded	Widespread over minority of materials	Widespread over majority of materials	–	–	Potential corrosion and salt attack	Soil material limitations table	Confident	Confident
Saline landscapes	Not recorded	Localised	Widespread	–	–		Landscape limitations table		Confident
ECe (dS/m) *(worst soil material)*	<0.1	0.1–2.0	>2.0	–	–	As above	Type profile lab data	Confident	Confident
Waterlogging									
Seasonal waterlogging	Not recorded	Localised	Widespread	–	–	Water weakens foundations, promotes corrosion & rising damp	Landscape limitations table	Confident	Confident
Permanently high water table	Not recorded	Localised	Widespread	–		Water weakens foundations, promotes corrosion & rising damp	Landscape limitations table	Confident	Probable
General foundation hazard	Not recorded	–	Localised	Widespread	–	Overall hazard perceived	Landscape limitations table	Certain	Confident
Constraint sub-scores[2]									
Total constraint score[3]									

[1] Certainty of correlation of attribute to ranking: The lowest ranking of certainty for any applicable limiting factor is applied to the entire table.

Certain	No doubt as to the relationship with hazard, very reliable data source
Confident	Confident relationship with hazard, sound observed and theoretical reasons to expect relationship, mostly reliable data
Probable	Relationship with hazard is based on findings from other aspects of soil science, data is of moderate reliability, may be moderate variability within the soil-landscape or facet
Uncertain	Relationship with hazard is theoretical, data is of questionable reliability may be significant variability within the soil-landscape or facet .

[2] Constraint sub-score: Score 1 point for each attribute group that falls in Moderate column, 3 points for each attribute group that falls in the High column, and 6 points for each attribute group that falls in the Very high column. Exceptions are for erosion hazard which attract lower scores of 1, 2 and 3 points respectively, to avoid duplication with slope constraint, and flood hazard (Very high) attracts 9 points.

[3] Total constraint score: Add sub-scores from Moderate, High and Very high columns.

3 High Density Development Constraint Rating

Version 2.04.07

This use refers to high density commercial development as might be established in expanding CBDs of towns and cities. Such developments would include:
- large buildings for office, commercial and residential apartment; these are assumed to be greater than 3 storeys with foundations, with excavation deep into solid bedrock
- sealed roads with kerbs and gutters, sealed parking areas and paved footpaths, with little or no unsealed surfaces
- extensive above and below ground infrastructure including plumbing, stormwater, power and telecommunication services.

Because of the intense scale and large financial resources of these developments, many constraints are relatively easily overcome and are not significant.

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data source	Theoretical correlation[1]	Correlation using data source[1]
Slope (%)	<5	5–10	10–20	20–40	>40	Increases complexity of construction and long-term access	DEM	Certain	Certain
Erosion hazard (tonnes/ha/year)	<6	6–15	15–110	>110	–	Loss of soil, degrades water quality, sedimentation of waterways	Soil erosion hazard map	Certain	Confident
Wave erosion hazard	Not recorded	–	–	Localised	Widespread	Unstable ground, damage by waves and water	Landscape limitations table	Confident	Confident
Flood hazard									
Probablity (%)	Nil	–	<1 events less frequent than 1 in 100 years	1–2 1 event in 50 to 100 years	>2 1 event in <50 years	Flooding poses a large potential threat to human life and built structures	From flood risk maps	Certain	Certain
General occurrence	Not observed	–	–	Localised	Widespread	As above	Landscape limitations table	Certain	Confident
Terrain unit	Hill slope units (excluding footslopes)	–	Low footslopes, plains (excluding floodplains)	High floodplains	Middle and lower floodplains, drainage depressions, stream channels	As above	Multi-attribute mapping, soil landscape descriptions, topographic maps	Certain	Confident
Acid sulfate soil risk	No occurrence	–	LP >4m	LP <4m	HP all	Threat to aquatic ecosystems, corrosion of structures	ASS risk maps	Confident	Confident
Mass movement	Not observed	Localised & slope <15%	Widespread & slope <15% Localised & slope >15%	Widespread & slope >15%	–	Potential failure of ground and structures	Landscape limitations table and slope estimate	Certain	
Shrink-swell potential									
Shrink-swell limitation	Not recorded	Widespread over any materials	–	–	–	Ground movement, potential cracking	Soil material limitations table	Certain	Confident
Volume expansion (%) *(worst soil material)*	<10	>10	–	–	–	As above	Type profile lab data		Confident

Salinity									
Saline soil materials	Not recorded	Widespread over any materials	–	–	–		Soil material limitations table	Confident	Confident
Saline landscapes	Not recorded	Widespread	–	–	–		Landscape limitations table		Confident
ECe (dS/m) *(worst soil material)*	<1	>1	–	–	–		Type profile lab data	Confident	Confident
General foundation hazard	Not recorded	Localised	Widespread	–	–	Overall hazard perceived	Landscape limitations table	Certain	Confident
Constraint sub-scores[2]									
Total constraint score[3]									

[1] Certainty of correlation of attribute to ranking: The lowest ranking of certainty for any applicable limiting factor is applied to the entire table.

Certain	No doubt as to the relationship with hazard, very reliable data source
Confident	Confident relationship with hazard, sound observed and theoretical reasons to expect relationship, mostly reliable data
Probable	Relationship with hazard is based on findings from other aspects of soil science, data is of moderate reliability, may be moderate variability within the soil-landscape or facet
Uncertain	Relationship with hazard is theoretical, data is of questionable reliability may be significant variability within the soil-landscape or facet .

[2] Constraint sub-score: Score 1 point for each attribute group that falls in the Moderate column, 3 points for each attribute group that falls in the High column, and 6 points for each attribute group that falls in the Very high column. Exception is for erosion hazard which attract lower scores of 1, 2 and 3 points respectively, to avoid duplication with slope constraint

[3] Total constraint score: Add sub-scores from Moderate, High and Very high columns.

4 Rural Residential Development Constraint Rating

Version 2.04.07

This use refers to low intensity residential development in rural settings, typically on the hinterland of urban centres. The rural residential blocks are generally at least 1 ha in size.

It is assumed that there is no reticulated sewerage system, thus domestic sewage treatment is carried out on site using septic tanks and wastewater disposal systems. Roads in these areas are generally unsealed.

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data source	Theoretical correlation[1]	Correlation using data source[1]
Slope (%)	<6	6–10	10–20	20–40	>40	Increases complexity of construction	DEM	Certain	Certain
Erosion hazard (tonnes/ha/year)	<3	3–10	10–40	40–135	>135	Loss of soil, degrades water quality, sedimentation of waterways	Soil erosion hazard map	Certain	Confident
Wave erosion hazard	Not recorded	–	–	Localised	Widespread	Unstable ground, damage by waves and water	Landscape limitations table	Confident	Confident
Flood hazard									
Probablity (%)	Nil	<1 events less frequent than 1 in 100 years	1–2 1 event in 50 to 100 years	2–10 1 event in 10 to 50 years	>10 events more frequent than 1 in 10 years	Flooding poses a large potential threat to human life and built structures	From flood risk maps	Certain	Certain
General occurrence	Not observed	–	Localised	–	Widespread	As above	Landscape limitations table	Certain	Confident
Terrain unit	Hill slope units (excluding footslopes)	Low footslopes, plains (excluding floodplains)	High floodplains	Middle floodplains	Lower floodplains, drainage depressions, stream channels	As above	Multi-attribute mapping, soil landscape descriptions, topographic maps	Certain	Confident
Mass movement hazard	Not observed	–	Localised & slope <15%	Widespread & slope <15% Localised & slope >15%	Widespread & slope >15%	Potential failure of ground and structures	Landscape limitations table and slope estimate	Certain	Confident
Acid sulfate soil risk	No occurrence	HP > 4m LP >4m	HP 2–4m LP 2–4m	LP <2m	HP <2m	Threat to aquatic ecosystems, corrosion of structures	ASS risk maps	Certain	Confident
Shrink-swell potential									
Shrink-swell limitation	Not recorded	–	Widespread over minority of materials	Widespread over majority of materials	–	Ground movement, potential cracking	Soil material limitations table	Certain	Confident
Volume expansion (%) *(worst soil material)*	<5	5–15	15–30	>30	–	As above	Type profile lab data		Confident

Soil strength									
Plasticity	Not recorded	Widespread over minority of materials	Widespread over majority of materials	–	–	Potential subsidence and cracking of structure	Soil material limitations table	Confident	Probable
Low wet bearing strength *(average of soil materials)*	Very high	High, mod	Low, very low	–	–	As above	Soil material limitations table	Confident	Probable
Organic soils	Not recorded	Widespread over <70% of materials	Widespread over >70% of materials	–	–	As above	Soil limitations table	Confident	Confident
Unified soil classification system *(worst soil material)*	All others	CL	ML, MH, CH, OL,	OH	Pt	As above	Type profile lab data	Confident	Confident
Salinity									
Saline soil materials	Not recorded	Widespread over minority of materials	Widespread over majority of materials	–	–	Potential corrosion and salt attack	Soil material limitations table	Confident	Confident
Saline landscapes	Not recorded	Localised	Widespread	–	–	As above	Landscape limitations table		Confident
ECe (dS/m) *(worst soil material)*	<0.1	0.1–2.0	>2.0	–	–	As above	Type profile lab data	Confident	Confident
Waterlogging					–				
Seasonal waterlogging	Not recorded	–	Localised	Widespread	–	Water weakens foundations, promotes corrosion & rising damp	Landscape limitations table	Confident	Confident
Permanently high watertable	Not recorded	–	Localised	Widespread	–	As above	Landscape limitations table	Confident	Confident
General foundation hazard	Not recorded	–	Localised	Widespread	–	Overall hazard perceived	Landscape limitations table	Certain	Confident
Rock outcrop	Not recorded	Localised	Widespread	–	–	Impedes construction	Landscape limitations table	Confident	Confident
Wastewater disposal *(dependent on method)*	Very low limitations	Low limitations	Moderate limitations	High limitations	Very high limitations	Pollution of waterways, health hazard	Wastewater disposal tables	Confident	
Constraint sub-scores[2]									
Total constraint score[3]									

[1] Certainty of correlation of attribute to ranking: The lowest ranking of certainty for any applicable limiting factor is applied to the entire table.

Certain	No doubt as to the relationship with hazard, very reliable data source.
Confident	Confident relationship with hazard, sound observed and theoretical reasons to expect relationship, mostly reliable data.
Probable	Relationship with hazard is based on findings from other aspects of soil science, data is of moderate reliability, may be moderate variability within the soil-landscape or facet.
Uncertain	Relationship with hazard is theoretical, data is of questionable reliability may be significant variability within the soil-landscape or facet.

[2] Constraint sub-score: Score 1 point for each attribute group that falls in the Moderate column, 3 points for each attribute group that falls in the High column, and 6 points for each attribute group that falls in the Very high column. Exception is for erosion hazard which attract lower scores of 1, 2 and 3 points respectively, to avoid duplication with slope constraint.

[3] Total constraint score: Add sub-scores from Moderate, High and Very high columns.

5 Agriculture – Cropping

Version: 2.04.07

This table deals with broad acre cropping use, under non-irrigated conditions. It considers crops such as cereals (e.g. wheat, corn and oats) and oils (e.g. canola and sunflower). It is assumed the area has already been cleared. Climatic conditions are not considered.

Constraint points are allocated for each attribute grouping as follows: Moderate constraint – 1 point; High constraint – 3 points; Very High constraint – 6 points.

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data source	Theoretical correlation[1]	Correlation using data source[1]
	High agricultural value		Moderate–low ag. value		Low ag. value				
Physical attributes									
Slope (%)	<1	1–3	3–6	6–15	>15	Exacerbates erosion hazard and impedes workability	DEM	Certain	Certain
Erosion hazard (tonnes/ha/year)	<2	2–5	5–10	10–80	>80	Loss of soil, degrades water quality, sedimentation of waterways	Soil erosion hazard map	Certain	Confident
Acid sulfate soil risk	No occurrence	HP 2–4m LP 2–4m	LP 1–2m	HP 1–2m LP <1m	HP <1m	Release of acid waters through disturbance or drainage	ASS risk maps	Confident	Confident
Soil depth									
Shallow soils hazard (<50 cm)	Not recorded	–	Localised	Widespread	–	Limits available soil	Landscape limitations table	Confident	Confident
Depth of type profile (m)	>1.5	0.6–1.5	0.3–0.6	0.15–0.3	<0.15	As above	Type profile data		Probable
Drainage/waterlogging									
Seasonal waterlogging	Not recorded	–	Localised	Widespread	–	Saturated soil inhibits plant growth.	Landscape limitations table	Confident	Confident
Poor drainage hazard	Not recorded	–	Localised	Widespread	–		Landscape limitations table		
Profile drainage of type profile	Mod well	Well, imperfect	Poor	Rapid, very poor	–	Waterlogging, poor water retention	Type profile data	Certain	Confident
Moisture availability									
Available waterholding capacity field estimate (average of soil materials)	Very high	High, moderate	Low	Very low	–	Poor water retention	Soil material data	Certain	Confident
Available waterholding capacity (%)	>20	15–20	5–15	<5	–	As above	Type profile lab data	Certain	Confident
Rock outcrop	Not recorded	localised	–	Widespread	–	Impedes cultivation, reduces available crop area	Landscape limitations table	Confident	Probable
Stoniness	Not recorded	Widespread in minority of soil materials	Widespread in minority of soil materials	–	–	Limits available soil	Soil material limitations table	Confident	Probable

Chemical attributes									
Acidity/alkalinity									
Acidity	Not recorded	Widespread in minority of soil materials	Widespread in minority of soil materials	–	–	Acid conditions	Soil material limitations table	Confident	Confident
Alkalinity	Not recorded	Widespread in minority of soil materials	Widespread in minority of soil materials	–	–	Strongly alkaline conditions	Soil material limitations table	Confident	Confident
pH (1:5 water) (*worst top 300 mm*)	6.5–7.5	5.5–6.5, 7.5–8.0	4.5–5.5, 8.0–9.0	3.5–4.5, 9.0–10.0	<3.5, >10.0	Highly acid or alkaline	Type profile lab data	Confident	Confident
Aluminium toxicity potential	Not recorded	Widespread in minority of soil materials	Widespread in majority of soil materials	–	–	Toxic conditions	Soil material limitations table	Certain	Confident
Sodicity									
Soil material sodicity	Not recorded	Widespread in minority of soil materials	Widespread in majority of soil materials	–	–	Low water infiltration	Soil material limitations table	Certain	Confident
Exchangeable sodium (%) (*worst top 300 mm*)	<4	4–8	8–20	20–30	>30	Sodic soils inhibit plant growth.	Type profile lab data	Certain	Confident
Salinity									
Saline landscape	Not recorded	–	Localised	Widespread	–	As above	Landscape limitations table	Certain	Confident
Saline soil material	Not recorded	–	Widespread in minority of soil materials	Widespread in majority of soil materials	–	Salt toxicity	Soil material limitations table	Certain	Confident
ECe dS/m	<2	2–4	4–8	8–16	>16	As above	Type profile lab data		
Fertility									
Landscape fertility	Not recorded	–	Localised	Widespread					
Soil material fertility	Very high	High, moderate	Low	Very low	–	Low fertility	Soil material data	Confident	Confident
Nutrient availability (*average top 500 mm*)									
– P (Bray) (mg/kg)	>15	3–10	1–3	<1	–	Low fertility	Type profile lab data	Confident	Confident
– Organic matter (%)	>5	2.5–5.0	1.0–2.5	<1.0	–	Low fertility	Type profile lab data	Confident	Confident
– CEC (me/100 g)	>25	10–25	5–10	<5	–	Low nutrient retaining capacity	Type profile lab data	Confident	Confident
Constraint sub-scores[2]									
Total constraint score[3]									

[1] Certainty of correlation: The lowest ranking of certainty for any applicable limiting factor is applied to the entire table.

- Certain — No doubt as to the relationship with hazard, very reliable data source.
- Confident — Confident relationship with hazard, sound observed and theoretical reasons to expect relationship, mostly reliable data.
- Probable — Relationship with hazard is based on findings from other aspects of soil science, data is of moderate reliability, may be moderate variability within the soil-landscape or facet.
- Uncertain — Relationship with hazard is theoretical, data is of questionable reliability may be significant variability within the soil-landscape or facet .

[2] Constraint sub-score: Score 1 point for each attribute group that falls in Moderate column, 3 points for each attribute group that falls in High column, and 6 points for each attribute group that falls in the Very high column. Exception is for erosion hazard which attracts lower scores of 1, 2 and 3 points respectively, to avoid duplication with slope constraint.

[3] Total constraint score: Add sub-scores from Moderate, High and Very high columns.

6 Agriculture – Grazing

This table refers to capability for open range grazing by livestock such as sheep and cattle on native pasture. It is assumed the area has already been cleared.

Note that the allocation of constraint points in this scheme differs from other schemes – see notes at base of table.

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data Source	Theoretical correlation[1]	Correlation using data source[1]
	High agricultural value		Moderate–low ag. value		Low ag. value				
Physical properties									
Slope (%)	<5	5–10	10–20	20–35	>35	Exacerbates erosion hazard and impedes workability	DEM	Certain	Certain
Erosion hazard (tonnes/ha/year)	<3	3–8	8–60	60–150	>150	Loss of soil, degrades water quality, sedimentation of waterways	Soil erosion hazard map	Certain	Confident
Acid sulfate soil risk	No occurrence	HP 2–4m LP 1–4m	HP 0–2m LP 1–2m	–	–	Release of acid waters through disturbance or drainage	ASS risk maps	Confident	Confident
Soil depth									
Shallow soils hazard (<50 cm)	Not recorded	–	Localised	Widespread	–	Limits available soil	Landscape limitations table	Confident	Confident
Depth of type profile (m)	>1.5	0.6–1.5	0.3–0.6	0.15–0.3	<0.15	As above			
Drainage/waterlogging									
Seasonal waterlogging	Not recorded	–	Localised	Widespread	–	Saturated soil inhibits plant growth	Landscape limitations table	Confident	Confident
Poor drainage hazard	Not recorded	–	Localised	Widespread	–		Landscape limitations table		
Profile drainage of type profile	Mod well	Well, imperfect	Poor	Rapid, very poor	–	Waterlogging, poor water retention	Type profile data	Certain	Confident
Moisture availability									
Available waterholding capacity (average of soil materials)	Very high	High, moderate	Low	Very low	–		Soil material data	Certain	Confident
Available waterholding capacity (%)	>20	15–20	5–15	<5	–	Poor water retention	Type profile lab data	Certain	Confident
Rock outcrop	Not recorded	Localised	–	Widespread	–	Reduces available pasture	Landscape limitations table	Confident	Probable
Stoniness	Not recorded	Widespread in minority of soil materials	Widespread in majority of soil materials	–	–	Limits available soil	Soil material limitations table	Confident	Probable

Chemical properties									
Acidity/alkalinity									
Acidity	Not recorded	Widespread in minority of soil materials	Widespread in minority of soil materials	–	–	Acid conditions	Soil material limitations table	Confident	Confident
Alkalinity	Not recorded	Widespread in minority of soil materials	Widespread in minority of soil materials	–	–	Strongly alkaline conditions	Soil material limitations table	Confident	Confident
pH (1:5 water) (*worst top 300 mm)*	6.5–7.5	5.5–6.5, 7.5–8.0	4.5–5.5, 8.0–9.0	3.5–4.5, 9.0–10.0	<3.5, >10.0	Highly acid or alkaline	Type profile lab data	Confident	Confident
Aluminium toxicity potential	Not recorded	Widespread in minority of soil materials in top 500 mm	Widespread in majority of soil materials in top 500 mm	–	–	Toxic conditions	Soil material limitations table	Certain	Confident
Sodicity									
Soil material sodicity	Not recorded	Widespread in minority of soil materials	Widespread in majority of soil materials	–	–	Low water infiltration	Soil material limitations table	Certain	Confident
Exchangeable sodium (%) (*worst top 300 mm)*	<4	4–8	8–20	20–30	>30	Sodic soils inhibit plant growth.	Type profile lab data	Certain	Confident
Salinity									
Saline landscape	Not recorded	–	Localised	Widespread	–	Salt toxicity	Soil material limitations table	Certain	Confident
Saline soil material	Not recorded	–	Widespread in minority of soil materials	Widespread in majority of soil materials	–	As above	Landscape limitations table	Certain	Confident
ECe dS/m	<2	2–4	4–8	8–16	>16	As above	Type profile lab data		
Fertility									
Landscape fertility	Not recorded	–	Localised	Widespread					
Soil material fertility	Very high	High, moderate	Low	Very low	–	Low fertility	Soil material limitations table	Confident	Confident
Nutrient availability (*average top 500mm)*									
– P (Bray) (mg/kg)	>15	3–10	1–3	<1	–	Low fertility	Type profile lab data	Confident	Confident
– Organic matter (%)	>5	2.5–5.0	1.0–2.5	<1.0	–	Low fertility	Type profile lab data	Confident	Confident
– CEC (me/100 g)	>25	10–25	5–10	<5	–	Low nutrient retaining capacity	Type profile lab data	Confident	Confident
Constraint sub-scores[2]									
Total constraint score[3]									

[1] Certainty of correlation

The lowest ranking of certainty for any applicable limiting factor is applied to the entire table.

- Certain — No doubt as to the relationship with hazard, very reliable data source.
- Confident — Confident relationship with hazard, sound observed and theoretical reasons to expect relationship, mostly reliable data.
- Probable — Relationship with hazard is based on findings from other aspects of soil science, data is of moderate reliability, may be moderate variability within the soil-landscape or facet
- Uncertain — Relationship with hazard is theoretical, data is of questionable reliability, may be significant variability within the soil-landscape or facet .

[2] Constraint sub-score: Score 1 point for each attribute group that falls in the Moderate column, 2 points for each attribute group that falls in the High column, and 4 points for each attribute group that falls in the Very high column. Exception is for erosion hazard which attracts lower scores of 1, 2 and 3 points respectively, to avoid duplication with slope constraint.

[3] Total constraint score: Add sub-scores from the Moderate, High and Very high columns.

7 On-site Domestic Wastewater Disposal: Surface Irrigation Constraint Rating

This refers to the physical potential of a site to apply the surface irrigation method to the disposal of treated domestic wastewater. Such on–site systems are required where there is no formal reticulated sewerage system. The effluent has been secondary treated and chlorinated, being derived from aerated wastewater treatment systems (AWTS) or from biological treatment systems such as peat beds. The method involves irrigating (usually by drip methods) a vegetated area with the treated wastewater. The vegetation typically comprises grasses such as kikuyu, buffalo, rye grass or couch. The size of an irrigation area would generally be 500–1000 sq m for an average single household (with four people).

The nutrients and other contaminants are taken up by the processes of soil absorption (and adsorption), and by the actively growing vegetation (which is periodically cut and removed from the site). Soil microbes serve to convert contaminants to less harmful materials or to gas that may escape into the air. Much of the actual water is removed by evaporation and plant transpiration processes.

Because the wastewater is applied at or near the surface, it requires secondary treatment before its release. It generally requires the second most suitable conditions of the three disposal methods considered in this report.

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data source	Theoretical correlation[1]	Correlation using data source[1]
Slope (%)	<3	3–6	6–12	12–20	>20	High slope lateral seepage, erosion hazard	DEM	Certain	Confident
Flooding									
Probablity (%)	Nil	<1 events less frequent than 1 in 100 years	1–2 1 event in 50–100 years	2–5 1 event in 20–50 years	>5 More than 1 event in 20 years	Potential damage to facility and surface water contamination	From flood risk maps	Certain	Certain
General occurrence	Not recorded	–	Localised	Widespread	–	As above	Landscape limitation tables	Certain	Confident
Terrain unit	Hill slope units (excluding footslopes)	low footslopes, plains (excluding floodplains)	High floodplains	Middle floodplains	Lower floodplains, drainage depressions, stream channels	As above	Multi-attribute mapping, soil landscape descriptions, topographic maps	Certain	Confident
Mass movement	Not recorded	–	Localised	Widespread	–	Potential damage to facility and surface water contamination	Landscape limitations tables	Confident	Confident
Shrink-swell									
Shrink-swell limitation	Not recorded	Widespread over minority of materials	Widespread over majority of materials	–	–	Potential damage to pipes and tanks	Soil material limitations tables		Confident
Shrink-swell (VE%) (*worst layer to 1 m*)	<10	10–20	20–30	>30	–	As above	Type profile lab data	Confident	Confident
Drainage/ waterlogging									
Seasonal waterlogging	Not recorded	–	Localised	Widespread	–	Waterlogging or excessive drainage limits effective treatment, potential water contamination	Landscape limitation tables	Certain	Confident
Permanent waterlogging	Not recorded	–	Localised	–	Widespread	As above	As above	Certain	Confident
Poor drainage hazard	Not recorded		Localised	Widespread	–	As above	As above		
Profile drainage	Well	Mod well	Imperfect, rapid	Poor	Very poor	As above	Type profile data	Certain	Confident
Permeability ranking (*average of layers to 600 mm*)	Moderate	High	Low, very high	Very low	–	Too high or too low permeability, inhibiting effective wastewater treatment and plant growth	Soil layer data	Certain	Confident
Permeability (mm/day) (*worst layer to 600 mm*)	480–2000	2000–2880	60–480, >2880	12–60	<12	As above	Type profile lab data	Certain	Confident
Watertable									
High watertable (<2 m)	Not recorded	–	Localised	Widespread	–	Limits absorption, potential groundwater contamination	As above	Certain	Probable
Groundwater pollution hazard	Not recorded	–	Localised	Widespread	–	Groundwater contamination	As above	Certain	Confident
Depth									
Shallow soils (<50 cm)	Not recorded	–	Localised	Widespread	–		Landscape limitation tables	Certain	Confident
Depth to hard layer – from type profile	>1.2	1.0–1.2	0.5–1.0	0.3–0.5	<0.3	Limits available soil	Type profile data	Certain	Confident
Stoniness									
Stoniness	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	As above	Soil material limitations tables	Confident	Probable
Coarse fragments (>2 mm) (%) (*average 0–600 mm*)	<10	10–20	20–50	>50	–	Limits available soil	Type profile data	Certain	Probable
Phosphorus sorption (mg/kg) (*average to 600 mm*)	>400	150–400	<150	–	–	Low absorption of phosphorus	Type profile lab data	Certain	Confident

Salinity									
Saline landscape	Not recorded	–	Localised	Widespread	–	Inhibits adsorption, micro-oganisms and plant growth	Landscape limitation tables	Certain	Confident
Saline soil material	Not recorded	–	Widespread over minority of soil materials	Widespread over majority of soil materials	–	As above	Soil material limitations tables		Confident
Salinity ECe (dS/m) (*worst to 600 mm*)	<1	1–2	2–4	4–10	>10	As above	Type profile lab data	Certain	Confident
Acidity/alkalinity									
Acidity limitation	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	Too high or low pH inhibits micro-oganisms, plant growth and treatment processes	Soil material limitations tables	Certain	Probable
Alkalinity limitation	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	As above	Soil material limitations tables	Confident	Probable
pH (1:5 water) (*worst 0–600 mm*)	5.5–7.5	4.5–5.5, 7.5–8.5	3.5–4.5, 8.5–10.0	<3.5, >10.0	–	As above	Type profile lab data	Certain	Confident
Sodicity									
Sodic soil materials	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	Limits water infiltration and nutrient absorption	Soil material limitations tables	Certain	Confident
Sodicity (ESP %) (*worst 0–600 mm where CEC> 0 me/100 g*)	<3	3–8	8–20	>20	–	As above	Type profile lab data	Certain	Confident
Constraint sub-scores[2]									
Total constraint score[3]									

[1] Certainty of correlation of attribute to ranking: The lowest ranking of certainty for any applicable limiting factor is applied to the entire table.

Certain	No doubt as to the relationship with hazard, very reliable data source.
Confident	Confident relationship with hazard, sound observed and theoretical reasons to expect relationship, mostly reliable data.
Probable	Relationship with hazard is based on findings from other aspects of soil science, data is of moderate reliability, may be moderate variability within the soil-landscape or facet.
Uncertain	Relationship with hazard is theoretical, data is of questionable reliability may be significant variability within the soil-landscape or facet.

[2] Constraint sub-score: Score 1 point for each attribute group that falls in Moderate column, 3 points for each attribute group that falls in High column, and 6 points for each attribute group that falls in Very high column.

[3] Total constraint score: Add sub-scores from Moderate, High and Very high columns.

Interpretation of scores

0–3 points: Good – requires nil or minor site amelioration
4–7 points: Fair – requires moderate site amelioration
>8 points: Poor – not capable of, or requires significant, site amelioration.

Main actions and processes

- Installation of septic tank and aerated wastewater treatment system (AWTS) including initial excavation of pit and connection with wastewater outflow pipes.
- Installation of an irrigation system over the site, this being connected to the AWTS and septic tank (as per AS 1547).
- Establishment of appropriate vegetation over the site (may involve initial period of exposed ground) and periodic cutting and removal.
- Application of wastewater and associated contaminants over the site.

Potential environmental and other impacts

- Inadequate treatment of surface water and groundwater may result in contamination of these waters by pathogens (such as bacteria, viruses), high nutrient levels, chemical contaminants (such as organo-chlorines, heavy metals), salt, sodium, fats and other materials.
- Contamination of the site itself.
- Erosion and sediment transport may occur over the site during the establishment phase and over the longer term if surface revegetation is inadequate.
- Loss of public amenity due to unpleasant odours and increased insect numbers may occur.

8 On-site Domestic Wastewater Disposal: Trench Absorption-Transpiration System Constraint Rating

Refers to the physical potential of the site to apply the trench absorption method to disposal of domestic wastewater. The wastewater is the primary treated effluent derived from a septic tank. The liquid is passed through a network of shallow trenches (generally 45 to 60 cm deep) filled with coarse aggregate then a topsoil layer. It then seeps and/or is absorbed into the surrounding and underlying soil allowing treatment as for the irrigation method. A portion of the actual water is transpired into the atmosphere from grasses growing on the surface.

Because the wastewater is released below ground, secondary treatment is not required. It requires the most suitable conditions of the three disposal methods considered in this report.

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data source	Theoretical correlation [1]	Correlation using data
Slope (%)	<3	3–9	9–18	18–25	>25	High slope lateral seepage, erosion hazard	DEM	Certain	Confident
Flooding									
Probablity (%)	Nil	<1 events less frequent than 1 in 100 years	1–2 1 event in 50 to 100 years	2–5 1 event in 20–50 years	>5 more than 1 event in 20 years	Potential damage to facility and surface water contamination	From flood risk maps	Certain	Certain
General occurrence	Not recorded	–	Localised	Widespread	–	As above	Landscape limitation tables	Certain	Confident
Terrain unit	Hill slope units (excluding footslopes)	Low footslopes, plains (excluding floodplains)	High floodplains	Middle floodplains	Lower floodplains, drainage depressions, stream channels	As above	Multi-attribute mapping, soil landscape descriptions, topographic maps	Certain	Confident
Mass movement	Not recorded	–	Localised	Widespread	–	Potential damage to facility and surface water contamination	Landscape limitations tables	Confident	Confident
Shrink-swell									
Shrink-swell limitation	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	Potential damage to pipes and tanks	Soil material limitations tables		Confident
Shrink-swell (VE%) *worst layer to 1 m*	<10	10–20	20–30	>30	–	As above	Type profile lab data	Confident	Confident
Drainage/waterlogging									
Seasonal waterlogging	Not recorded	–	Localised	Widespread	–	Waterlogging or excessive drainage limits effective treatment, potential water contamination.	Landscape limitation tables	Certain	Confident
Permanent waterlogging	Not recorded	–	Localised	–	Widespread	As above	As above	Certain	Confident
Poor drainage hazard	Not recorded		Localised	Widespread	–	As above	As above		
Profile drainage	Well	Mod well	Imperfect, rapid	Poor	Very poor	As above	Type profile data	Certain	Confident
Permeability ranking (*average of layers to 1 m)*	Moderate	High	Low, very high	Very low	–	Too high or too low permeability, inhibiting effective wastewater treatment and plant growth	Soil layer data	Certain	Confident
Permeability (mm/day) (*worst layer to 1 m)*	480–1440	–	100–480, 1440–2880	24–100, >2880	<24	As above	Type profile lab data	Certain	Confident
Watertable									
High watertable (<2 m)	Not recorded	–	Localised	Widespread	–	Limits absorption, potential groundwater contamination	As above	Certain	Probable
Groundwater pollution hazard	Not recorded	–	Localised	Widespread	–	Groundwater contamination	As above	Certain	Confident
Depth									
Shallow soils (<50 cm)	Not recorded	–	Localised	Widespread	–		Landscape limitation tables	Certain	Confident
Depth to hard layer – from type profile	>1.5	1.2–1.5	0.9–1.2	0.6–0.9	<0.6	Limits available soil	Type profile data	Certain	Confident
Stoniness									
Stoniness	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	As above	Soil material limitations tables	Confident	Probable
Coarse fragments (>2 mm) (%) *average to 1 m*	<10	10–20	20–50	>50	–	Limits available soil	Type profile data	Certain	Probable
Phosphorus sorption (mg/kg) *average to 1 m*	>300	100–300	<100	–	–	Low absorption of phosphorus	Type profile lab data	Certain	Confident

Salinity									
Saline landscape	Not recorded	–	Localised	Widespread	–	Inhibits adsorption, micro-oganisms and plant growth	Landscape limitation tables	Certain	Confident
Saline soil material	Not recorded	–	Widespread over minority of soil materials	Widespread over majority of soil materials	–	As above	Soil material limitations tables		Confident
Salinity ECe (dS/m) *worst to 1 m*	<1	1–3	3–6	6–12	>12	As above	Type profile lab data	Certain	Confident
Acidity/alkalinity									
Acidity limitation	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	Too high or low pH inhibits micro-oganisms, plant growth and treatment processes	Soil material limitations tables	Certain	Probable
Alkalinity limitation	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	As above	Soil material limitations tables	Confident	Probable
pH (1:5 water) *worst 1 m*	5.5–7.5	4.5–5.5, 7.5–8.5	3.5–4.5, 8.5–10.0	<3.5, >10.0	–	As above	Type profile lab data	Certain	Confident
Sodicity									
Sodic soil materials	Not recorded	–	Widespread over minority of soil materials	Widespread over majority of soil materials	–	Limits water infiltration and nutrient absorption	Soil material limitations tables	Certain	Confident
Sodicity (ESP %) *worst to 1 m where CEC>0 me/100 g*	<3	3–8	6–15	>15	–	As above	Type profile lab data	Certain	Confident
Constraint sub-scores[2]									
Total constraint score[3]									

[1] Certainty of correlation of attribute to ranking: The lowest ranking of certainty for any applicable limiting factor is applied to the entire table.

Certain	No doubt as to the relationship with hazard, very reliable data source.
Confident	Confident relationship with hazard, sound observed and theoretical reasons to expect relationship, mostly reliable data.
Probable	Relationship with hazard is based on findings from other aspects of soil science, data is of moderate reliability, may be moderate variability within the soil-landscape or facet.
Uncertain	Relationship with hazard is theoretical, data is of questionable reliability may be significant variability within the soil-landscape or facet .

[2] Constraint sub-score: Score 1 point for each attribute group that falls in the Moderate column, 3 points for each attribute group that falls in the High column, and 6 points for each attribute group that falls in the Very high column.

[3] Total constraint score: Add sub-scores from the Moderate, High and Very high columns.

Interpretation of scores

0–3 points: Good – requires nil or minor site amelioration.
4–7 points: Fair – requires moderate site amelioration.
>8 points: Poor – not capable or requires significant site amelioration.

Main actions and processes

- Installation of septic tank including initial excavation of pit and connection with wastewater outflow pipes.
- Excavation of a network of trenches in the absorption field, generally 45–60 cm deep, 50 cm wide (as per AS 1547).
- Revegetation of absorption field following completion of trenches.
- Partially treated wastewater from the septic tank passing along the trenches and into the surrounding and underlying soil mass, with nutrients, faecal material and other contaminants being absorbed by

Potential environmental and other impacts

- Inadequate treatment may result in contamination of surface water and groundwater by various materials as described for the irrigation method. Although buried trenches reduce the potential for contamination of surface water, contamination remains a threat.
- Contamination of the site and plants that may enter the human food chain creates a health hazard.
- Erosion and sediment transport may occur over the site during the establishment phase and over the longer term if surface revegetation is inadequate.

9 On-site Domestic Wastewater Disposal: Pump-out System Constraint Rating

This system is based on the regular pumping out of all wastewater derived from a septic tank and holding tank into a road tanker allowing their removal and effective disposal elsewhere. The need for capability assessment of these systems arises due to the high potential for escape of untreated wastewater that arises due to the possibility of overflow (from inadequate collection services or other failures). Although failure may be infrequent, the consequences of this may be high. This means site and soil conditions should be at least acceptable for wastewater treatment, by processes as mentioned for the irrigation and trench methods (including plant growth). However, the conditions need not be as stringent as for these methods. It requires the least suitable conditions of the three disposal methods considered in this report.

Attribute	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint	Rationale	Data source	Theoretical correlation[1]	Correlation using data source[1]
Slope (%)	<6	6–15	15–25	25–35	>35	Rapid runoff in event of failure	DEM	Certain	Confident
Flooding									
Probablity (%)	Nil	<1 events less frequent than 1 in 100 years	1–2 1 event in 50 to 100 years	2–5 1 event in 20–50 years	>5 more than 1 event in 20 years	Potential damage to facility and surface water contamination	From flood risk maps	Certain	Certain
General occurrence	Not recorded	–	Localised	Widespread	–	As above	Landscape limitation tables	Certain	Confident
Terrain unit	Hill slope units (excluding footslopes)	Low footslopes, plains (excluding floodplains)	High floodplains	Middle floodplains	Lower floodplains, drainage depressions, stream channels	As above	Multi-attribute mapping, soil landscape descriptions, topographic maps	Certain	Confident
Mass movement	Not recorded	–	Localised	Widespread		Potential damage to facility and surface water contamination	Landscape limitations table	Confident	Confident
Shrink-swell									
Shrink-swell limitation	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	Potential damage to pipes and tanks	Soil material limitations tables		Confident
Shrink-swell (VE%) *worst layer to 1 m*	<10	10–20	20–30	>30	–	As above	Type profile lab data	Confident	Confident
Drainage/ waterlogging									
Seasonal waterlogging	Not recorded	–	Localised	Widespread	–	Waterlogging or excessive drainage limits effective treatment, potential water contamination	Landscape limitation table	Certain	Confident
Permanent waterlogging	Not recorded	–	Localised	–	Widespread	As above	As above	Certain	Confident
Poor drainage hazard	Not recorded		Localised	Widespread	–	As above	As above		
Profile drainage	Well	Mod well	Imperfect, poor, rapid	Very poor	–	As above	Type profile data	Certain	Confident
Permeability ranking *average of layers to 600 mm*	Moderate	High	Low, very high	Very low	–	Too high or too low permeability, inhibiting effective wastewater treatment and plant growth	Soil layer data	Certain	Confident
Permeability (mm/day) *worst layer to 600 mm*	480–1440	1440–2880	60–480, >2880	<60	–	As above	Type profile lab data	Certain	Confident
High watertable (<2 m)	Not recorded	–	Localised	Widespread	–	Limits absorption, potential groundwater contamination	As above	Certain	Probable
Groundwater pollution hazard	Not recorded	–	Localised	Widespread	–	Groundwater contamination	As above	Certain	Confident
Depth									
Shallow soils (<50 cm)	Not recorded	–	Localised	Widespread	–		Landscape limitation tables	Certain	Confident
Depth to hard layer – from type profile	>1.0	0.6–1.0	0.4–0.6	0.2–0.4	<0.2	Limits available soil	Type profile data	Certain	Confident

Acidity/alkalinity									
Acidity limitation	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	Too high or low pH inhibits micro-oganisms, plant growth and treatment processes	Soil material limitations tables	Certain	Probable
Alkalinity limitation	Not recorded	Widespread over minority of soil materials	Widespread over majority of soil materials	–	–	As above	Soil material limitations tables	Confident	Probable
pH (1:5 water) *worst 0–300 mm*	5.5–7.5	4.0–5.5, 7.5–9.0	<4.0, >9.0	–	–	As above	Type profile lab data	Certain	Confident
Constraint sub-scores[2]									
Total constraint score[3]									

[1] Certainty of correlation of attribute to ranking: The lowest ranking of certainty for any applicable limiting factor is applied to the entire table.

Certain	No doubt as to the relationship with hazard, very reliable data source.
Confident	Confident relationship with hazard, sound observed and theoretical reasons to expect relationship, mostly reliable data.
Probable	Relationship with hazard is based on findings from other aspects of soil science, data is of moderate reliability, may be moderate variability within the soil-landscape or facet.
Uncertain	Relationship with hazard is theoretical, data is of questionable reliability may be significant variability within the soil-landscape or facet .

[2] Constraint sub-score: Score 1 point for each attribute group that falls in Moderate column, 3 points for each attribute group that falls in High column, and 6 points for each attribute group that falls in Very High column.

[3] Total constraint score: Add sub-scores from Moderate, High and Very High columns.

Interpretation of scores

0–3 points: Good – requires nil or minor site amelioration
4–7 points: Fair – requires moderate site amelioration
>8 points: Poor – not capable or requires significant site amelioration

Main actions and processes

- Installation of septic tank, storage tank and connection pipes, including initial excavation of pits.

Potential environmental and other impacts

- Failure of the system, usually due to overflow from an inadequate collection service, may result in contamination of surface water and groundwater by various materials as described for irrigation method.
- Contamination of the site itself.

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