LAND CAPABILITY CLASSIFICATION FOR FOREST ECOSYSTEMS IN THE OIL SANDS REGION

Revised Edition
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CAN-AG ENTERPRISES LTD.

TAILINGS SAND RECLAMATION PRACTICES

WORKING GROUP

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PREFACE

The goal of land reclamation in Alberta is to create land capability equivalent to that which existed prior to disturbance. A primary requirement is to salvage all topsoil and material that can be used as an amendment to topsoil prior to disturbance and to replace it during the reclamation process. **Topsoil is defined as the uppermost mineral and organic soil materials which are valued as a growth medium.** It includes the A horizon (Ah, Ahe, Ap and optional Ae) and leaf litter in mineral soils, and peat or organic layers (Of, Om and Oh horizons) in peaty mineral and organic soils. Other soil handling requirements are based on soil characteristics, landscape features, ecoregion, and present and potential land use. These requirements are planned and implemented on a project-specific basis.

This classification system is a "tool" for assisting in the planning process and for evaluating land capability. It is based primarily on soils and landscape features. It is assumed that climate remains unchanged through the disturbance and reclamation period thus it is not rated. The ecoregion, ecosite, etc. provides regional information about the climate, plant communities and levels of productivity. Evaluation of reclamation success can be determined by comparing capability before and after disturbance.

The rating system provides the user the flexibility of addressing the primary components, soil and landscape, individually or in combination. The choice of how "equivalent capability" is determined, including "trade-offs" among components or classes, is made during the planning process. A linkage between the soil, landscape and potential forest productivity is made via the ecoregion.

Regardless of evaluation procedures used, successful reclamation is dependent upon reconstructing favorable growing conditions in the soil profile, with emphasis on the root zone which is primarily the upper 50 cm. Key factors relating to root zone quality that are used in this system include: available water holding capacity (AWHC), organic carbon content (OC), nutrient retention capacity, surface peat thickness, structure and consistence, salinity, sodicity, soil reaction, and moisture and nutrient regimes. The main landscape parameters include: slope, position, aspect, stoniness and erosion. The standard references for identifying ecoregions are *Ecoregions of Alberta* (Strong and Leggat 1992) and *Field Guide to Ecosites of Northern Alberta* (Beckingham and Archibald 1996).

This capability system provides a basis for planning and evaluating land reclamation for forest ecosystems. Information about planning, establishing, and evaluating ecosystems on reclaimed lands is given in a "sister" document entitled *Guidelines for Reclamation of Terrestrial Vegetation in the Oil Sands Region* (Oil Sands Vegetation Reclamation Committee 1998).

ACKNOWLEDGMENTS

Development of this capability classification system commenced in 1995, and was completed early in 1996. This 1998 update is the result of field testing during 1996 and 1997. The objective was to use it in the Alberta Environmental Protection Environmental Impact Assessment Applications and Conservation and Reclamation Applications for EPEA Approvals for new oil sands mines in 1996. In June 1995, a workshop at Suncor Inc. and Syncrude Canada Ltd., Fort McMurray, Alberta was held with industry and government stakeholders. Subsequently, a Tailings Sand Reclamation Practices Working Group was established to develop the *Land Capability Classification for Forest Ecosystems in the Oil Sands Region*. The working group consists of Mr. Steve Tuttle, Suncor Energy Inc.; Mr. Tom Coolen and Dr. Ron Pauls, Syncrude Canada Ltd.; Mr. Chris Powter, Mr. Travis Ferguson (1996), Mr. Jeff Sansom (1997), Mr. Chris Hale, Dr. Dave McNabb, (1996) Alberta Environmental Protection; Mr. Terry Macyk, Alberta Research Council; Mr. Carl Warner, AGRA Earth & Environmental Limited; and Mr. Leonard Leskiw, Can-Ag Enterprises Ltd.

The Working Group met five times and conducted a second workshop in February 1996 to present the initial *Land Capability Classification for Forest Ecosystems in the Oil Sands Region* to stakeholders.

This revised system is the result of refinements made through 1996 and 1997, agreed to by a Working Group meeting in December 1997.

Suncor Energy Inc. and Syncrude Canada Ltd. continued to financially support the development of this land capability classification. We at Can-Ag are grateful to the members of the Working Group for their ongoing evaluation and commitment in refining this document.

1.0 INTRODUCTION

This land classification system is used to evaluate pre-disturbance and post-disturbance land capability for forest production. It is designed to aid in planning soil handling procedures and measuring land capability. Soils factors and landscape features are quantified by assigning numerical ratings to individual components, then combining these to produce an overall land capability rating. The system is intended for the oil sands region of Alberta where surface disturbances are caused by the oil sands mining, transportation, utilities, and pipeline corridors. The system assumes soils are "clean" and meet Alberta Tier I Criteria (Alberta Environmental Protection 1994) (e.g., not contaminated with heavy metals, sterilants, herbicides, salt, etc.). Bitumen is found in some natural soils in the area and is permitted at similar or lower concentrations than background levels in reclaimed soils.

The soil capability evaluation applies to the upper one metre (1.0 m) of soil and is closely related to the forest productivity. The focus is on soil chemical and physical properties and the resultant quality of the root zone. The soil capability rating of undisturbed soil is based on the natural soil horizons, notably the LFH, A, B and C horizons in mineral soils and O (B, C) horizons in organic soils. Topsoil begins at the mineral surface.

The reclaimed soil profile is assigned three principal "horizons": topsoil (TS); upper subsoil (US); and lower subsoil (LS) (Figure 1). Surface organic litter or peat is not included in reclaimed upland soils unless it is mixed with enough mineral material to be a “mineral” soil (at least 17% mineral dry weight basis). The topsoil surface begins at this “mineral” surface.

Natural and reclaimed organic profiles are also rated on the basis of three horizons (layers): 0-20, 20-50, and 50-100 cm intervals. The topsoil surface is the organic surface.

Soil quality is a good indicator of site productivity. Soils interact with climate, physiography and vegetation to govern productivity by providing air, water and nutrients to roots. Soil quality is measurable based on technical data and professional judgment and is used to infer changes in productivity. A 20% reduction in inherent forest productivity is the target used for establishing threshold values between classes of soils (Classes 1 to 5). As a guideline, and given a similar level of inputs, Class 2 soils would have 20% lower yields than Class 1 soils, Class 3 soils would have 20% lower yields than Class 2 soils, and so forth. Yields on Class 4 soils are less than 40% of those on Class 1 soils. A 20% yield reduction per class closely matches that of the original CLI Forest Capability Classification (McCormack 1970, Archibald et al. 1979).

The landscape capability evaluation relates to forest productivity from a landscape perspective. This does not address equipment operations (mechanized clearcutting and site preparation). Factors considered include slope position, aspect, stoniness and erosion.

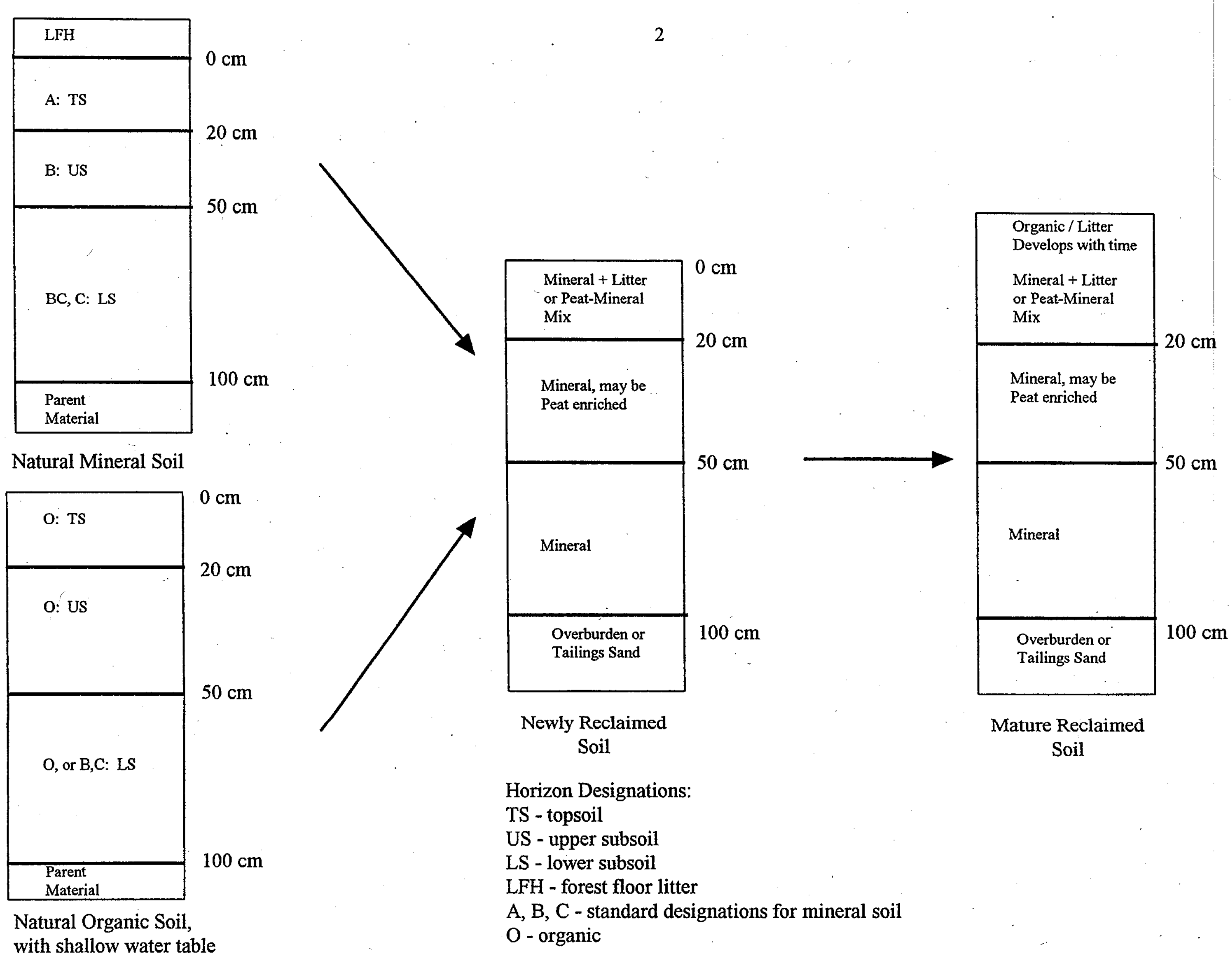


Figure 1. Schematic natural and reclaimed soil profiles.

2.0 SYSTEM DEVELOPMENT

2.1 FRAMEWORK

The land capability classification for forest ecosystems in the oil sands region is based primarily on soil, and landscape components. It closely follows the format of *Land Reclamation: Agricultural Capability Classification* (Leskiw 1993 and Leskiw and Kutash 1993) for determining land capability. This system works well for agricultural soils and crops, (for examples of use see Bateman 1996, Leskiw 1995). Inventory requirements are also specified, based on modification of the guidelines presented in the *Soil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987b). This revised edition also uses information from recent forestry related publications, principally *Forest Site Interpretation and Silvicultural Prescription Guide for Alberta* (Environmental Training Centre 1996), *Field Guide to Ecosites of West-Central Alberta* (Beckingham, Corns, and Archibald 1996), *Field Guide to Forest Ecosystems of West-Central Alberta* (Corns and Annas 1986), and *Field Guide to Ecosites of Northern Alberta* (Beckingham and Archibald 1996).

Reclamation success is dependent upon favourable conditions in the root zone for optimum forest growth. Soil parameters influencing growth can be quantitatively measured, and these measurements are integrated to estimate the sustained productivity of reclaimed lands. Key soil factors relating to root zone quality include: available water holding capacity (AWHC), total organic carbon (OC), structure and consistence, salinity, sodicity, soil reaction, nutrient retention ability, surface peat, and moisture and nutrient regimes. The main landscape factors include: slope steepness, slope position, aspect, stoniness, and erosion. Ecoregions are identified to provide a necessary linkage to vegetation management and performance as well as to reflect climatic conditions.

Each component, soil and landscape, is given a numeric rating derived from values assigned to defined categories for all the key factors mentioned above. Soils are assigned an interim rating based on characteristics of three principal layers: topsoil (TS, A or O horizon), upper subsoil (US, B, or O horizon) and lower subsoil (LS, BC, C or O horizon). Soil moisture and nutrient regimes are interpreted and are used to adjust the interim soil rating, leading to a final soil rating. Landscape factors affecting tree growth are rated the same in reclaimed and undisturbed lands. A relationship to the natural vegetation and its productivity is made by ecoregion, ecosite, etc. Targeted production levels on reclaimed lands should match those on natural lands, given approximately the same level of inputs.

The forest land capability rating system is limited to 1 m depth, although material characterization below 1 m may help in predicting sustainability, as deeper materials may affect soil performance. For rating purposes, the rooting depth is 1 m and the relative contribution of increasing depths within the root zone to the productivity of the soil is reflected by root distribution and water uptake during the growing season. A review of 19 published studies (Gale and Grigal 1987) indicated some important general trends: the majority (about 40 to 60%) of tree roots are in the upper 10 cm of the profile and about 90% are in the upper 50 cm. Differences are related to various factors, including shade tolerance, species, tree age, soil properties, water table depth, nutrient cycling, successional status and adaptation. Average rooting depths in northeast Alberta (Krumlik 1980) are shown in Table 1. The principal species of interest, jack pine, aspen, white spruce, and black spruce, all have a rooting depth of about 40 to 60 cm, to a maximum of about 90 cm. Shallower rooting depths occur in areas with shallow water tables and fine-textured soils. It is recognized that root location is strongly determined by where nutrients, as well as moisture, are available. For example, near surface rooting is an advantage where precipitation is light and seldom wets more than the upper profile, regardless of available water holding capacity. Kiniry et al. 1983 (in Henderson et al. 1990) predicted fractions of root growth in ideal soils as graphically portrayed in Figure 2. This root distribution pattern represents actual water depletion determined from measurements in ideal soils (Kiniry et al. 1983). Given the ranges of root abundance with depth in natural soils, the root distribution in the ideal soil (Figure 2) serves as the model for this system. Approximately 50% of the roots are in the upper 20 cm, about 85% are in the upper 50 cm and 100% are within 100 cm.

In the typical reclaimed profile with topsoil 20 cm, upper subsoil 30 cm, and lower subsoil 50 cm, the sum of available water holding capacity (AWHC) of each horizon divided by 3 provides a weighted AWHC for the profile. AWHC is the difference between field capacity (-33 kPa) and wilting point (-1500 kPa) for loams and finer textures. Sandy loam and coarser soils are evaluated using -10 kPa as a measure of field capacity. The weighting is such that 50% importance is assigned to the upper 20 cm, 30% to the next 30 cm or 80% to the upper 50 cm, and 20% to the lower 50 cm. Thus the root distribution is approximated as reported in the literature, and provides a simple, effective method for assessing profile AWHC. Furthermore, the topsoil layer being most important (at least 50% of rooting) is assigned major importance in value and major deductions for other limitations. Upper subsoils, which are valued twice as much as lower subsoils, are given twice the deduction of lower subsoils (2/3:1/3 ratio). This approach is very similar to that used in the *Land Reclamation: Agricultural Capability Classification* (Leskiw 1993).

Guidelines for rating natural and reclaimed soils follow based on illustrations presented in Figure 1. Rate topsoil based on properties of surface 20 cm, and if shallower, use the mixed 20 cm surface layer or a weighted average related to thickness. The upper subsoil (B horizon) underlies the topsoil and extends to 50 cm depth. Lower subsoil extends from 50 to 100 cm in depth.

Table 1. Average rooting depths (cm) in northeast Alberta (from Krumlik 1980).

Soil Type *(n)	Jack Pine	Aspen	White Spruce	Black Spruce	Productivity
Sandy Brunisol (6)	42 (10-62)*				Poor
Sandy Brunisol (2)	31 (30-32)				Poor
Sandy Brunisol (4)	63 (40-91)				Poor
Sandy Brunisol (2)	48 (45-50)				Poor
Sandy Regosol (1)		80			Poor
Sandy Brunisol (2)		53 (39-67)			High
Sandy loam Brunisol (9)			54 (30-80)		Poor
Clay loam Luvisol (3)			55 (50-70)		High
Clay loam Luvisol (1)			40		High
Clay loam Brunisol (2)			23 (17-30)		High
Sandy loam Brunisol (2)				40 (35-45)	Poor
Organic (1)				20	Very poor
Organic (4)				(25-75)	Very poor

*(n) number of sites ** mean (range) cm

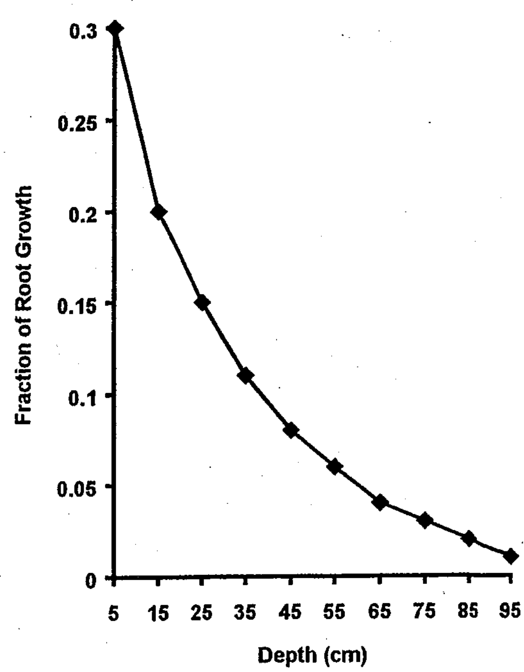


Figure 2. Root distribution in ideal forest soils (from Kiniry et al 1983).

2.2 APPROACHES AND ASSUMPTIONS

A capability classification approach to the rating of reclaimed land is used. Definitions as used in this report are:

Land capability - the ability of the land to support a given land use, based on an evaluation of the physical, chemical and biological characteristics of the land, including topography, drainage, hydrology, soils and vegetation. It combines the soil and landscape evaluation.

Soil capability - the nature and degree of limitations imposed by the physical, chemical and biological characteristics of a soil for forest productivity.

Land - terrestrial, semi-aquatic and aquatic landscapes when the term is used in the definitions of "land capability" and "equivalent land capability".

Landscape capability - the evaluation of the landscape factors as they affect general tree growth, including: slopes, position, aspect, stoniness, and erosion.

Peat-mineral mix - is a mixture of peat and mineral material resulting in a "mineral" soil. It may be obtained by either overstripping peat into the mineral soil, or by placing peat material and then rotovating into underlying mineral material. Peat mineral mixes contain a ratio of peat:mineral ranging from 1:1 to 4:1 (vol.). Higher proportions of peat likely behave as an organic material.

Productivity - expression of tree growth by site index which is a measurement of tree growth expressed as height (m) at 50 years breast height.

Sustainability - the reclaimed plant communities establish and progress to maturation without the operators ongoing input of nutrients, water, seeds or seedlings. Furthermore, the reclaimed sites must be able to recover from infrequent, naturally occurring environmental disturbances such as fire, floods or drought at the same rate as similar natural areas.

Sustained yield - the yields that a forest can produce continuously at a given intensity of management.

Basic concepts of the original *Land Capability for Forestry in Alberta* (Prokopchuk and Archibald 1976), *Alberta Land Inventory Capability Classification for Forestry*, (Archibald et al. 1979) and the *Land Capability Classification for Arable Agriculture in Alberta* (ASAC 1987a) were adopted to create the relationship of capability class to index points (Table 2). Class 1 (similar to previous CLI Class 3) has the highest capability for forestry (least limitations for production and management) and Class 5 (similar to previous CLI Class 7) the lowest capability (most severe limitations) in the present system. (In the original forestry and agricultural rating systems seven classes were recognized, with Class 7 being the lowest capability.) Assumptions to the present approach are:

1. It is an interpretive system based on limitations for forest productivity for common trees, including aspen, balsam poplar, pine and white spruce. While the focus is on trees, it is assumed that appropriate understory species will become established over a period of several years to create a thriving plant community.
2. Minimal soil management practices are assumed.
3. Lands in each class are similar in degree, but not necessarily in kind, of limitations for forest production.
4. Productivity of principal tree species is considered, such that a 20% growth reduction per class is used as a guide in setting point deductions for various parameters.
5. The present Classes 1 to 5 are approximately equivalent to the Forestry CLI (Canada Land Inventory) Classes 3 to 7 in terms of soil conditions; however, the present class boundaries are only related to, not determined by, mean annual increment.
6. Point deductions have changed and continue to change as additional research and testing is conducted.
7. The soils are not contaminated with heavy metals, sterilants, etc. (meet Alberta Tier 1 Criteria, Alberta Environmental Protection 1994).
   Natural bitumen is present within natural soil profiles in areas of shallow residual (tar sand) deposits. Similar background levels of bitumen are therefore acceptable in reclaimed soils.

Table 2. Relationship of capability class to index points.

Capability Class	Index Points	Productivity	Limitations
1	81-100	High	None to slight
2	61-80	Moderate	Moderate
3	41-60	Low	Moderately severe
4	21-40	Conditionally Productive	Very severe
5	0-20	Non-productive	Extreme

The major components - soil and landscape - are considered separately and each is assessed an index value between 0 and 100. Conventionally, the final rating is based on the most limiting of the two. In reclaimed land settings, this rating system provides the user a choice of individual components, or the most limiting of soil and landscape components, to attain the "equivalent capability". The system also identifies specific limiting factors and their relative contribution. The regional climate or ecoregion remains the same, but soils and landscape features can be upgraded, or trade-offs can be negotiated, through specific management strategies. Identification of the major limitations (if serious enough to downgrade one or more capability classes) is recommended when describing the results of the capability assessment.

Some factors are more important than others, as reflected by the ratings:

1. The entire point deduction range of 0 to 100 is not used for all parameters.
2. Some factors are modifiers to a base rating and are treated as percentage rather than absolute deductions, such as, subsoil limitations.
3. Moisture and nutrient regime are interpreted and may either upgrade or downgrade the interim soil rating.

2.3 SYSTEM DESCRIPTION

There are five classes of land, rated according to potential and limitations for productive forest use. Classes 1 to 3 are capable of supporting productive forests, while Classes 4 and 5 are non-productive forest lands. The classes are an assessment of the degree or intensity of limitation. For example, Class 3 land has limitations which are more severe and may be different than Class 2. The subclasses describe the kind of limitations responsible for class designation. Such information is useful in land use planning, soil handling for reclamation and subsequent land management.

2.3.1 Land Capability Classes

Class 1 **High Capability (Index 81 to 100):** Land having no significant limitations to supporting productive forestry, or only minor limitations that will be overcome with normal management practices.

Class 2 **Moderate Capability (Index 61 to 80):** Land having limitations which in aggregate are moderately limiting for forest production. The limitations will reduce productivity or benefits, or increase inputs to the extent that the overall advantage to be gained from the use will be still attractive, but appreciably inferior to that expected on Class 1 land.

Class 3 **Low Capability (Index 41 to 60):** Land having limitations which in aggregate are moderately severe for forest production. The limitations will reduce productivity or benefits, or increase inputs to the extent that the overall advantage to be gained from the use will be low.

Class 4 **Conditionally Productive (Index 21 to 40):** Land having severe limitations; some of which may be surmountable through management, but which cannot be corrected with existing knowledge.

Class 5 **Non-Productive (Index 0 to 20):** Land having limitations which appear so severe as to preclude any possibility of successful forest production.

2.3.2 Land Capability Subclasses

A subclass, denoted by the letter in brackets, indicates the kind of limitation, as follows:

Soils (S)

Physical Parameters

- available water holding capacity (M)
- structure/consistence (D)
- organic carbon (F)
- surface peat (O)

Chemical Parameters

- acidity/alkalinity (V)
- salinity (N)
- sodicity/saturation percentage (Y)
- nutrient retention capacity (K)

Edaphic Regime (R)

- soil moisture regime
- soil nutrient regime

Landscape (L)

- Slope (T)
- Exposure (X) - configuration of slope, aspect
- Stoniness (P)
- Erosion (E) - visible gully erosion

3.0 INVENTORY REQUIREMENTS

To use the rating system, data (observations, measurements or estimates) are required for each of the identified factors within the soil and landscape components. Some values can be estimated from maps and reports while other data are collected by site inspection. The level and purpose of the capability rating also has a bearing on the detail required. Regional assessments can be made by estimates from published data but assessment of individual land parcels requires detailed site investigations.

3.1 SOIL SURVEY

Soil and landscape data must be collected in the field. The definition and descriptions of individual parameters for natural soils follow standards presented in *The Canada Soil Information System: Manual for Describing Soils in the Field* (Working Group on Soil Survey Data 1975) and *The Canadian System of Soil Classification* (Agriculture Canada Expert Committee on Soil Survey 1987).

Descriptions of some important parameters vary in disturbed soils, hence, the need to define "equivalent" ratings. Regional soil survey reports and maps prepared by Alberta Soil Survey (Alberta Research Council, Agriculture Canada, University of Alberta) provide the most comprehensive set of soil and landscape data. Similar information is collected by the Resource Data (formerly Resource Evaluation and Planning) Division of Alberta Environmental Protection. Private sector soils reports, development and reclamation plans, and aerial photographs should also be consulted where applicable.

The basic feature of soil survey maps is that similarly identified areas have the same characteristics and are therefore predictive in permitting information from one area to be extrapolated to others based on similarity of soils. Thus soil surveys and the interpretations are useful in the reclamation process in four specific areas:

1. Land Use Planning - Plan preparation that affects the use of the land considering suitability and limitations for various forestry operations.
2. Soil Handling - The selective salvage, conservation and replacement of materials of differing quality, in a manner that meets planning objectives.
3. Soil Management - The conditioning of the land for forestry uses.
4. Land Capability Evaluation - Determines whether the reclaimed land meets the objective of the reclamation plan, or meets equivalent capability.

Equivalent land capability means the ability of the land to support various land uses after conservation and reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical (Alberta Regulation 115/93).

3.1.1 Design

Soil surveys are planned or designed as follows:

1. Establish the objectives. Baseline soils mapping should provide information on the types of soils present, in sufficient detail, to permit decision making regarding optimum site location, materials, handling and post disturbance soil reconstruction.
2. Determine the smallest area in the field to be described and delineated and which can be read by users. The Expert Committee of Soil Survey (1981) recommends that a minimum size delineation on a soil survey map is 0.5 cm^2. For linear features this corresponds to 0.5 cm.
3. Determine the survey intensity level (SIL). SIL is defined as the required number of field inspections per unit area or other estimates of accuracy. SIL is based on inspection densities, scale, survey techniques, levels of soil taxonomy used and accuracy of boundaries. Level 1 surveys are conducted for specific operations tailored to the type of activity. Level 2 surveys are conducted to aid in general planning. Table 3 provides suggested scale limits for the two intensity levels defined and Table 4 provides recommended scales for mapping. The scale of mapping is based mainly on the minimum size of field delineation. For example, if soil units with different use potentials must be recognized down to a size of 4 ha then the scale should be at least 1:20 000. Where reclaimed areas are <16 ha, very detailed mapping is recommended (suggest a minimum of 25 inspections following a grid or transects to cover the study area). As well, inspect adjoining undisturbed lands at a minimum of 8 sites per major soil type, for comparison where baseline information may be unavailable). For post-disturbance mapping, a scale of 1:5 000 is suggested for nonselectively handled areas or where materials handling techniques were minimal. Where selective handling techniques are employed a scale of 1:10 000 is recommended.
4. Alberta Environmental Protection should be contacted to confirm mapping detail/scale for specific projects.

Table 3. Criteria for identifying survey intensity levels[a]

		Definitive Characteristics		Associated Features		
Survey Intensity Level (SIL)	Common Name	Inspection Intensity	Methods of Investigations	Main Kinds of Soil Components	Map Units[b]	Appropriate Scale (Usual)[c]
SIL1	very detailed	At least one inspection in every delineation (1 per 1 to 5 ha). A minimum of 25 per area at small reclaimed sites (<16 ha). Boundaries observed throughout entire length. Where baseline data are inadequate, check at least 8 control sites per soil type.	Transects and traverses less than 0.5 km apart. profile descriptions and samples for all soils.	Series or phases of series	Mainly simple units	1:14 000 or larger (1:5 000)
SIL2	detailed	At least one inspection in 90% of the delineations (1 per 2 to 20 ha). Boundaries plotted by observations and interpretation of remotely sensed data verified at closely spaced intervals.	Transects and traverses less than 1.5 km apart. Profile descriptions and analyses for all major soils.	Series or phases of series	Simple and compound units	1:5 000 to 1:40 000 (1:20 000)

a Adapted from a Soil Mapping System for Canada: Revised (Expert Committee on Soil Survey 1981).

b Simple units have over 80% of a single component or a nonlimiting inclusion. Compound units are complexes or associations of two or more components.

c Appropriate publication scale.

Table 4. Guidelines for conducting soil surveys relative to development and reclamation in the Northern Forest Region.

Purpose	Level of Survey	Recommended Publication Scale	Min. Size Area Represented by	Inspection Density	Sampling Density	Overburden Sampling (optional)
Mapping Land Areas			1 cm^2 on Map (ha)	(ha/Insp)	(Profile, Sites) ha/sample	ha/sample Site
Baseline	1 or 2	1:10 000	1	1 to 5	10 to 50	150 to 300
Post-Disturbance (Nonselective Handling[a])	1	1:5 000	0.25	0.25 to 1.25	1.25 to 6.25	--
Post-Disturbance (Selective Handling[a])	1	1:10 000	1	1 to 5	10 to 50	—
Mapping Linear Corridors			1 cm on Map	Insp/km	Sites/Soil	Sites/Soil
Baseline	1	1:10 000	100 m[b]	5[c]	1 to 5	1 to 5
Post-Disturbance	1	1:10 000	100 m[b]	5[c]	1 to 5	1 to 5
Mapping Sites (<16 ha)			1 cm^2 on Map (ha)	(ha/Insp)	(Profile, Sites) ha/sample	ha/Sample Site
Baseline	1	1:1 000	0.1	<1[d]	<5	<5
Post-disturbance	1	1:1 000	0.1	<1[d]	<5	<5

a Nonselective Handling. Soil materials excavated and replaced without selective handling, that is, salvaging better materials.
Selective Handling. Soil materials excavated, stored or transported, and replaced in a planned manner to salvage better quality materials. Areas of different materials, depths, and handling procedures are known, in accordance with reclamation plans.

b For similar map units 100 m is minimum, for contrasting units 25 m is the suggested minimum and/or a symbol notation may be used.

c This includes a minimum of two descriptions to depth of disturbance (e.g. trench depth) and three to 50 cm (A and B horizon).

d At small areas such as wellsites or gravel pits where pre-disturbance mapping is not available, a minimum of 25 inspections within the disturbance and a minimum of 10 on the adjoining undisturbed land is suggested to compare pre- and post-disturbance quality.

Source: Soil Quality Criteria Relative to Disturbance and Reclamation, Alberta Soils Advisory Committee 1987b.

3.1.2 Soil Profile Characteristics and Landscape Features

Soil mapping involves the recognition of soil profile characteristics and landscape features. Morphological characteristics of the soil profile normally include:

1. horizon thickness and sequence;
2. colour;
3. texture;
4. structure (aggregate shape and size);
5. consistence (aggregate strength);
6. effervescence and salt crystals;
7. coarse fragments;
8. field pH (not required for all observation sites);
9. presence of mottles, water table; and
10. roots (abundance, depth, pattern, restrictions).

To complete a site description include the following:

1. slope class (topography), length and position; configuration (concave, convex);
2. aspect;
3. landform and parent material;
4. stoniness (percentage volume within 1 m profile);
5. surface and internal drainage, drainage class, moisture regime;
6. extent of erosion;
7. present land use (as related to delineated soil types); and
8. vegetation cover - trees, shrubs, herbs, grasses, and mosses (as related to delineated soil types). Identify ecoregion, ecosite, etc., as appropriate.

Not all of the above need to be recorded at each inspection site, but they should be documented for each profile sampling site, and each principal map unit. Parameters recorded will vary relative to the type of disturbance involved.

3.1.3 Map Presentation

It is recommended that detailed survey information be presented on an aerial photo mosaic base, preferably ortho-photos. Semi-detailed or reconnaissance maps are usually printed in colour.

3.2 SOIL SAMPLING

Methods of sampling vary with purpose. Sampling intensity is dependent on the scale of mapping used, variability of the soils in the survey and components to be analyzed.

3.2.1 Sampling for Baseline Evaluation Purposes

The number of sampling sites selected is determined by the frequency of the individual map units. Sufficient samples are to be collected to properly characterize the map units. In baseline mapping, the samples are required for characterization and classification. Sampling intensity refers to sampling of soil pits. Some "grab" samples of surface, or deeper, materials may be collected and included in the recommended number of sampling sites. For baseline purposes, at least 50% of the sampled sites should be to 1 m depth. Where organic soils occur, determine the depth of the peat where >1 m.

Table 4 provides a range in the sampling density required for a particular scale. For example, in a Level 2 survey conducted at a scale of 1:10 000, a density of one site per 10 to 50 ha is recommended.

3.2.2 Methodology of Sampling for Baseline Purposes

The following procedure for baseline evaluation purposes is recommended:

1. select sample sites typical of the soils that the samples are intended to represent (McKeague 1978);
2. sites should be away from fences, roads and other features that may cause abnormal properties;
3. samples should be collected from freshly dug pits or cuts. The pit should 1 m deep, or to the bottom of the control section (Agriculture Canada Expert Committee on Soil Survey 1987), whichever is deeper.
4. sample on a horizon or "homogeneous layer" basis and from a face about 50 cm wide for laterally uniform soils. If horizons are discontinuous, or vary greatly in thickness or degree of expression, collect samples from different locations on the pit face to ensure a representative sample of each horizon. Some discontinuous horizons may not be significant enough in amount or characteristics to warrant sampling and analysis; and
5. start sampling at the bottom of the pit.

3.2.3 Sampling Post-Disturbance Areas

Sampling of reconstructed soils should be done on the basis of layers or materials such as topsoil, upper and lower subsoil, and on depth intervals within each of these layers (Table 5).

Table 5. Sampling depth intervals for reconstructed soils.

Material	Depth Interval (cm)	Notes
Topsoil	0 to 20	The topsoil layer should be taken in one sample. If topsoil depth is less than 20 cm then either take a mixed sample of the 20 cm or sample the materials separately so that weighted average properties can be determined as appropriate. If the topsoil layer is much greater than 20 cm in thickness, sample two intervals. (Note that more detailed sampling is usually required for contaminated soils.)
Upper Subsoil	20 to 50	The upper subsoil sampling interval is the minimum suggested. If materials are variable, differing strata should be sampled separately.
Lower Subsoil	50 to 100	The lower subsoil sampling interval is the minimum suggested. If materials are variable, differing strata should be sampled separately.

3.3 ANALYTICAL REQUIREMENTS

Analytical requirements are presented for baseline characterization and for disturbed areas. These analyses help to characterize soils for classification, mapping and making interpretations relative to the quality of the soils in the undisturbed and reconstructed states. Primary emphasis is on organic carbon content, particle size distribution (include sand size fractions), and limiting growth factors such as abnormal levels of salinity, sodicity or pH. Fine textured sodic and saline-sodic materials occur in Alberta and will restrict tree growth if they are near the surface.

Analyses to quantify other soil characteristics are required less often. Bulk density, penetrometer resistance, permeability and clod size distribution data are recommended in calibrating field descriptions of subsoil structure and consistence, particularly in disturbed soils. Cation exchange capacity, organic carbon, nitrogen, and macronutrient analyses are useful in assessing availability, balance and mobility of nutrients. Extractable aluminum and manganese analyses are useful on low pH soils in toxicity assessment. AWHC determinations are not generally recommended because of variability and inability to measure it easily in the field; instead, texture is used to infer AWHC.

Analyses are required for topsoil within 20 cm (A horizon), upper subsoil at 20 to 50 cm (B horizon), and lower subsoil at 50 to 100 cm (BC, C horizons). Additional layers may be sampled to suit horizonation. Analyses are required on selected samples from at least two representative profiles (topsoil and upper subsoil or A and B horizons) per major soil type or map unit.

Summary of recommended analyses:

• pH ($CaCl_2$ or H_2O)	(Optional Analysis)
• Organic carbon (topsoil)	• Cation exchange capacity[b]
• Nitrogen (total or mineralisable)	• Exchangeable cations[b]
• Particle size distribution	• Bulk density[b]
• Saturation percentage[a]	• Gypsum[b]
• Electrical conductivity[a]	• Calcium carbonate equivalent[b]
• Soluble cations[a] and SAR	• Aluminum and manganese-extractable[b]

a Where there is no evidence of salinity and sodicity these analyses are not required, but are recommended on selected samples to confirm absence of salts.

b Optional, to be conducted on selected, representative profiles.

4.0 FACTORS FOR SOILS

Rating of soils is considered in steps:

1. available water holding capacity as inferred from texture (0 to 100 cm),
2. topsoil (surface 20 cm),
3. upper subsoil (20 to 50 cm),
4. lower subsoil (50 to 100 cm),
5. moisture and nutrient regimes.

The water holding capacity plus topsoil rating provides the basic soil rating assessed by point deductions. Subsurface factors, and soil moisture and soil nutrient regimes are percentage modifiers. There are important differences in applying point deductions for individual factors to different soils (mineral vs. organic, natural vs. reclaimed). These are explained in the following sections.

4.1 SURFACE FACTORS

Key parameters are characterized: moisture availability (in the 100 cm profile, but weighted to favour surface layer) which is based on texture; structure and consistence; organic carbon equivalent; peaty surface; soil reaction; salinity; sodicity; nutrient retention capacity; and nutrient and moisture regimes. In forest soils the topsoil (Ah, Ahe, Ap, Ae, O, or an acceptable mixture of mineral and organic materials) is assessed to a standard depth of 20 cm. If topsoil is shallower, either use a mixed 20 cm layer or evaluate the sublayers separately and determine a weighted average. The topsoil surface is at the mineral surface in mineral soils and is at the organic (peat) surface in Organic soils and Peaty Gleysols with >20 cm peat.

4.1.1 Available Water Holding Capacity Based On Texture: Subclass M

The amount of water available is a prime factor governing tree production. The main controlling soil factor in dry upland settings is available water holding capacity (AWHC), which is dependant on depth and texture. Occurrence of shallow water tables or seepage eliminates a moisture retention deduction. The calculation involves determining water holding capacity based on texture using Table 6 and assigning point deductions as shown in Table 7. Four examples demonstrate the procedure for rating available AWHC. The first step is to determine the AWHC for the entire profile. This can be calculated by determining dominant texture for each of the three principal horizons, then assigning the corresponding mm of water for the prescribed depth, in accordance with the last three columns in Table 6.

Profile AWHC can also be determined by summing the AWHC for each soil layer of differing texture (ie. depth (cm) x mm/cm water, as shown in the first column of numbers in Table 6).

Important assumptions:

1. Water supply is the single most important factor in determining forest productivity and accounts for about half the contribution to tree growth. Hence 50 points, or percent, is used as the maximum deduction.
2. For sandy loams and coarser soils it was found that AWHC measured in the field is more closely related to field capacity measured at -10 kPa than to -33 kPa (Moskal and Leskiw 1998). Additionally, the demonstrated relationship between AWHC and tree growth supported this. Therefore, -10 kPa is used for sandy loam to sand textured soils.
3. Loams and finer soils are considered to be non-limiting in terms of AWHC. Consequently, ≥150 mm of AWHC in the profile is the threshold above which no deductions are made.

In the calculations, the profile AWHC is divided by 3. That is, 150/3 = 50, 50 subtracted from 50 equals no point deduction. Thus, with a profile AWHC of >150, there is no deduction. If profile AWHC is <150, then a deduction will likely result (eg. profile AWHC of 120, then 120/3 = 40, 40 subtract 50 equals a 10 point deduction).

The AWHC of LFH or peat horizons is not included in the calculations unless the litter or peat is incorporated (mixed with mineral soil) and classed as mineral soil (see Section 4.1.4 for distinction). The AWHC deductions are not made for natural or reclaimed organic soils with a shallow water table (<1 m) or a moisture regime that is subhygric or wetter. The footnotes below Table 6 indicate assumptions and recommended modifications. Adjustments should be reported when employed.

Table 6. Available water holding capacity based on texture: Subclass M.

Texture Natural and Reclaimed Soils		AWHC (mm)			
		mm/cm	TS mm/20cm	US mm/30cm	LS mm/50cm
-10 kPa[a] field capacity	Sand	0.8	16	24	40
	Loamy sand	1.1	22	33	55
	Sandy loam	1.4	28	42	70
-33 kPa field capacity	Loam, sandy clay	1.5	30	45	75
	Sandy clay loam	1.5	30	45	75
	Clay loam	1.7	34	51	85
	Silt loam, silt, Silty sand	1.8	36	54	90
	Clay	1.6	32	48	80
	Silty clay loam	1.6	32	48	80
	Silty clay	1.6	32	48	80
Soils with shallow water table (<1m): Assume no limitation **Soils with subhygric or wetter moisture regime: Assume no limitation**					

Tailings Sand

-10 kPa field capacity	Tailings sand	1.0	20	30	50

Peat-Mineral Mixes
1:1 to 1:4 vol. mix or more peat

-10 kPa field capacity	peat + LS or S	1.2	24	36	60
	peat + SL or finer	1.7	34	51	85

Stony or Gravelly modifier: *Deduct percentage of moisture equivalent to percentage volume of stones or gravel when >20% by volume, to nearest 10%. For example, in a sandy loam US with 30% gravel, adjust values by multiplying available moisture by 0.70. (29 instead of 42)*

[a]
1) For sandy loam and coarser soils AWHC = (-10 kPa) - (-1500 kPa)
2) For loams and finer soils AWHC = (-33 kPa) - (-1500 kPa)
3) In sand and loamy sand soils there often are about 1 cm thick, horizontal, clay enriched bands about 15 to 20 cm apart in the subsoil. Where these occur, it is recommended that AWHC be upgraded one textural class as the layering effects of the clayey bands will increase water retention. This should be noted when rating soils and tested further to confirm the impact of this phenomenon.
4) Likewise, consider upgrading sand, loamy sand, and sandy loam AWHC by one textural class in the overlying horizons when there is a relatively impermeable layer (bedrock, clay, tar sand) between 50 and 100 cm. This requires further testing and should be noted and justified (with tree productivity measurements) in the meantime.

Sources: T. Moskal M.Sc. research project in progress, and Appendix.

Table 7. Deductions for available moisture holding capacity.

	Horizon	Dominant Texture	Water (mm)
Topsoil 0 to 20 cm	TS	________	a)________
Upper Subsoil 20 to 50 cm	US	________	b) ________
Lower Subsoil 50 to 100 cm	LS	________	c)________
Total 0 to 100 cm			________

$$\text{Point Deduction} = 50 - \left(\frac{a+b+c}{3}\right) = \_\_\_\_\_\_\_\_\_\_,\ \text{or,}$$

$$\text{Point Deduction} = 50 - \left(\frac{layer1....layer5}{3}\right) = \_\_\_\_\_\_\_\_\_\_$$

Examples:

1. LFH
   TS = SL = 28
   US = CL = 51
   LS = CL = 85
   Total = 164
   Deduction = 50 - 164/3 = -5 or 0 Points

2. TS = peat + LS = 24
   US = Tailings sand = 30
   LS = Tailings sand = 50
   Total = 104
   Deduction = 50 - 104/3 = 15 Points

3. 10 cm peat + SL = 17
   60 cm CL = 102
   30 cm Tailings sand = 30
   Total = 149
   Deduction = 50 - 149/3 = 0 Points

4. 20 cm peat + LS = 24
   20 cm SL = 28
   20 cm CL = 34
   20 cm L = 30
   20 cm SCL = 30
   Total = = 146
   Deduction = 50 - 146/3 = 1 Point

4.1.2 Structure/Consistence: Subclass D

Structure, the aggregation of soil particles, is important to infiltration, water permeability, aeration and tilth. It is described in terms of the size and shape of aggregates, and it is influenced by texture and organic matter content. Consistence, refers to resistance to crushing, which depends on stability of aggregates, bulk density and compactness. Relationships between structure, consistence, texture, bulk density and deductions for plant growth are shown in Table 8 and additional information is given in the Appendix. This factor is restricted to a maximum 25 point deduction in the topsoil rating because management can modify surface features in site preparation of soils. Note that in natural undisturbed soils there is usually no deduction if the litter or peat is in place, unless there is severe compaction or the consistence is loose (sand texture).

Notes for Table 8:

- Examine the surface 20 cm mineral horizon. No deductions for organic layers.
- Rate the most limiting structure or consistence. For layered, bedded materials, or compacted materials that have firmer/harder consistence, rate the most limiting part of a layer.
- Perviousness, compaction and rooting provide supporting evidence to rate the conditions. Perviousness is the capacity of the soil to transmit air and water. Surface runoff and erosion imply a structure limitation.
- Aggregation is determined by dropping a mass of soil (spade full) one metre onto a hard surface (plywood), and visually estimating the dominant size category of aggregates or soil clods.

Table 8. Topsoil structure and consistence categories and deductions in 0 to 20 cm surface.

Structure	Perviousness	Compaction	Rooting	Point Deduction
Dominant soil aggregates <1 cm diameter; Consistence very friable/soft or friable/slightly hard or firm/hard.				
granular, platy, subangular blocky, fine blocky,	rapid to moderate, many continuous cracks, pores	none, slight	normal, non-limiting	**0**
This category equivalent to/includes mellow, Ah, Ahe, Ae, AB and some Bt horizons. If topsoil does not meet above criteria, proceed to category below, and so forth. If there is a natural leaf litter or peat on the surface the mineral horizon usually fits this category. Organic horizons have no deductions.				
Dominant soil aggregates <1 cm in diameter; Consistence loose/loose.				
single grain, sands, tailings and	rapid many inter grain cracks	none, slight	normal non-limiting	**10**
This category is equivalent to/includes many Ae, Bm horizons. Even if there is litter or peat on the surface, but the mineral soil is loose sand, deduct 10 points.				
Layered topsoil with dominant soil aggregates <1 cm over >1 cm diameter; Consistence friable/slightly hard or better over firm/hard or tougher.				
restricting layer at 10 to 16 cm.	rapid to moderate, over slow	none, slight over severe	not restricted over restricted	**10**
restricting layer at 4 to 10 cm	same	same	same	**15**
This category is intermediate to be used where topsoils are less than 16 cm deep. If >16 cm, round off as 20 cm.				
Dominant soil aggregates >1 cm in diameter; Consistence firm/hard.				
cloddy, blocky, massive	slow, few cracks, pores	severe	restricted root mats, compressed roots, along cracks/peds	**20**
Dominant soil aggregates >1 cm in diameter; Consistence very firm/very hard.				
as above	as above	as above	as above	**25**
These categories are equivalent to many Bt, C horizons exposed at the surface.				

4.1.3 Organic Carbon: Subclass F

All topsoil should be salvaged. Topsoil, and especially organic carbon (humus, litter or peat), is a very important component, contributing to biological activity, the nutrient pool (mainly nitrogen), structure, infiltration, AWHC, CEC, and resistance to erosion.

Total organic content is measurable in the laboratory or in many cases it can be estimated by soil colour and feel. In mineral soils with stable organic matter, the "value" component (the darkness or gray component) of the Munsell Soil Colour notation correlates well with percentage organic carbon in a dry soil as shown in Table 9. Where the A horizon is less than 20 cm thick the dry colour of the upper 20 cm layer is used to estimate the organic carbon content. In the absence of a dry colour, increase the "value" of a moist colour by 1 unit to approximate the dry value (suggest this relationship be tested and supporting documentation be provided when this approach is used). In sands and loamy sands with less than about 3% OC, the dry colours tend to overestimate OC content. Laboratory verification is recommended to calibrate field estimates of OC content.

In agricultural organic soils in California, subsidence of 8 cm per year has been observed (Maki 1974). However, in drained forested organic soils in North Carolina, subsidence appears minimal after 30 years, after the initial compression of the fibric surface, which is desirable (Maki 1974). In forested land, litter or peat decomposition appears to be very slow, therefore, the natural, undisturbed organic litter or surface peat layer is included in determining organic carbon mass per hectare. The organic carbon in decaying wood is not included in the calculation procedures because LFH measurements do not take these sources into account. The OC in decaying wood often amounts to more than 30 t/ha in mature forests and can be a significant nutrient source in sandy soils.

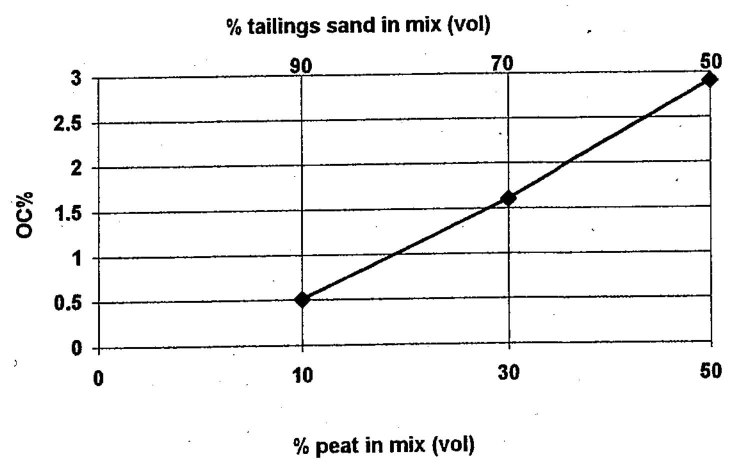
In soils with added organic amendments (litter, peat, compost, straw, wood chips, etc.) the organic carbon content can be analyzed, but this organic material may decompose over time, especially if not mixed with mineral soil, resulting in less total organic carbon in the longer term. Experience over 15 years at Suncor and Syncrude indicates little breakdown of peat amendments when mixed with soil. Furthermore, the reclamation process in the Oil Sands Region is such that peat, when excavated, is overstripped and mixed with mineral soil. This results in a mineral soil rich in peat when placed on the reclaimed landscape. In such reclaimed soils, the “litter or peat” carbon is incorporated and is included in the calculation of OC mass. However, if the peat is loose on the surface, it is prone to burning or decomposing rapidly. In this case it is considered to be unstable and is not counted in the OC pool. An example would be the placement of pure peat (≧ 17% organic carbon by weight) over mineral soil without any incorporation. If there is a shallow water table (<1 m) and the peat is not likely to burn or decompose rapidly, the OC mass could be counted (explain justification if using this approach). It is desirable to add woody debris or extra peat to compensate for "decaying wood" and maintain overall OC levels in the ecosystem.

For natural soils, to calculate OC deduction, determine the total organic carbon in the natural litter plus A horizon based on material-depth relationships shown in Table 9. For example, an LFH 6 cm thick and a 20 cm Ae with dry colour value 6 have 30 plus 20 t/ha of OC, totaling 50 t/ha. Figure 3 shows the relationship between peat-tailings sand mixes (volume basis) and organic carbon content. This is based on the replaced peat having an OC = 9.5%, which is typical for field operations. Read Figure 4 to determine deduction, zero in this example.

Table 9. Estimation of topsoil organic carbon equivalent of natural and amended soils.

			Equivalent Categories (Natural horizons)			
OC t/ha	Dry Colour Value of A	Ae, Ah or Ahe (20 cm) OC	LFH (cm)	Of (cm)	Om (cm)	Oh (cm)
10	7	0.5%	2	4	2	1.5
20	6	1.0%	4	8	4	3
30	5.5	1.5%	6	12	6	4
40	5	2.0%	8	16	8	5.5
50	4.5	2.5%	10	20	10	7

Note: These values for natural horizons are based on approximate bulk densities of LFH = 0.14, Of = 0.07, Om = 0.14, Oh = 0.21 g/cm³, and OC = 35%



Source: Macyk and Turchenek 1995

Figure 3. Relationship between peat-tailings sand mixes and organic carbon content.

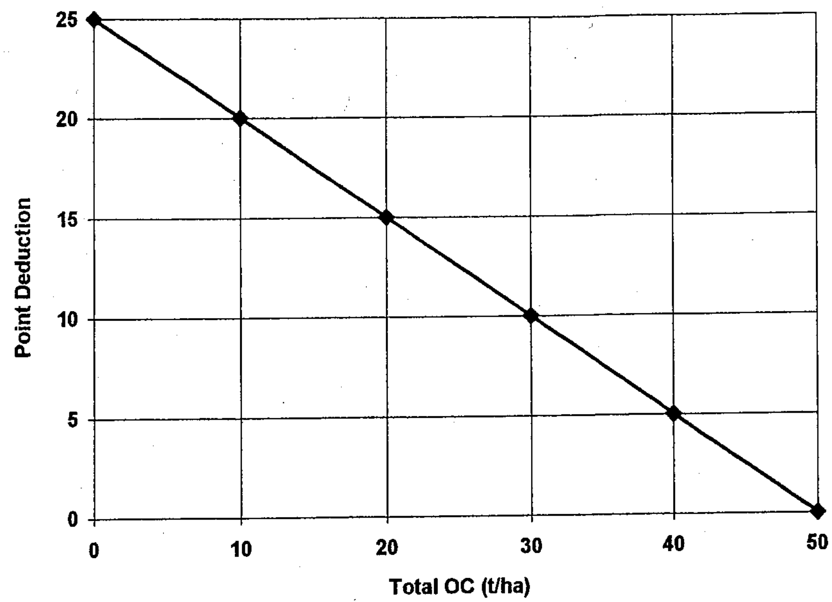


Figure 4. Topsoil organic carbon deductions.

4.1.4 Organic (Peat) Surface: Subclass O

Deep organic surfaces, when exposed, present special risks and management problems related to the degree of decomposition of the peat and depth of organic material. Well decomposed (dark coloured, mesic to humic, sedge) peats, well compacted with a granular structure are the most favorable. Least favorable are the raw (light coloured, fibric, moss) peats which are porous. Peaty (surface peat) mineral soils grade to Organic soils (deep peat) when the depth of humic or mesic peat exceeds 40 cm (>60 cm if fibric peat). In reclaimed soils it is desirable to mix some mineral material with the peat.

Surficial peat is advantageous for erosion control, improving infiltration, surface temperature modification and nutrient supply. Too much peat hampers germination, seedling development, insulates the soil making it colder, and is a fire hazard. Table 10 indicates point deductions for increasing thicknesses of "pure peat", not a peat-mineral mix. When deducting points note:

- Natural peats = deduct points as per Table 10
- Reclaimed peats (no mineral mix) = deduct points as per Table 10
- Reclaimed peats with mineral mix = no deduction (this is normal practice in the Oil Sands Region, or in other reclamation where litter is removed with the Ae horizon).

Mineral soil is heavy compared to organic material and significantly increases bulk density. Bulk density gradually trends upward from no mineral content towards a mineral content of 65% (weight basis), and rises very rapidly above a mineral content of 85% (weight), (Lynn et al. 1974). The transition zone between 65 and 85% corresponds roughly to the taxonomic transition between organic and mineral soils. The limits selected for differentiating peat and peat-mineral mixes in this report are based on the Canadian System of Soil Classification. Peat is defined as having ≥17% organic carbon (30% organic matter) by weight. This corresponds to approximately >80% peat by volume (based on relationship provided by Lynn et al. 1974). This also corresponds to a bulk density of approximately 0.30 g/cm^3.

Table 10. Point deduction for organic (peaty) surfaces.

Depth of Peat[a] (cm)	Points Deducted
≤20[b]	0
30	10
40	20
50	25
≥60	40

[a] Peat is defined as ≥17% OC by weight, or >80% peat by volume, or a density <0.30 g/cm^3.
[b] Round off to nearest 10 cm.

4.1.5 Soil Reaction: Subclass V

A slightly acid condition is the ideal situation for a balanced nutrient supply (Table 11). Soil reaction deviating from slightly acid lowers forest production so percentage deductions are made accordingly (Table 12).

Soils more acidic than pH 5.0 cause lower productivity. At pH levels below 4.0 some elements may be present in toxic quantities. High pH or alkaline conditions also affect plant response but they are usually associated with saline or sodic conditions. Values above 8.5 only occur if there is a relatively high sodium content associated with a low lime content, a situation rare in Alberta. Where a deduction is made for salinity or sodicity no deduction is made for high pH values (to avoid a double penalty). Seasonal variation in soil pH is in the order of 0.5 units. Note that values of 8.0 are given a 20 point deduction. This is probably appropriate for conifers, but it may be harsh for pure poplar stands. Interpretation of the literature suggests that pine is more sensitive to high pH, and that white spruce and poplar are quite tolerant to pH levels of 7.5 to 8.0. Different point deductions for different species may be justified pending further research.

Table 11. Relationship between pH and tree growth.

Reference	pH	Tree Species	Comments
Ballard 1980 (Washington, USA)	4.8-5.5	Conifers	- associated with good conifer seedling growth
Cochran 1984 (Oregon, USA)	8	Lodgepole pine	- appears to limit its existence
Dickmann and Stuart 1983 (Eastern North America - USA)	5.5-7.5 <4.5, >8.5	Poplars Poplars	- best conditions - worst conditions
Dix and Swan 1971 (Saskatchewan)		White spruce, Black spruce, and Aspen poplar; Jack pine Balsam poplar	-tolerate wide range in pH -prefers lower pH (<5.3) -prefers higher pH (>7.2)
Dumanski et al. 1973 (West Central Alberta)	5.1-5.5 - decrease by 25% 5.6-6.0 - No adjustment 6.1-6.5 - decrease by 20% 6.6-7.3 - decrease by 30% 7.4-7.8 - decrease by 40% 7.9-8.4 - decrease by 50%	Lodgepole Pine	- optimal soils for Hinton-Edson Region
International Poplar Commission, FAO 1979 (Europe)	4.5-4.6	Poplars and Aspen	- will accommodate themselves to a degree of acidity of 4.5-4.6
Monenco 1983 (Northeast Alberta)	4.8-7.0	Jack pine	- minimal pH for starter soils
Monenco 1983 (Northeast Alberta)	4.7-6.5	Mixedwood	- minimal pH for starter soils
Ontario Ministry of Natural Resources 1984 (Ontario, Canada)	5.2-8.5	Cottonwood-type Hybrid	- positive relationship between pH and growth - preference for more basic soils - poorer growth below pH 5.5

Table 12. Surface soil reaction deductions.

Topsoil pH (H_20)[a]	Topsoil pH ($CaCl_2$)[a]	Percent Deduction
≥9.0	≥8.5	80
8.5	8.0	40
8.0	7.5	20
7.5	7.0	10
5.0-7.0	4.5-6.5	0
4.5	4.0	10
4	3.5	20
3.5	3.0	40
≤3.0	≤2.5	80

[a] Round off to nearest 0.5 units, pH (H_20) is the regulatory standard.

4.1.6 Salinity: Subclass N

Salinity refers to the presence of excessive amounts of soluble salts such as sodium and magnesium sulphates (chlorides usually associated with brine). Salinity affects tree growth through chemical effects of salts as well as reduction of water availability to plants. Salinity is expressed in terms of electrical conductivity (EC) and is measured in the field or laboratory. Table 13 outlines the relative annual growth of common trees based on percentage growth decrease with increasing EC (McKenzie 1994). While it is recognized that some of these species will not be used in reclamation in Northern Alberta, they are included for reference as this is the best information found. Figure 5 shows the deductions for salinity based on findings reported in Table 13.

Table 13. Relative annual growth of common trees related to salinity.

	% Relative Annual Growth, EC (dS/m)										
Common Name	1	2	3	4	5	6	7	8	9	10	% Growth Decrease per dS/m Increase
Brooks Poplar	100	92	84	76	68	61	53	45	37	29	8
Siberian Larch	100	92	84	76	68	60	53	45	37	29	8
White Spruce	100	91	82	73	64	55	46	37	28	19	9
Scots Pine	100	91	81	72	63	53	44	35	25	16	9
Colorado Spruce	100	91	81	72	63	53	44	34	25	16	9
Acute Leaf Willow	100	91	81	72	62	53	43	34	24	15	10
Saskatoon	100	90	81	71	62	52	42	33	23	14	10
Northwest Poplar	100	90	79	69	58	48	38	27	17	6	10
Laurel Leaf Willow	100	89	78	67	57	46	35	24	13	2	11
Paper Birch	100	87	75	62	50	37	25	12	0	0	13
Mean	100	90.4	80.6	71	61.5	51.8	42.3	32.6	22.9	14.6	10

Source: McKenzie 1994.

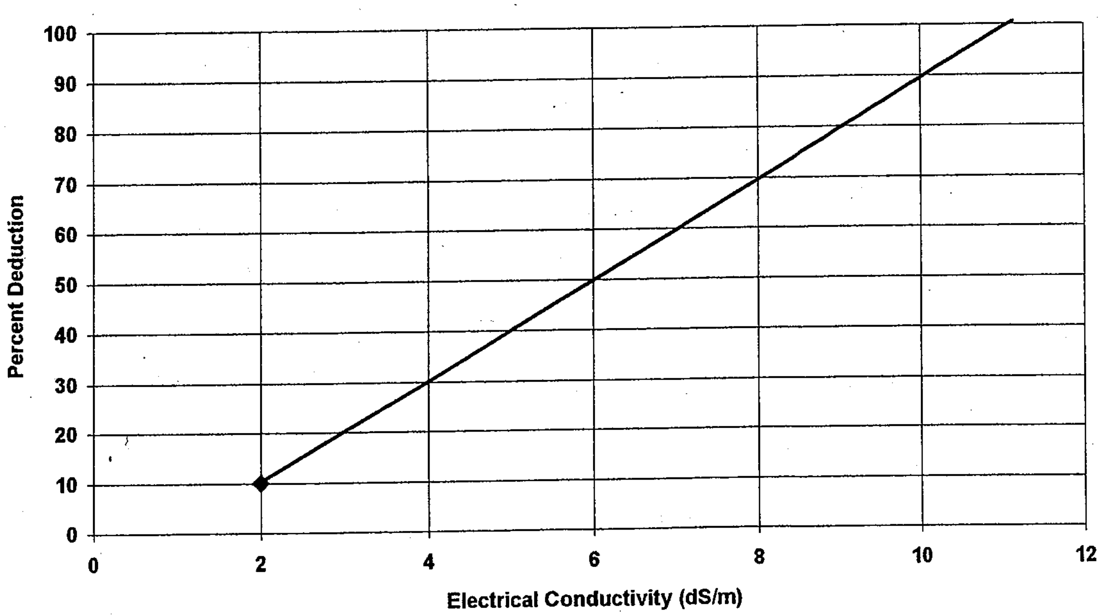


Figure 5. Topsoil salinity deductions.

4.1.7 Sodicity and Saturation Percentage: Subclass Y

As the sodium adsorption ratio (SAR) increases above 12 (usually associated with a pH over 8.5), the stability of soil aggregates decreases markedly. The finer soil particles, clays and organic matter, become dispersed resulting in adverse physical conditions (i.e., massive and sticky when wet and extremely hard when dry). Soil colour is darkened by organic staining.

Saturation percentage (Sat%) is closely associated with SAR in soils of loam or finer texture. In the evaluation of sodicity and saturation percentage only the most limiting of the two measurements is used (Figure 6). High saturation percentages may occur in non-sodic (SAR of 4 or less) soils with high organic matter content, if so, do not deduct points for saturation percentage. Also, if topsoil texture is coarser than loam, do not deduct SAR because the lack of clays should not result in a serious impact on soil structure. Caution is advised in assessing high SAR in sandy soils because trees may be sensitive to sodium, even if soil physical properties are not seriously affected.

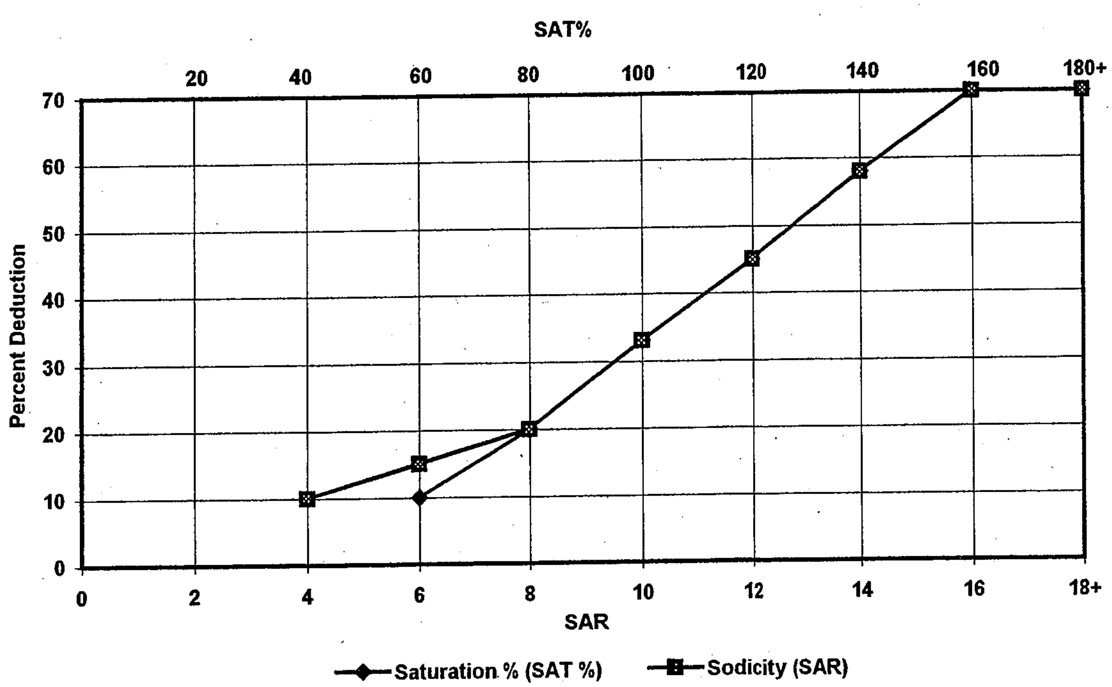


Figure 6. Topsoil SAR and saturation % deductions.

4.1.8 Nutrient Retention Capacity: Subclass K

The nutrient retention capacity is based on clay content, organic carbon content, cation exchange capacity, base saturation, and soil reaction. Some of these parameters along with potential acidification and aluminum solubilization are principal determinants in the rating of soil sensitivity to acidic inputs (Holowaychuk and Fessenden 1987). The nutrient retention capacity is inversely related to sensitivity to acidification, therefore some of the same categorical limits could be used. However, to ensure sustainability, given the potential for litter or peat to be burned off or decomposed in time, this rating is also based on content of mineral clay and silt. Texture is employed in addition to parameters in Table 14 which could be significantly influenced by organic carbon. The texture and organic carbon content of the topsoil and upper subsoil layers are both considered to make comparisons among natural and reclaimed soils. Deductions for nutrient retention capacity are shown in Table 15.

Table 14. Criteria for rating the sensitivity of mineral soils to acidic inputs.

		Sensitivity			
CEC (cmol/kg)	pH ($CaCl_2$)	Base Loss	Acidification	Aluminum Solubilization	Overall Sensitivity
≤5	<4.6	H	L	H	H
	4.6-5.0	H	L	H	H
	5.1-5.5	H	M	H	H
	5.6-6.0	H	H	M	H
	6.1-6.5	H	H	L	H
	>6.5	L	L	L	L
6-15	<4.6	H	L	H	H
	4.6-5.9	M	L	H	M
	5.1-5.5	M	L-M	M	M
	5.6-6.0	M	L-M	L-M	M
	>6.0	L	L	L	L
≥16	<4.6	H	L	H	H
	4.6-5.0	M	L	H	M
	5.1-5.5	M	L	M	M
	5.6-6.0	L	L-M	L-M	L
	>6.0	L	L	L	L

cmol/kg or me/100 g, H = High, M = Moderate, L = Low

Source: Holowaychuk and Fessenden 1987.

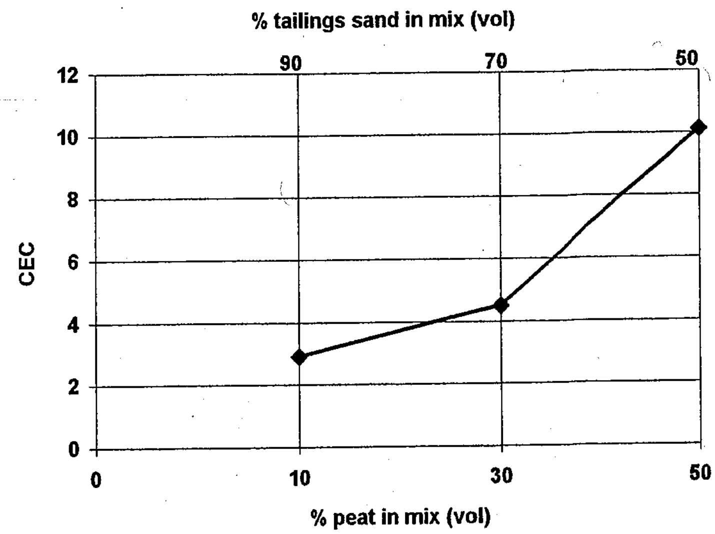


Figure 7. Relationship between peat/tailings sand mixes and cation exchange capacity. (Source: Macyk and Turchenek 1995.)

Table 15. Topsoil nutrient retention categories and deductions.

Nutrient Retention Capacity	Topsoil/ Upper Subsoil Texture Combinations			Percent Deduction	
	Mineral Soils			<4% OC	≥4% OC
Low	S/SL, SL/S	S/LS, LS,S	S/S, LS/LS	20	10
Medium	SL/ SL	SL or finer/LS,S	LS/SL or finer	10	5
High	SL or finer/finer than SL	finer than SL/SL or finer		0	0
	Peat Soils (≥17% OC by weight)				
	Exchange Bases	pH ($CaCl_2$)	% Base Sat	Percent Deduction	
Low	≤5	≤4.5	≤40	20	
Medium	6-15	4.6-5.9	41-80	10	
High	≥16	≥6.0	≥81	0	

An easier rating approach is: Let S = 1, LS = 2, SL = 3, other textures = 4, then, for < 4% OC, if sum TS +US ≤ 4, deduct 20; if sum = 5 or 6, deduct 10; if sum ≥ 7, no deduction. Deductions are 10, 5, 0, respectively for ≧ 4 % OC.

Use finest texture >10 cm thickness in calculation.

Rate peat soils according to dominant identical categories (e.g. 2 or 3 mediums are rated medium) or assign mean value where three levels occur (e.g. low, medium, high is rated medium).

4.2 SUBSURFACE FACTORS

Subsoil is divided into upper (20 to 50 cm) and lower subsoil (50 to 100 cm). A relative weighting of 2:1 or 67:33% is assigned to these layers, respectively, in calculating the deductions for subsoils.

1. upper layer deductions X x 0.67 = adjusted rating where X = most limiting deduction for upper subsoil layer
2. lower layer deductions Y x 0.33 = adjusted rating where Y = most limiting deduction for lower subsoil layer

Subsurface factors are modifiers to the surface rating and are managed as percentage reductions of the primary rating. A depth of 100 cm matches that used for rating undisturbed soils and is considered to be the effective rooting zone. Four factors are recognized in this category for both upper and lower subsoils. They are structure and consistence, acidity, salinity and sodicity. Only the most limiting is deducted.

4.2.1 Subsoil Structure: Subclass D

Structure and related properties affect root penetration and the availability of water, air and nutrients to plants. The ratings are subjective, based mainly on the abundance and size of reasonably stable soil aggregates and consistence (Table 16). Perviousness, compaction and rooting patterns also aid in rating subsoil structure.

The causes, impacts, and amelioration of compaction of forest soils as related to forest harvesting practices on natural soils are described in a very practical manner in a Workshop Manual (McNabb 1993). Additional references by McNabb (1992a, 1992b), McNabb and Froehlich (1983), and McNabb and Campbell (1985) provide substantial relevant scientific data.

Table 16. Subsoil structure and consistence.

Structure	Perviousness	Compaction	Rooting	Percent Deduction
Dominant soil aggregates <2 cm diameter; Consistence very friable/soft or friable/slightly hard or firm/hard				
crumb, fine, medium subangular blocky, single grain, tailings sand	rapid to moderate, many continuous cracks, pores	none, slight	normal, non-limiting	**0**
This category equivalent to/includes AB, Bm, Btj, and many Bt, BC and C horizons. If subsoil does not meet above criteria, proceed to category below, and so forth.				
Dominant soil aggregates <2 cm in diameter; Consistence very firm/very hard.				
medium angular & subangular-blocky.	moderate, common continuous cracks, pores	moderate	slightly restricted	**10**
This category is equivalent to/includes many Bt, Btnj horizons.				
Dominant soil aggregates 2 to 10 cm in diameter, firm/hard.				
coarse, very coarse subangular-blocky & angular blocky, medium prismatic	moderate, common continuous cracks, pores	moderate-severe	moderately restricted	**20**
This category is equivalent to/includes many Bt, Btnj, C horizons.				
Dominant soil aggregates 2 to 10 cm in diameter, very firm/very hard.				
cloddy, prismatic, columnar.	slow, few cracks, pores	severe	restricted root mats, compressed roots, along cracks/peds	**30**
This category is equivalent to/includes many Bnt, Bn, C horizons.				

Continued...

Table 16. Concluded.

Structure	Perviousness	Compaction	Rooting	Percent Deduction
Dominant soil aggregates 10 to 30 cm diameter, very firm/very hard.				
cloddy, columnar, massive.	very slow, very few cracks, pores	severe-extreme	roots along cracks only	**50**
This category is equivalent to/includes some Bnt, many C horizons.				
Soil is massive, aggregates >30 cm diameter, extremely firm/extremely hard.				
massive, bedded.	very slow, very few cracks, pores	extreme	no roots, root mat above restricting layer	**70**
This category results from compaction as in roads, heavy traffic areas, and includes soft bedrock deposits. This material can be augered with difficulty.				
Consolidated material that is massive, >30 cm sized blocks, extremely firm/extremely hard.				
cemented, bedrock, nonsoil.	impervious, no cracks, no pores	extreme	no roots, root mat above restricting layer	**90**
This category includes hard bedrock deposits, buried concrete, etc. This material cannot be augered.				

Notes:
- For layered, bedded materials, or compacted materials that have firmer/harder consistence, rate the most limiting part of a layer. Rate the most limiting structure or consistence.
- Perviousness, compaction and rooting provide supporting evidence to rate the conditions. Perviousness is the capacity of the soil to transmit air and water.
- Aggregation is determined by dropping a mass of soil (spade full) one metre onto a hard surface (plywood), and visually estimating the dominant size category of aggregates or soil clods.

4.2.2 Subsoil Reaction: Subclass V

Subsoil pH levels have the same effects on nutrient availability and tree growth as in the surface layer. Deductions are made as shown in Table 17.

Table 17. Subsoil reaction deductions.

Subsoil pH (H_20)[a]	Subsoil pH ($CaCl_2$)[a]	Percent Deduction
≥9.0	≥8.5	80
8.5	8.0	40
8.0	7.5	20
7.5	7.0	10
5.0-7.0	4.5-6.5	0
4.5	4.0	10
4	3.5	20
3.5	3.0	40
≤3.0	≤2.5	80

[a] Round off to nearest 0.5 units, pH (H_20) is the regulatory standard.

4.2.3 Subsoil Salinity: Subclass N

A subsoil salinity deduction is made regardless of the surface or topsoil condition. Deductions are identical to those for topsoil salinity, and are repeated here (Figure 8).

4.2.4 Subsoil Sodicity and Saturation Percentage: Subclass Y

Only the most limiting of SAR or Sat% is deducted. Figure 9 indicates the percent deductions for the various SAR and Sat% classes. If soil texture is coarser than loam, an SAR deduction is not made.

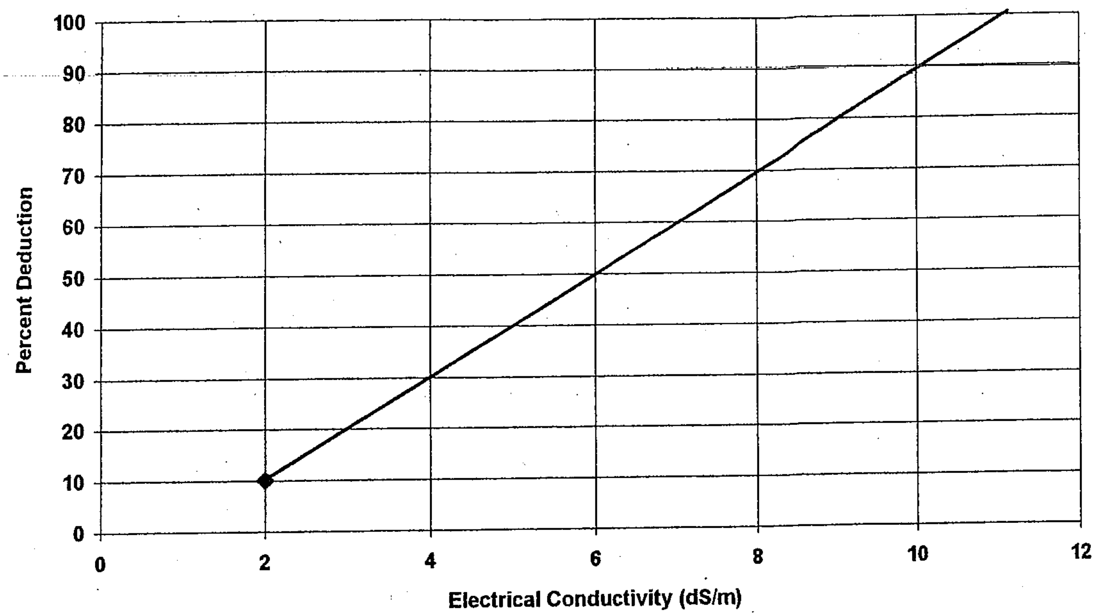


Figure 8. Subsoil salinity deductions.

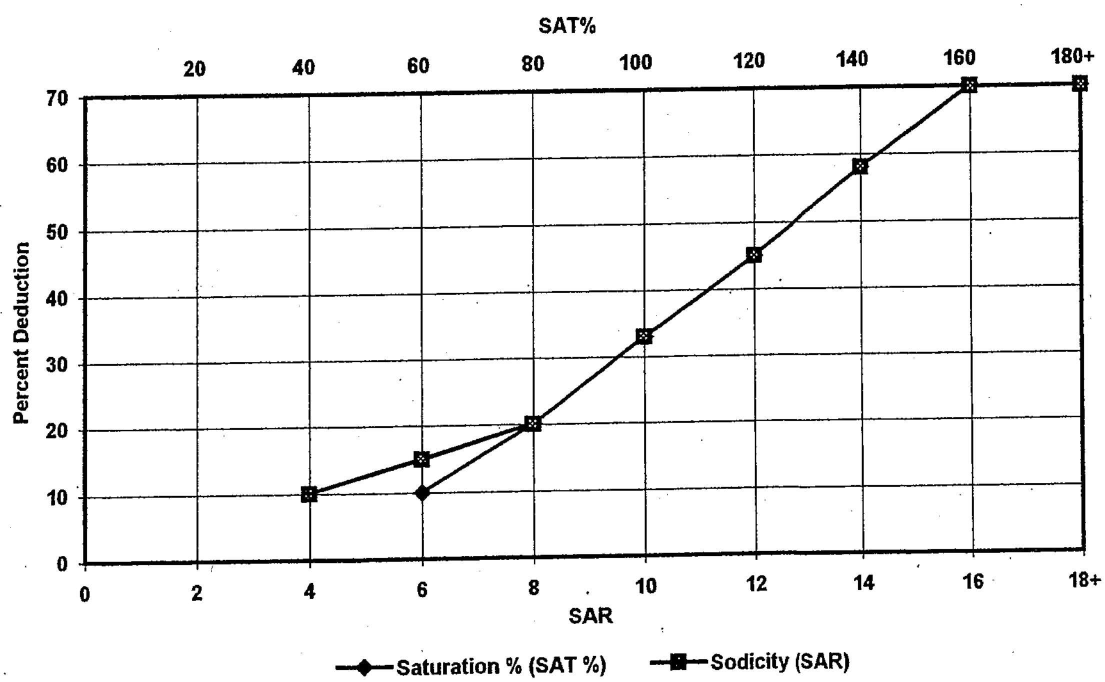


Figure 9. Subsoil SAR and saturation percent deductions.

4.3 EDAPHIC REGIME

The final step of the soil rating procedure links the moisture and nutrient regimes with the interim soil rating, and may increase, not change, or decrease the final soil rating. The amount of water available to plants is a function of AWHC as well as slope configuration, aspect, water table and regional climate (as reflected by Ecoregion). For example, limited soil moisture storage, inhibited rooting or other restrictions are all magnified in a drier climate. On the other hand, lateral seepage, a shallow water table or accumulation of runoff from elsewhere enhances moisture supply. A nine class moisture regime is presented, matching moisture regime categories used in forest site classification (Table 18). Moisture regime in this context refers to water supply to the root zone, either excess or deficiency. In evaluation of excessive wetness, the main factor considered is water table level during the growing season and this can be measured or inferred from vegetation and soil colour. The various categories presented are a guide to determining moisture regime, not all conditions (columns) have to be met For example, a shallow loam over impermeable bedrock on a ridge could be xeric. Table 19 illustrates the optimal and limiting water table levels for tree growth, based on a review of the literature.

4.3 1 Moisture Regime

A moisture/nutrient grid displays the potential ranges of relative moisture (very xeric to hydric) and nutrient (poor to rich) conditions and presents the corresponding multipliers (Table 20) The grid multipliers presented in Table 20 are primarily related to moisture regime In natural soils, the drier ecosite types are usually considered to be low to medium in nutrient regime, while in wetter sites they range from low to rich. In reclaimed soils all conditions are possible. In practice to date, mineral soils with low OC levels (<4%) are considered to have low nutrient levels whereas enriched OC levels (>4%) and peat-mineral mixes are considered to have a medium nutrient regime. Rich nutrient regimes are not assigned because of a wide C.N ratio limiting availability of nitrogen. In time, a rich nutrient regime may develop at some locations More discussion is presented in the next section.

Table 18. Characteristics of moisture regime classes.

Moisture regime	Description	Primary water source	Topographic position	Effective texture[a]	Soil drainage	AWHC[b] (mm/100 cm profile)	Surface organic thickness	Slope and aspect
Very xeric (1)	Water removed extremely rapidly in relation to supply; soil is moist for a negligible time after precipitation	Precipitation	Ridge, crest, shedding	Very coarse (gravel-S); abundant coarse fragments (>50%)	Very rapid	<20	(<3 cm)	(>30%) southerly aspect
Xeric (2)	Water removed very rapidly in relation to supply; soil is moist for brief periods following precipitation	Precipitation	Ridge, crest, shedding		Very rapid to rapid	<60	(<3 cm)	(>30%) southerly aspect
Subxeric (3)	Water removed rapidly in relation to supply; soil is moist for short periods following precipitation	Precipitation	Upper slope, shedding	Coarse to moderately coarse (LS-SL); moderate coarse fragments	Rapid	<100	(<3 cm)	(>15%) southerly aspect
Submesic (4)	Water removed readily in relation to supply; water available for moderately short periods following precipitation	Precipitation	Upper slope, shedding		Rapid to well	<140	(3-5 cm)	(2-30%) variable aspect
Mesic (5)	Water removed somewhat slowly in relation to supply; soil may remain moist for significant but sometimes short periods of the year; available soil water reflects climatic input	Precipitation in moderate to fine-textured soils and limited seepage in coarse-textured soils	Midslope rolling to flat	Medium (SiL-L) to fine (SCL-C); few coarse fragments	Well to moderately well	>140	(6-9 cm)	(2-30%) variable aspect
Subhygric (6)	Water removed slowly enough to keep the soil wet for a significant part of the growing season; some temporary seepage and possible mottling below 20 cm	Precipitation and seepage	Lower slope, receiving	Variable depending on seepage	Moderately well to imperfect	>140	(10-40 cm)	(2-9%) variable aspect
Hygric (7)	Water removed slowly enough to keep the soil wet for most of the growing season; permanent seepage and mottling present (7 aerated); >50% gleying present within 50 cm (7 reduced)	Seepage	Lower slope, receiving	Variable depending on seepage	Imperfect to poor	Variable	(16-40 cm)	(2-5%)
Subhydric (8)	Water removed slowly enough to keep the water table at or near the surface for most of the year; organic and gleyed mineral soils; permanent seepage less than 30 cm below the surface	Seepage or permanent water table	Depression and level, receiving	Variable depending on seepage	Poor to very poor	Variable	(>40 cm)	(2-5%)
Hydric (9)	Water removed so slowly that the water table is at or above the soil surface all year; organic and gleyed mineral soils	Permanent water table	Depression and level, receiving	Variable depending on seepage	Very poor	Variable	(>40 cm)	(<2%)

[a] Symbols under effective texture are as follows: L = loam, S = Sand, Si = silt, C = clay
[b] Based on - 10 kPa field capacity in S to SL and - 33 kPa field capacity in finer soils (see Table 6).
Adapted from Luttmerding et al. 1990.

Table 19. Relationship between water table depths and tree growth.

Reference And Area Of Study	Water Table Depth (cm)	Tree Species	Comments
Dickmann and Stuart 1983 (Eastern North America - USA)	100 - 200 (best conditions) <300, >200 (worst conditions)	Poplar Poplar	
International Poplar Commission, FAO 1979 (Europe)	not given	Poplar	-development of plunging roots is limited by water table
Krumlik 1980 (Northeast Alberta)	25-75	Black Spruce	-on Fibric and Humic Organic Cryosols, Terric Humisols and Hydric Mesisols rooting depth is restricted by either frozen water or soil water level
Lowry 1972 (Boreal Forest of Canada)	100-300	Black Spruce	-optimum water table depth
Peterson and Peterson 1992 (Prairie Provinces, Canada)	100 - 250 (British Columbia) 70 - 200 (Lake States)	Aspen	-associated with good or excellent growth
Prichett and Fisher 1987 (USA)	45 90	Slash Pine	-grown for 5 years, those trees grown with a water table maintained at 45 cm were 11% taller than those with a water table maintained at 90 cm and 60% taller than those with a fluctuating water table
Prichett and Fisher 1987 (USA)	not given	General discussion in text	-frequent fluctuations of water table depth tend to restrict deep root development -high or perched water tables are not detrimental as long as there is little fluctuation -trees obtain moisture from the water table or capillary fringe with the reach of their deep roots, even when the water is at considerable depth
Strong and La Roi 1983a (Central Alberta)	10-30	Black Spruce	-most roots occurred 7 to 10 cm below ground level, just above the water table
Strong and La Roi 1983b (Central Alberta)	>100 cm on sand	Jack Pine, Balsam Fir, and Aspen	-use deep water sources to decrease water deficit on xeric sites -root development can be limited by a high water table
Alberta Environmental Protection (1996)	50 - 100cm (preferred depth) 50 - 150 cm (acceptable condition) > 150cm, <50 cm (severe condition)	Lodgepole Pine, White Spruce, Engelmann Spruce	

Table 20. Edaphic grid multipliers.

Moisture Regime		Nutrient Regime		
		Poor	Medium	Rich
Very Xeric 1		0.75	0.75	0.75
Xeric 2		0.75	0.75	0.75
Subxeric 3		0.75	0.75	0.75
Submesic 4		0.75	1.00	1.00
Mesic 5		1.00	1.00	1.00
Subhygric 6		1.25	1.25	1.25
Hygric 7	**aerated**	1.00	1.00	1.00
	reduced	0.50	0.50	0.50
Subhydric 8		0 25	0.25	0 25
Hydric 9		0.25	0.25	0.25

Multiply interim soil rating by above "multiplier" (percentage adjustment) to determine final soil rating.

4.3.2 Soil Nutrient Regime

The soil capability rating is designed to reflect sustainable forest productivity A stable, balanced nutrient supply integrated with moisture regime indicates the potential of the soil to support forest growth. Several soil parameters were evaluated to develop poor, medium and rich nutrient levels based on natural forest soil horizons LFH, O and A. Table 21 shows the determinative categories for carbon:nitrogen (C:N) ratio and total nitrogen (N) levels. Table 28 in the Appendix gives values for other nutrients. The data were collected from several sources (Can-Ag Enterprises Ltd. 1996, Kabzems and Klinka 1987, Pritchett and Fisher 1987, La Roi and Pluth 1986, Canstar 1982). The bulk densities and soil depth of each horizon are taken into account to calculate the topsoil/organic and/or mineral nutrient levels in kg/ha. These nutrient levels in each and total N values are the primary indicators reflecting nutrient status, to be used in selecting the appropriate "grid" in Table 20, in order to determine the percentage deductions or increases.

Table 21. Soil nutrient regime based on nitrogen.

Parameter (LFH or O + A horizons)	Poor	Medium	Rich
C:N	>30	20-30	<20
Total N (kg/ha)	<1000	1000-3000	>3000

Note: Rating is determined by most limiting category.
Sources: Can-Ag Enterprises Ltd. 1996; Kabzems and Klinka 1987, Canstar 1982; La Roi and Pluth 1986; Pritchett and Fisher 1987.

4.3.3 Relationship of Peat-Mineral Mix to Soil Rating Factors

For planning and capability evaluation purposes it is helpful to know the expected soil properties when different peat-mineral mixes are used.

Important relationships between organic carbon levels and ratings assigned to various soil components as part of the rating procedure are summarized in Figure 10. When evaluating AWHC (from Table 6), the peat-mineral mix water retention levels are applied to soils within the range of 1:1 to 4:1 peat:mineral soil mix.

Lower organic carbon or peat levels are treated as a mineral soil whereas higher peat levels are treated as organic soil. Ratings of nutrient retention are largely dependent on cation exchange capacity which, in turn, is dependent on clay and organic matter contents. As a guide, peat:mineral mixes of 1:1, or more peat, result in 4% or more organic carbon and are therefore assigned the lower deductions in Table 15. The 1:2 ratio, or 2% organic carbon level is used in distinguishing between low and medium nutrient regime levels (Table 20).

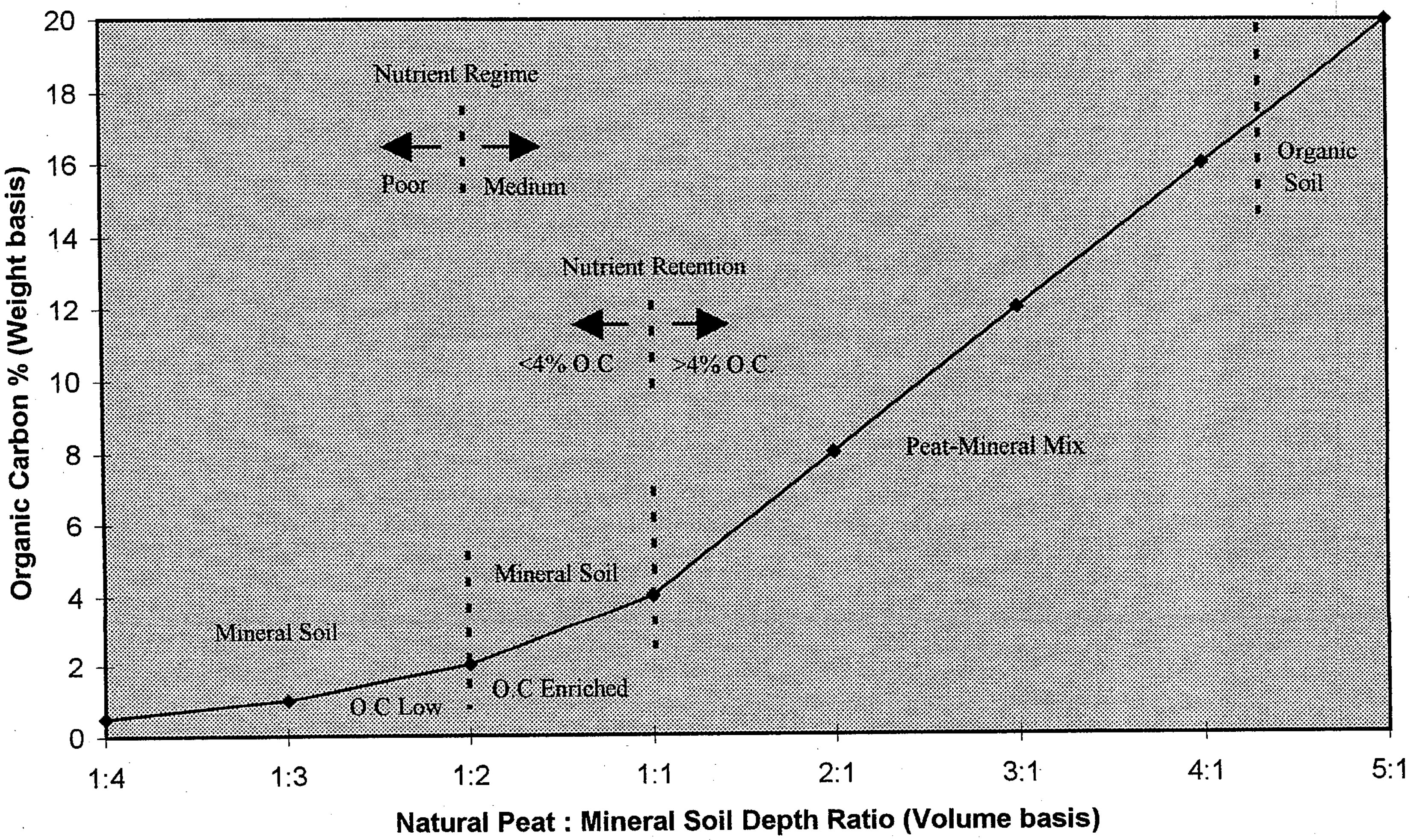


Figure 10. Relationship of soil properties to peat-mineral composition in the determination of ratings.

4.4 CALCULATION OF SOIL CAPABILITY

The Soil Capability Rating Form is used as follows:

1. Examine surface soil (or supplied information) and fill in a "value" for each parameter. Determine moisture availability based on texture of the upper 100 cm and calculate moisture deduction. Using the tables/charts in this section assign deductions to other factors.
2. From 80 subtract the point deductions for AWHC and the physical factors. Make the deduction for the most limiting chemical parameter and determine the basic soil rating.
3. Determine "values" for the subsoil factors for each subsoil horizon/layer, and deduct the most limiting only. Calculate weighted subsoil percentage deductions.
4. Basic soil rating - subsoil deductions = interim soil rating .
5. Determine moisture and nutrient regime and using the edaphic regime, multiply by interim soil rating to get final soil rating.
6. Place into a soil capability class using the classification index. Identify factors which resulted in a greater than 20 point or percentage deduction and assign the appropriate subclass symbol. For example, a 20 point organic carbon deduction and a 20 point soil structure deduction results in a rating of Class 3FD. A Class 2 soil may have no deductions except a moisture regime that is not subhygric. In such instances use of an R subclass is optional (2 or 2R) and the convention used should be indicated.

5.0 THE LANDSCAPE FACTORS

Landscape evaluation focuses on tree productivity as determined by steepness of slopes, as well as effects of slope position, aspect, stoniness, and erosion within the context of sustainable productivity. Topography determines the basic rating while exposure, stoniness, and visible erosion are modifiers.

5.1 SLOPE STEEPNESS (SUBCLASS T)

Slopes above 30% create increasing limitations to tree growth and erosion. The landscape capability classes reflect limitations to growth and are not linked to regulatory conditions.

In the Hinton-Edson region Dumanski et al. (1973) reported that optimal growing conditions for lodgepole pine were on 15-30% slopes, attributed to better drainage. In the Alberta Foothills they found that productivity did not decrease on slopes increasing to 60%. However on the Alberta Plains and Alberta Plateau Benchlands productivity began to decline on slopes exceeding 25 to 30%, while on sand and gravel declines occurred on slopes exceeding 20% (Dumanski et al. 1973).

This capability system applies to the Northern Forest Region where soil and overburden materials are unconsolidated and prone to slumping, sliding, etc. Steeper stable slopes occur in natural landscapes in the foothills and mountains, but there the soils are generally shallow over consolidated bedrock, and are more stable on steeper slopes. Taking forest growth, erosion, and slope stability into account, a relationship between slope and point deduction for the oil sands region was established, as shown in Figure 11.

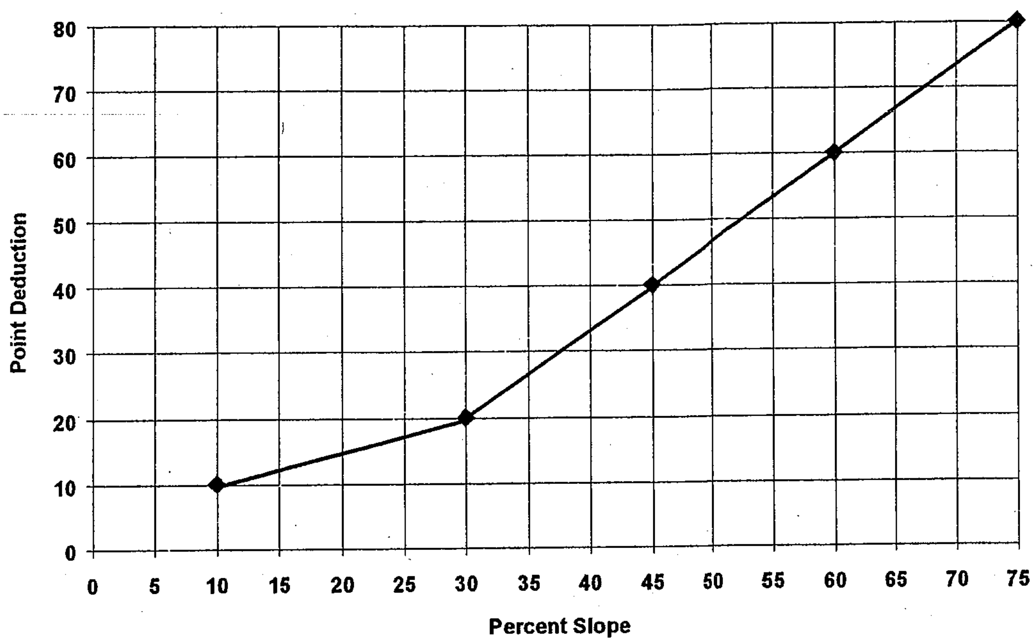


Figure 11. Point deduction related to slope steepness.

5.2 EXPOSURE

5.2.1 Slope Position

Average rainfall run-off, in percent, rises sharply with initial increase in slope to about 18% on a 10% slope, thereafter, increase in runoff is more gradual (Jones 1969). It follows that on a 20% slope, 21% is lost in run-off, and assuming little or no replacement at the slope crest position, 79% of the unit rainfall is retained. Farther downslope, the run-off is added to the unit rainfall; a 21% loss of this total leaves a retention of 0.96. This process continues downslope resulting in net accumulation at the foot of the slope, the amount depending on the steepness and length of the antecedent slopes. Where the water table is at or near the soil surface, run-off as a moisture factor becomes negligible.

Slope position is used on slopes exceeding 10%, to rate the landscape configuration with respect to potential (in reclaimed lands) or actual (in natural lands) impacts on moisture regime. The crests and upper slopes are downgraded by 10%, mid slopes are unchanged, lower to toe configurations are upgraded 10%, level areas are unchanged, and depressional areas prone to waterlogging are downgraded 10%. Consideration must also be given to convex or concave slopes within a slope. For example a convex site on the lower slope of a hill could be rated as an upper slope. Figure 12 depicts the slope positions. These are defined below and percentage modifiers used in the rating exposure are given.

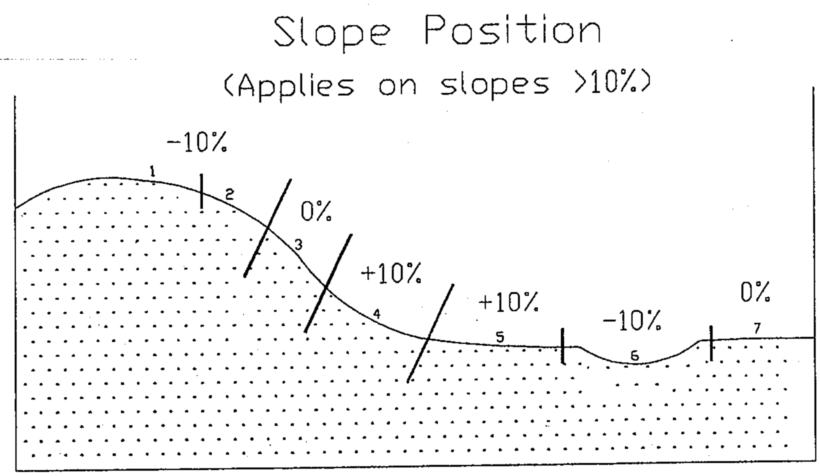


Figure 12. Slope positions and percentage change.

Use these adjustments on slopes >10%. The deduction for depressions applies to closed basins without a drainage outlet.

1. **Crest** - the upper most portion of a slope, shape usually convex in all directions with no distinct aspect. ***Deduct 10%.***
2. **Upper slope** - the upper portion of the slope immediately below the crest, slope shape usually convex with a specific aspect. ***Deduct 10%.***
3. **Middle slope** - the area of the slope between the upper and the lower slope where the slope shape is usually straight with a specific aspect. ***No deduction.***
4. **Lower slope** - the lower portion of the slope immediately above the toe, slope shape usually concave with a specific aspect. ***Upgrade 10%.***
5. **Toe** - the lower most portion of the slope immediately below or adjacent to the lower slope, slope shape concave grading rapidly to level with no distinct aspect. ***Upgrade 10%.***
6. **Depression** - any area that is concave in all directions, usually at the toe of the slope or within level topography. ***Deduct 10%.***
7. **Level** - any level area excluding toe slopes, generally horizontal with no distinct aspect. ***No deduction.***

5.2.2 Aspect

The effect of aspect on the moisture regime is an important consideration in ecosystem development. Slopes in excess of 20% are prone to excessive drying when they face the south-east to west, as illustrated in Figure 13. A deduction of 10% is assigned to south slopes. North slopes are more moist but the better moisture régime is offset by cooler temperatures so growth is not significantly affected. Recommended tree species may differ for south and north slopes. Note that this deduction can be added to a 10% slope position deduction resulting in an upper slope with a south-west aspect having a combined 20% deduction.

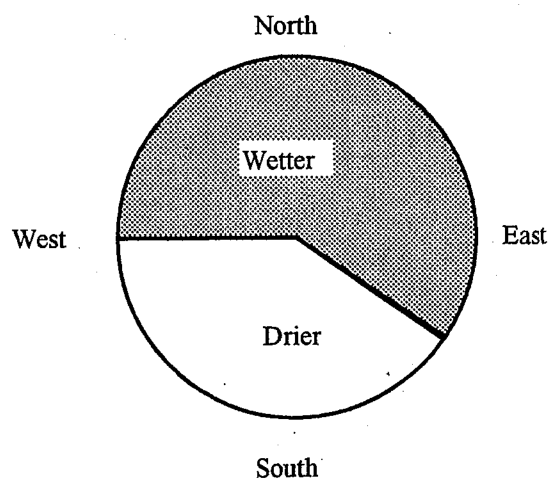


Figure 13. Aspect deduction 10% for drier slopes.

5.3 STONINESS FACTOR: SUBCLASS P

Stones (>10 cm), gravels (<10 cm), rock outcrops, and shallow depth to bedrock reduce soil rooting volume, and lower capability. Moisture retention is also affected, but it is rated under "soils", specifically, available water holding capacity. This section downgrades stoniness as a reduction to rooting volume and a limitation to soil management. Stoniness is rated as a percent deduction rounded to the nearest 10%, on a volume basis, with a minimum deduction of 20% (Figure 14).

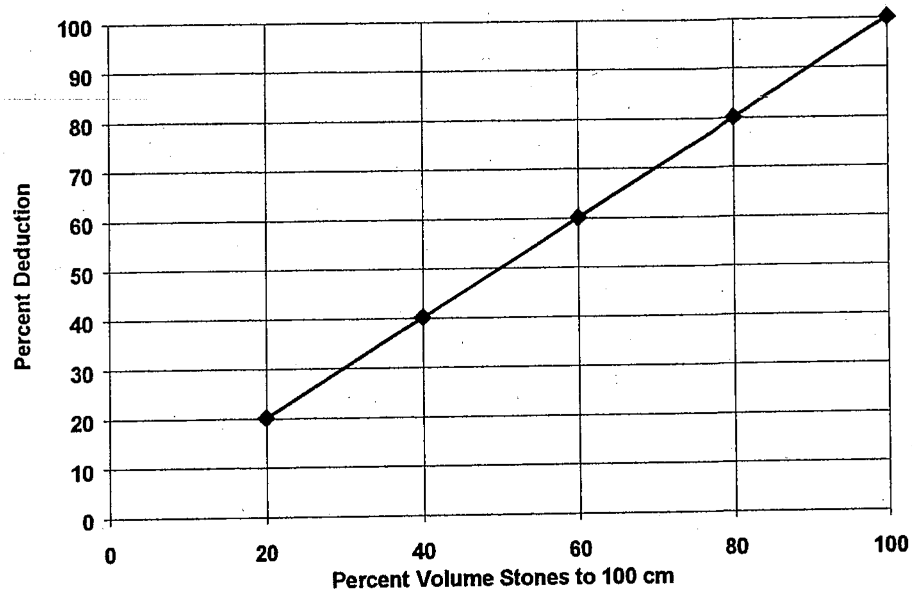


Figure 14. Relationship between stoniness and percent deduction.

5.4 EROSION FACTOR: SUBCLASS E

Erosion depends on length and steepness of slope, as well as timing, amount and intensity of precipitation, management practices, and kind and condition of soil. The erosion ratings in Table 22 refer to active visible rill and gully erosion. If there are rills or gullies, determine the number of years since reclamation, estimate volume of soil loss by rill and gully erosion, calculate average annual loss and assign the appropriate deduction (Table 22). To estimate erosion loss,

- select a representative 100 x 100 m square (1 ha) on a slope;
- establish a transect (A-A') across the middle of the "hectare", along the contour (perpendicular to direction of rills and gullies);
- tally number of rills and gullies and cross-sectional area of each in square decimetres (that is, estimated number of 10 x 10 cm "frames" per cross-section of rill or gully);
- total number of these "frames" equals soil loss in cubic metres per ha, assuming 100 m length of rills or gullies (see diagram following).

Figure 15 helps to illustrate two examples of this method of calculation. Example #1 (a line marked #1 representing rill or gully erosion) refers to a rill 30 cm wide at the top, 20 cm wide at the bottom, and 20 cm deep that has an approximate cross sectional area of 5 "frames", each 10 x 10 cm. Such a rill that is 100 m long represents a soil loss of 5 m^3. If six such rills formed in one year the annual soil loss would be 30 m^3/ha, which is a 40% deduction. Example 2 also illustrates the volume of soil loss using the “frame” method.

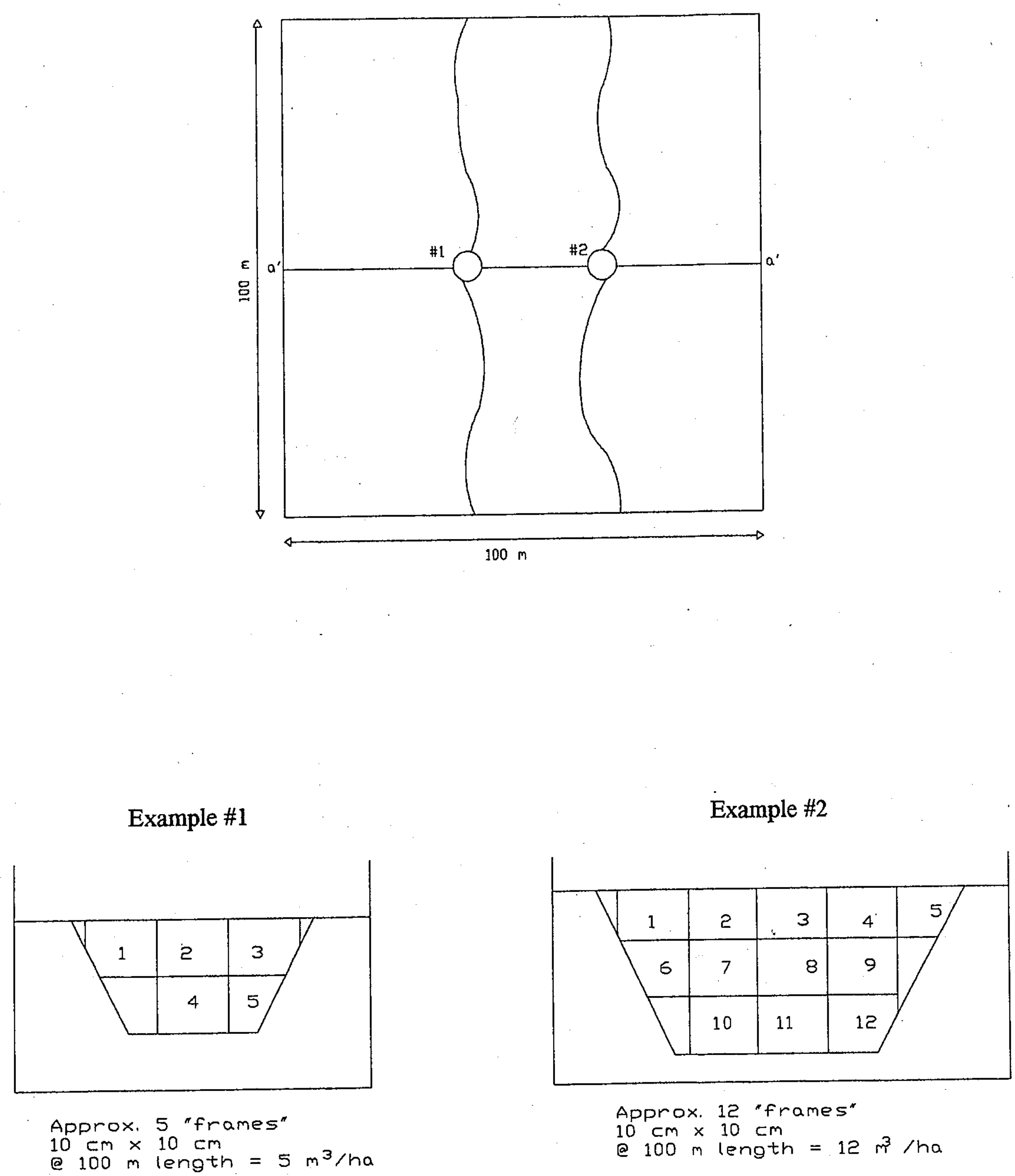


Figure 15. Erosion example calculations.

Table 22. Soil erosion categories.

Percent Deduction	Category	Annual Soil Loss (weight t/ha)	(volume m^3/ha)
0	None	<6	<4.4
10	Slight	6 - <11	4.4 - <8
20	Moderate	11 - <22	8 - <16
30	Severe	22 - <33	16 - <24
40	Very Severe	- 33 <55	24 - <40
50	Extreme	≥55	≥40

Note: Assume average bulk density of 1.35 g/cm^3.

5.5 CALCULATION OF LANDSCAPE CAPABILITY

Use the Capability Rating Form and:

1. Determine the average slope steepness and point deduction.
2. Assign the exposure rating and percent deduction.
3. Assign the stoniness/rock outcrop percent deduction.
4. Determine erosion category and assign percent deduction.
5. Calculate the final landscape rating.
6. Place the landscape factor into a capability class. Identify factors which resulted in a greater than 20 point or percentage deduction and assign the appropriate subclass symbol. For example, a final rating of 70 with 20 points deducted for slope (topography) and 10 points deducted for erosion is rated 2T.

5.6 MAPPING APPLICATIONS

In reports, land capability classes should show both the soil capability and landscape capability separately, as well as the combined capability (lower rating of soils or landscape factors).

On maps it is usually more convenient to show only the most limiting capability. Within map polygons there is variation in soils, landscapes and resultant capabilities. The following conventions are recommended in an effort to standardize procedures. Methods used in any given report should be explained. An 80:20 approach in referencing ratings of polygons is recommended, and an effort should be made to keep symbols simple.

Table 23. Mapping conventions to indicate purity of soil polygons.

Capability Class	Description of Soil Polygon Purity
1	≧80% of the polygon contains soils with a class 1 rating. The remaining soils are inclusions of poorer classes.
2 3 4	For classes 2, 3, and 4, ≧60% of the polygon contains soils within a given class. It is normally expected that remaining soils will span higher and lower capability classes. This implies a polygon designated class 3 contains at least 60% class 3 soils plus about 20% class 2 and 1 soils, thus 80% of the polygon is class 3 or better.
5	≧80% of the polygon contains soils with a class 5 rating. The remaining soils are inclusions of better classes.
Complexes (2-3)	If two different classes each make up 40 to 60% of a polygon, show both classes, for example, 2-3. In calculating hectares assign a 50:50 split unless more accurate proportions are known.
(2-5)	If three different classes each make up about a third of a polygon, show only extreme classes, for example, 2-3-5 is shown as 2-5.

On reclaimed oil sands lands two levels of inspection are recommended. The inspection intensities are a minimum.

- quality control of material placement depths: inspections should be made following leveling of materials on a 50 m grid, 4 or more sites per ha, (critical depths are those required to maintain targeted capability). Where salinity or sodicity problems are expected, additional sampling of source materials is recommended to ensure quality will meet targeted capability;
- uniformity and capability: inspections made at 1 inspection per ha, at least 5 years after material placement, as part of certification application. Sampling is required at least at 1 site per 10 ha to confirm capability.
- In any of the above, if an abnormal depth or quality is encountered, use a step-out procedure whereby 3 sites radiating 10 m from the original are inspected, and the average value of these three is used for the site.

6.0 THE ECOREGION CATEGORIZATION

In rating reclaimed lands it is helpful to know the ecoregion, ecosite, ecosite phase, and plant community type characteristics of the predisturbance landscape and those proposed for the reclaimed site to aid in understanding the forest ecosystems. If this information is not available it can be inferred from regional maps, or from similar undisturbed forested lands. *Ecoregions of Alberta* (Strong and Leggat 1992), *Field Guide to Ecosites of Northern Alberta* (Beckingham and Archibald 1996), *Preharvest Ecological Assessment Handbook* (Environmental Training Center 1994), *Forest Site Interpretation and Silvicultural Prescription Guide for Alberta* (Environmental Training Centre 1996), and *Mixedwood Section in an Ecological Perspective, Saskatchewan* (Kabzems et al. 1986) are excellent references in this regard.

While this capability classification focuses on soils and landscapes, it is well known that an understanding of soil-forest interactions is essential to using and refining the rating system to meet reclamation and management needs.

7.0 HOW TO USE THE SYSTEM

This section illustrates the field application of the rating system. It includes:

1. Soil Description Form
2. Soil Capability Rating Form
3. Landscape Capability Rating Form
4. Spreadsheet Form (Appendix)

FORMS

Soil Description Form

<table>
<tr><td colspan="3">Location/Site</td><td colspan="3"></td></tr>
<tr><td colspan="3">Map Unit/Soil Series</td><td colspan="3"></td></tr>
<tr><td colspan="3">Soil Classification</td><td colspan="3"></td></tr>
<tr><td colspan="3">Parent Material</td><td colspan="3">Genetic Expression</td></tr>
<tr><td colspan="3">Drainage</td><td colspan="3">R W MW I P VP</td></tr>
<tr><td colspan="3">Soil Moisture Regime</td><td colspan="3">1 2 3 4 5 6 7a 7b 8 9</td></tr>
<tr><td colspan="3">Soil Nutrient Regime</td><td colspan="3">L M H</td></tr>
<tr><td colspan="3">Topography</td><td colspan="3">Percent Position Aspect</td></tr>
<tr><td colspan="3">Stoniness (to 1 m)</td><td colspan="3">Gravel Stones</td></tr>
<tr><td colspan="3">Gully and Rill Erosion (Visible)</td><td colspan="3">None Sli Mod Sev V.Sev. Ext</td></tr>
<tr><td colspan="3">Land Use (at time of investigation)</td><td colspan="3">F M WT G C Other</td></tr>
<tr><td colspan="3">Stand Quality</td><td colspan="3">High Moderate Low Non-Productive</td></tr>
<tr><td colspan="3">Compaction</td><td colspan="3">None Sli Mod Sev V.Sev Ext</td></tr>
<tr><td colspan="3">PROFILE:</td><td colspan="3">Samples</td></tr>
<tr><th>Horizon</th><th>Depth</th><th>Colour</th><th>Texture</th><th>Structure</th><th>Consistence</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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</table>

<u>Comments:</u>

1. Soil inventory notes, such as, associated soils, variations, etc.
2. Plant community, productivity level, depth to water table, health of stand, rooting pattern, etc.
3. Reclamation issues, including, quality of materials, limitations, etc.

Soil Capability (S) **Location:** ____________ **Surveyor:** ____________ **Date:** ____________

	Value	Interim Deduction	Final Deduction
1. Profile AWHC (M)			
$50 - \left(\frac{TS \quad + US \quad + LS}{3}\right) =$	$50 - \left(\frac{\_\_\_}{3}\right)$	= (a)	______
2. Topsoil Factors			
Physical: *Choose D plus most limiting of F or O*			
• structure / consistence (D)	______	______	
• organic equivalent (F)	______	______	
• peaty surface (O)	______	______ = (b)	______
Chemical: *Choose most limiting*		% deduction	
• acidity (V)	______	______	
• salinity (N)	______	______	
• sodicity / saturation % (Y)	______	______	
• nutrient retention (K)	______	______	

c = (80 -(a) ______ -(b) ______) (V, N, Y, or K %) = (c) ______

Basic Soil Rating d = 80 -(a) ______ -(b) ______ -(c) ______ = (d) ______

	Value	Interim Deduction	Final Deduction
3. Upper Subsoil Factors - *Choose most limiting*			
• structure (D)	______	______	
• acidity (V)	______	______	
• salinity (N)	______	______	
• sodicity / saturation % (Y)	______	______	
Upper subsoil deduction =	______	% of (d) x 0.67 = (e)	______
4. Lower Subsoil Factors - *Choose most limiting*		% deduction	
• structure (D)	______	______	
• acidity (V)	______	______	
• salinity (N)	______	______	
• sodicity / saturation % (Y)	______	______	
Lower subsoil deduction	______	% of (d) x 0.33 = (f)	______

Interim Soil Rating = (d) ______ - (e) ______ - (f) ______ = (g) ______

5. Edaphic Regime (R)
- moisture ______
- nutrients ______

Edaphic Grid multiplier = (h) ______

FINAL SOIL RATING (S) = (g) ______ **x (h)** ______ = ______

______ **Class** ______ **Subclass**

Subclass, denoted by Uppercase letter codes (e.g., M, D, Y), when ≥20 point deduction in (a), (b), (c), (e), (f), and (h if < 1.25).
If more than two subclasses use S, or SR if R is a limitation.

Landscape Capability (L)

1. Slope (T) Value Point Deduction
   - slope steepness % __________ = (a) __________

   Basic Landscape Rating = 100– (a) __________ = (b) __________

2. Exposure (X) % deduction
   - position ________ + aspect ________ = ________

     ( ) x (b) = (c) __________

   (position to be deducted on slopes >10%)
   (aspect to be deducted on slopes >20%)

3. Stoniness (P)
   - % volume to 1 m __________ __________

   Stoniness deduction = __________ % x (b) =(d) __________

4. Erosion (E) % deduction
   - estimated volume loss in gullies __________
   - years since reclamation __________
   - annual gully erosion __________

   Erosion deduction = __________ % x (b) = (e) __________

FINAL LANDSCAPE RATING (L) = (b) ______ -(c) ______ -(d) ______ -(e) ______ = ________

= __________ __________

Class Subclass

Subclass, denoted by Uppercase letter codes (e.g., T, X, P), when ≥20 point deduction in (a), (c), (d), or (e). If more than two subclasses use L.

FINAL COMBINED RATING

	Index	Class	Limiting	Factors
S=	______	______ ,	______ ,	______
L=	______	______ ,	______ ,	______

Index	Class
81 - 100	1
61 - 80	2
41 - 60	3
21 - 40	4
0 -20	5

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9.0 APPENDIX

9.1 SOIL MOISTURE RELATIONSHIPS.

Tables 24, 25, 26, and 27 present information about soil texture and water holding capacity relationships. These data were used in establishing the values used in the rating system as shown in Table 6. Note there is significant variation among various studies.

Table 24. Average soil physical characteristics (ranges are shown in parentheses).

Textural Class	Bulk Density (D_b)	Total Pore Space (V_P%)	Field Capacity (VOL%)	Wilting Point (VOL%)	Available Moisture By Volume (AMC%=mm/dm)	Air Capacity At Field Capacity (V_A%)	Average Sp (%)
Sandy	1.65	38	15	7	8	23	23
	(1.55-1.80)	(32-42)	(10-20)	(4-10)	(6-10)		
Sandy Loam	1.50	43	21	9	12	22	28
	(1.40-1.60)	(40-47)	(15-27)	(6-12)	(9-15)		
Loam	1.40	47	31	14	17	16	33
	(1.35-1.50)	(43-49)	(25-36)	(11-17)	(14-20)		
Clay Loam	1.35	49	36	17	19	13	36
	(1.30-1.40)	(47-51)	(31-41)	(15-20)	(16.22)		
Silty Clay	1.30	51	40	19	21	11	39
	(1.25-1.35)	(49-53)	(35-46)	(17-23)	(18-23)		
Clay	1.25	53	44	21	23	9	42
	(1.20-1.30)	(51-55)	(39-49)	(19-24)	(20-25)		

Source: 1981. ILACO B.V.

Table 25. Variations in relationship between texture and water holding capacity from four references.

Texture	This Report	Donohue	Brady	Alta Agric.	ILACO B.V.
			cm/ 100 cm		
sand	4	-	-	-	-
medium sand	-	7	5	-	-
fine sand	-	9	-	-	-
loamy sand	6	-	-	10	8
sandy loam	10	12	10	14	12
fine sandy loam	-	15	-	-	-
loam	15	17	15	18	17
silt loam	18	17	18	20	-
clay loam	17	17	17	20	19
clay	16	12	16	19	23

Note: These values are all based on field capacity @ -33 kPa.
Source: Donohue et al. 1983, Brady 1984, Alberta Agriculture 1983, ILACO B.V. 1981

Table 26. Available water content in various peats, mineral soils and peat-soil mixes.

Material	Available Moisture mm/100 cm
Moss (fibric)	80
Sedge (mesic)	120
Reed (humic)	140
Loamy fine sand (LfS)	60
Coarse sand (cS)	12
Clay (C)	143
LfS + moss	72
LfS + sedge	80
LfS + reed	80
cS + moss	56
cS + reed	40
C + moss	95
C + sedge	110
C + reed	130

Note: These values are all based on field capacity @ -33 kPa.
Source: Feustel and Byers 1936 as cited by Logan 1978 (all mixes 50% peat and 50% soil on a volume basis).

Table 27. Volumetric moisture contents (mm/cm) of sandy soils and peat-mineral mixes.

Texture Bulk Density(g/cm³)[a]	**S** 1.30	**LS** 1.35	**SL** 1.35	**TSS** 1.40	**Pt** 0.55	**PtS** 0.55	**PtLS** 0.75	**PtSL** 1.00	**PtL** 0.70
1997 Results									
Laboratory FC[b] -10 kPa	1.1 n=15	1.4 n=2	2.4 n=5	0.9 n=26	3.1 n=3	1.7 n=2	2.6 n=2	3.1 n=15	3.7 n=4
Laboratory PWP[b] -1500 kPa	0.3 n=15	0.5 n=2	0.6 n=5	0.3 n=26	1.5 n=3	0.8 n=2	1.4 n=2	1.3 n=15	2.0 n=4
Laboratory AWHC[b] (-10 kPa)- (-1500 kPa)	0.9	1.0	1.8	0.7	1.6	0.9	1.2	1.7	1.7
Field FC (48hrs after sat'n)	1.2 n=46	1.0 n=4	1.8 n=10	2.2 n=18	3.2 n=9	1.3 n=4	4.2 n=26	2.4 n=33	3.6 n=4
Field AWHC (Field FC-Lab PWP)[c]	0.9	0.5	1.2	1.9	1.7	0.5	2.8	1.1	1.6
1996 Results									
Laboratory FC -10 kPa	1.1 n=11	1.6 n=2	2.8 n=2	1.0 n=9			3.6 n=4	3.0 n=4	
Laboratory PWP -1500 kPa	0.4 n=11	0.3 n=2	8 n=2	2 n=9			1.2 n=4	1.5 n=4	
Laboratory AWHC (-10 kPa)- (-1500 kPa)	0.6	1.3	2.0	0.9			2.0	2.5	
1996 AWHC (Table 6) based on FC at -33 kPa	0.4	0.6	1.0	0.75	1.2	1.6	1.6	1.6	1.6
Current AWHC (Table 6) based on FC at -10 kPa	0.8	1.1	1.4	0.8	2.0	2.0	2.0	2.0	2.0

[a] Average from all sites / horizons in 1997, rounded to nearest 0.05.
[b] FC = field capacity; PWP = permanent wilting point; AWHC = available water holding capacity.
[c] Unable to determine PWP in field, therefore use Field FC - Lab PWP.
Source: *Available Water Holding Capacity Determinations on Sandy Soils and Peat-Mineral Mixes* (Moskal and Leskiw 1997).

Table 28. Available water holding capacity (mm) of field and laboratory measurements.

Site No.	Materials	Field AWHC Volumetric Total for 100 cm	Lab AWHC Volumetric Total for 100 cm (FC = -10 kPa)	Lab AWHC Volumetric Total for 100 cm (FC = -33 kPa)
1	10 cm of overlay / 50 cm of peat-mineral mix / 40 cm tailings sand	115	141	69
2	30 cm of peat-mineral mix / 70 cm burrow sand	139	130	75
3	Ae 10 cm / Bm 70 cm / BC 20 cm	55	43	34
4	peat-mineral mix 100 cm	237	238	180
5	Ahe, Ae 20 cm / Bm 80 cm	57	51	47
6	Ahe 20 cm / Bm 80 cm	62	90	75
7	20 cm of peat-mineral mix / 80 cm tailings sand	108	145	105
8	25 cm of peat-mineral mix / 75 cm tailings sand	157	184	107
9	40 cm of peat-mineral mix / 60 cm tailings sand	76	160	52
10	30 cm of peat-mineral mix / 70 cm tailings sand	108	123	57
11	20 cm of peat-mineral mix / 80 cm tailings sand	147	86	45
12	20 cm of peat-mineral mix / 80 cm tailings sand	165	134	84
13	tailings sand 100 cm	120	125	42
14	10 cm of peat-mineral mix / 90 cm tailings sand - deciduous cover	111	158	57
15	Ae 10 cm / Bm 60 cm / BC 30 cm	64	117	69
16	90 cm of peat-mineral mix / 10 cm tailings sand	418	621	445

Source: Field and laboratory measurements based on 10 cm intervals to 100 cm depth, from Moskal and Leskiw 1997.

Note: Statistical evaluation (paired t-test) indicates no significant difference between Field and Lab (-10 kPa) values, but there is a significant difference between Field and Lab (-33 kPa) values.

9.2 SOIL CHEMICAL PROPERTIES.

Tables 29 and 30 present supplemental information on soil properties used in developing the nutrient retention and nutrient regime aspects of the rating system.

Table 29. Chemical properties of peat/sand mixtures and tailings.

	1:9*	3:7*	5:5*	Tailings	Peat Pile
pH (H_2O)	6.5	6.8	6.6	7.5	6.5
CEC	1.7	4.5	10.1	1.0	45
Base Sat'n	>100%	>100%	>100%	>100%	>100%
C/N	6	12.5	17	3	17
Total C%	0.56	1.57	2.88	0.25	9.5
Total N%	0.09	0.12	0.17	0.08	0.55
N kg/ha	2520	3120	4420	2240	7700
Bulk density g/cm^3*	1.4	1.3	1.3	1.4	0.7
EC	0.81	1.45	1.91	0.20	2.42
SAR	2.6	1.62	0.98	0.80	0.6

* Means of 4 samples, peat-sand mix, volume basis
Source: Macyk and Turchenek 1995.

Table 30. Estimated levels of selected nutrients in forest soil surface horizons.

Parameter (LFH + O + A horizons)	Poor	Medium	Rich
Total P (kg/ha)	<100	100-500	>500
Min N (kg/ha)	<50	50-100	>100
Available NH_4 (kg/ha)	<2	2-5	>5
Available NO_3 (kg/ha)	<0.5	0.5-1.5	>1.5
Available P (kg/ha)	<2	2-10	>10
Available K (kg/ha)	<50	50-150	>150
Available S (kg/ha)	<5	5-15	>15

Sources: Can-Ag Enterprises Ltd. 1966; Kabzems and Klinka 1987, Canstar 1982; La Roi and Pluth 1986; Pritchett and Fisher 1987.

9.3 SOIL CAPABILITY

Soil capability evaluations of numerous profiles in the oil sands region are provided. Table 31 shows comparisons of final ratings as determined by different measurements of AWHC. The revised AWHC values in this 1998 edition of the manual are based on a "best fit" of field and lab measurements. Note there is considerable variation and this is normal for soil systems. A statistical evaluation (paired t-test, $p = 0.05$) indicated no significant difference among 1998 Table 6 values, AWHC measured in the field, and AWHC measured in the laboratory (field capacity -10 kPa). There is a significant difference between the 1996 Table 6 values and current ones. Table 32 provides a summary of soil characteristics and capability of soils reclaimed to date at Suncor and Syncrude.

Table 31. Summary of forest capability ratings based on the original AWHC in the Land Capability Manuals, field, and laboratory measurements.

Site No.	Materials Sandy soils	Class and Index Using AWHC from 1998 Table 6[a]	Class and Index Using AWHC from 1996 Table 6[b]	Class and Index Using AWHC from In Situ Field Capacity	Class and Index Using AWHC from -10 kPa Field Capacity AWHC
1	10 cm of overlay / 50 cm of peat-mineral mix / 40 cm tailings sand	3-46[c]	3-48	3-48	3-54
2	30 cm of peat-mineral mix / 70 cm burrow sand	3-47	3-42	3-55	3-53
3	Ae 10 cm / Bm 70 cm / BC 20 cm	4-37	4-27	4-31	4-27
4	peat-mineral mix 100 cm	2-66	2-72	2-72	2-72
5	Ahe, Ae 20 cm / Bm 80 cm	4-32	5-19	5-19	5-18
6	Ahe 20 cm / Bm 80 cm	3-44	4-31	4-33	4-40
7	20 cm of peat-mineral mix / 80 cm tailings sand	3-50	3-47	3-51	2-61
8	25 cm of peat-mineral mix / 75 cm tailings sand	3-50	3-45	3-58	3-58
9	40 cm of peat-mineral mix / 60 cm tailings sand	3-40	4-36	4-29	3-45
10	30 cm of peat-mineral mix / 70 cm tailings sand	3-51	3-48	3-48	3-51
11	20 cm of peat-mineral mix / 80 cm tailings sand	3-54	3-49	2-63	3-47
12	20 cm of peat-mineral mix / 80 cm tailings sand	3-61	3-55	2-72	2-67
13	tailings sand 100 cm	5-16	5-12	5-19	5-20
14	10 cm of peat-mineral mix / 90 cm tailings sand - deciduous cover	3-46	3-42	3-48	3-58
15	Ae 10 cm / Bm 60 cm / BC 30 cm	4-29	5-19	4-25	4-39
16	90 cm of peat-mineral mix / 10 cm tailings sand	2-65	2-65	2-65	2-65
Average		3-46a[d]	3-41b	3-46a	3-48a

[a] Table 6 of this report, revised edition, 1998.
[b] Table 6 of this report, 1996 edition.
[c] 3-46; Soil capability class - soil index
[d] Numbers followed by a different letter are significantly different ($p = 0.05$).

Table 32. Reclaimed oil sands soils, soil capability, and features.

Soil Series	Reclaimed Soils (depth ±5 cm)	Soil Capability	Drainage Class	Moisture Regime	Nutrient Regime	Salinity (EC; dS/m)
A	20 cm peat-mineral mix/ 30 cm clay/ TSS	2	W-MW	mesic	medium	<1
		1	I	subhygric		
B	50 cm clay/ TSS	3	W-MW	mesic	low	<1
		2	I	subhygric		
C	50 cm sandy loam/ TSS	3	R-W	submesic	low	<1
D	20 cm peat-mineral mix/ 30 cm sandy loam/ TSS	3	W	mesic	medium	<1
		2	I	subhygric		
E	20 cm peat-mineral mix/ 30 cm clay/ OB[a]	2	W-MW	mesic	medium	3 (2-4)
		1	I	subhygric		
F	50 cm clay/ OB	3	W-MW	mesic	low	3 (2-4)
		2	I	subhygric		
G	Overlay of >50 cm TSS	4	R-W	subxeric	low	<1
H	20 cm peat-mineral mix/ TSS	3	R-W	submesic	medium	<1
		2	I	subhygric		
I	20 cm peat-mineral mix/ OB	2	W-MW	mesic	medium	3 (2-4)
		1	I	subhygric		
J	100 cm peat-mineral mix	2	W-MW	mesic	medium	<1
		4	VP	subhydric		
K	100 cm mineral soil	4	P	hygric (r)	low	<1
		5	VP	subhydric		
L	20 cm peat-mineral mix/ 80 cm mineral soil	4	P	hygric (r)	medium	<1
		5	VP	subhydric		

Sources: *Reclaimed Soils and Forest Ecosystem Capability of Syncrude Canada Ltd* (Leskiw and Moskal 1997b). *Reclaimed Soils and Forest Ecosystem Capability of Suncor Inc. Oil Sands Group* (Leskiw and Moskal 1997a).

9.4 SOIL PRODUCTIVITY RELATIONSHIP

Can-Ag Enterprises has been involved in related projects over the past two years, allowing comparison of forest productivity and soil capability. This section presents summarized comparisons of soils and their productivity. The regression equations differ slightly among study areas. Nevertheless, the trends are consistently similar.

As a guide, appreciating considerable variation within natural systems, the soil capability class versus site index relationship is:

Soil Capability Class	Site Index @ 50 y bh
1	18-22+
2	14-18
3	14-18
4	10-14
5	<10

In open jack pine stands (<25% canopy cover), the site index is adjusted by multiplying by 0.60. This multiplier was used for some plots represented in Figures 16 and 19. This provides a more realistic assessment of site productivity and is commensurate with that measured by mean annual increment.

Table 33. Summary of soils data and average site index by tree species for the 80 permanent sample plots.

Capability Class	Summary Description				Average Site Index by Tree Species at 50 y bh					
	Subgroup	Moisture Regime	Surface/ Subsurface	LFH or Peat depth (cm); median (range)	Aw (n)	Sw (n)	Pj (n)	Pl (n)	Sb (n)	Overall Site Index (n)
1	Gleyed Luvisol	Subhygric	SL, L, SiL / SCL[a]	5(5-30)	20.8 (7)	19.8 (9)	24.8 (1)	24.0 (1)	24.3 (1)	20.9 (19)
2	Luvisol	Mesic	SiL, SL, L / CL, SCL, C	8(5-20)	18.8 (53)	18.9 (25)	15.2 (2)	16.1 (30)	13.8 (7)	17.6 (117)
3	Luvisol Brunisol	Submesic-mesic	SiL, LS, SL / SiL, SL, CL	5(0-5)	16.5 (2)	17.6 (4)	- (0)	12.5 (2)	- (0)	16.0 (8)
4	Brunisol	Xeric-subxeric (sandy) or	LS, S / S or	5(0-30)	- (0)	- (0)	9.5 (19)	- (0)	- (0)	9.5 (19)
	Gleysol	Hygric (finer)	SL, SCL / SL, SCL		- (0)	14.4 (4)	- (0)	- (0)	8.0 (2)	12.3 (6)
5	Mesisol	Subhydric	peat / peat	70(45-100)	- (0)	- (0)	- (0)	- (0)	5.7 (3)	5.7 (3)

[a] C = clay; L = loam; S = sand; Si = silt

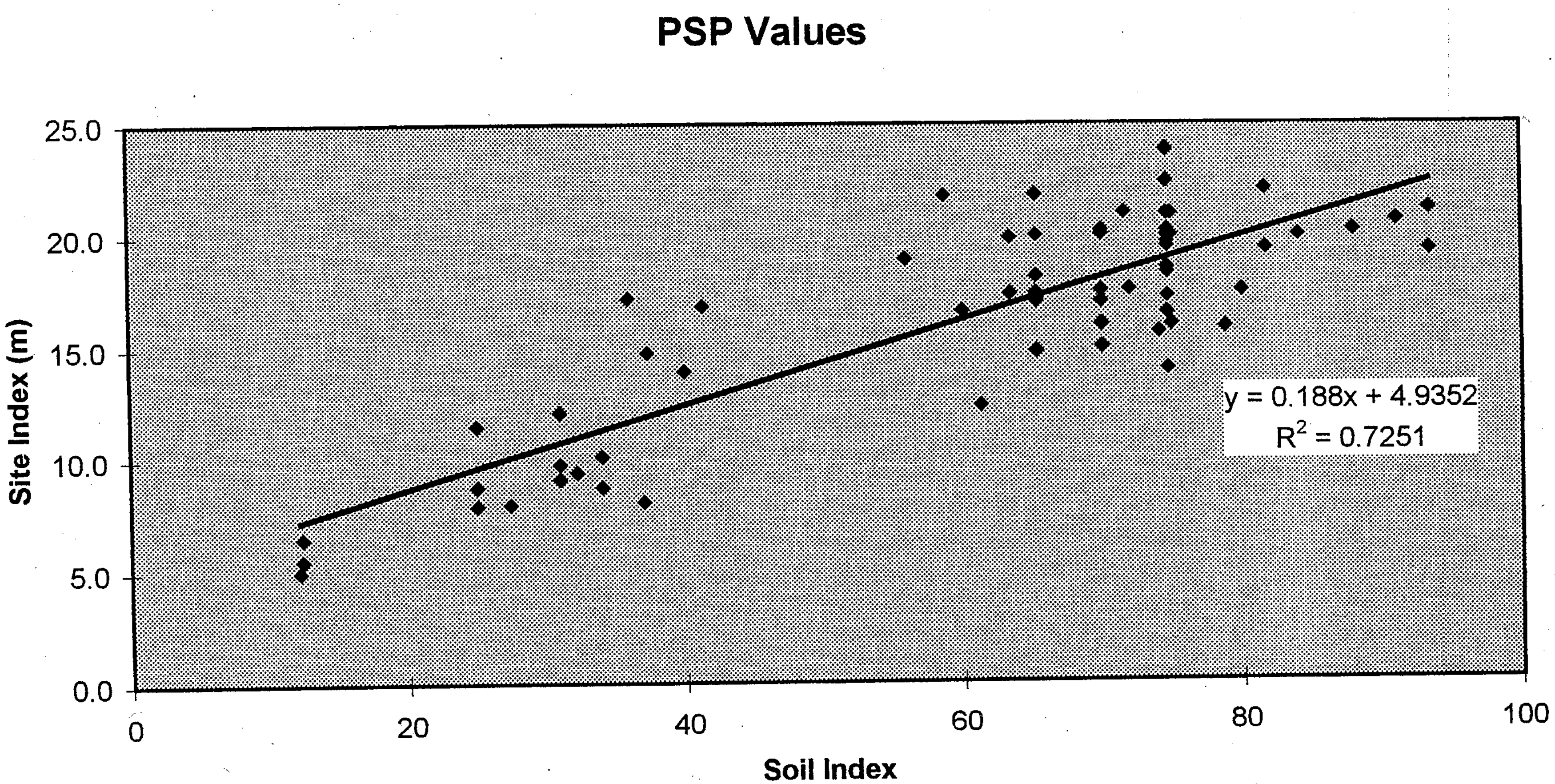

Figure 16. Relationship between site index and soil capability class for 80 permanent sample plots.

Table 34. Soils and average site index by tree species for 60 sites, Shell Lease 13 Project.

	Summary Description				Average Site Index by Tree Species at 50 y bh				
Capability Class	Subgroup	Moisture Regime	Surface/ Subsurface	LFH or Peat depth (cm); median (range)	Aw (n)	Sw (n)	Pj (n)	Sb (n)	Overall Site Index (n)
1	Gleyed Luvisol	Subhygric	SL / SL[a]	15 (4-20)	- (0)	22 (3)	- (0)	- (0)	22 (3)
2	Brunisol Gleysol	Mesic Hygric (aerated)	SL, LS, SiL, / L, SL, LS, residual	13 (4-35)	22 (2)	19 (10)	10 (2)	18 (1)	18 (15)
3	Brunisol Luvisol	Submesic Mesic	LS, / LS, S, CL	4 (1-10)	18 (10)	18 (6)	10 (6)	- (0)	16 (22)
4	Brunisol Gleysol	Submesic Hygric (reduced)	S, LS, / S, LS, CL	7 (2-17)	- (0)	13 (4)	10 (9)	11 (4)	11 (17)
5	Mesisol	Subhydric	peat / peat	72 (11-160)	- (0)	- (0)	- (0)	11 (3)	11 (3)

[1] C = clay; L = loam; S = sand; Si = silt; pt = peat

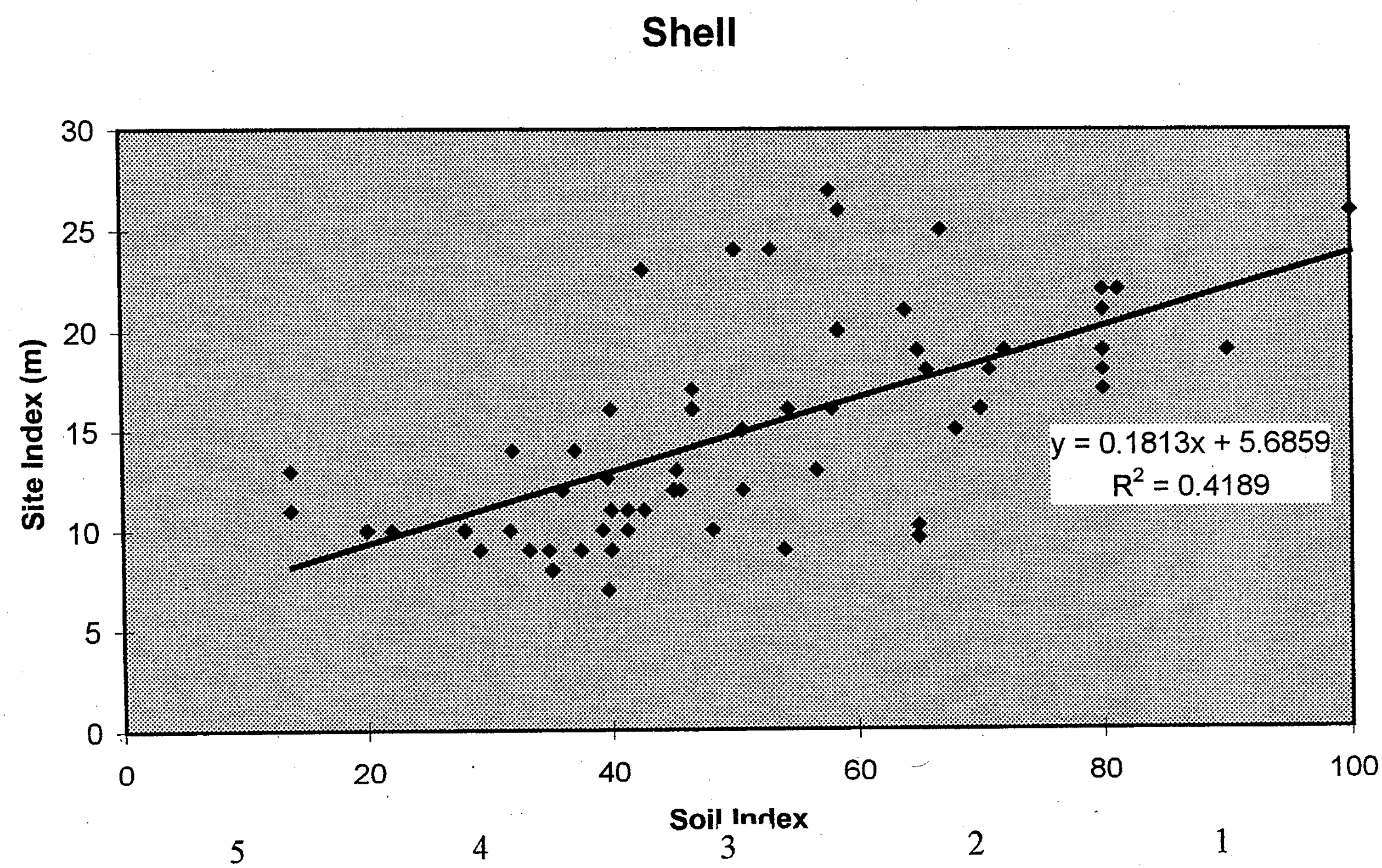

Figure 17. Relationship between site index and soil capability class for sites in the Shell Lease 13 project area.

Table 35. Soils and average site index by tree species for 57 sites, Suncor Millenium Project.

Capability Class	Summary Description				Average Site Index by Tree Species at 50 y bh				
	Subgroup	Moisture Regime	Surface/ Subsurface	LFH or Peat depth (cm); median (range)	Aw (n)	Sw (n)	Pj (n)	Sb (n)	Overall Site Index (n)
1	Gleyed Luvisol	Subhygric	SL / CL[a]	8 (6-20)	19 (3)	19 (4)	- (0)	- (0)	19 (7)
2	Luvisol Gleysol	Mesic Hygric (aerated)	SL, SiL / SCL, CL	10 (5-20)	17 (8)	17 (8)	- (0)	12 (1)	17 (17)
3	Luvisol	Mesic	LS, / SCL,	23 (5-40)	17 (1)	17 (1)	- (0)	- (0)	17 (2)
4	Gleysol	Hygric (reduced)	peat, SL, / SCL, CL	20 (10-50)	- (0)	- (0)	8 (1)	10 (14)	10 (15)
5	Mesisol	Subhydric	peat / peat	55 (0-120)	- (0)	8 (1)	10 (1)	9 (14)	9 (16)

[1] C = clay; L = loam; S = sand; Si = silt

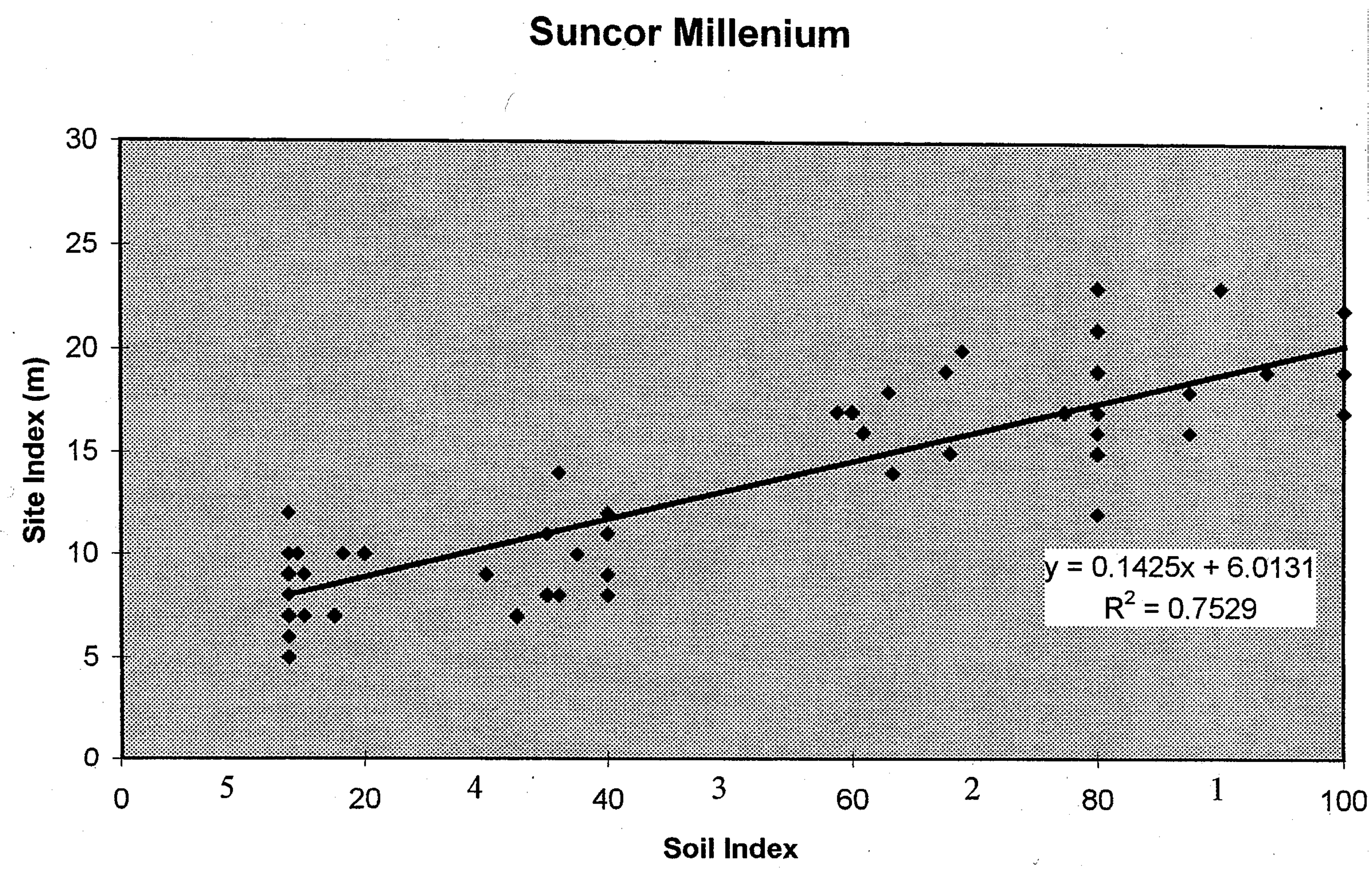

Figure 18. Relationship between site index and soil capability class for sites in the Suncor Millenium project area.

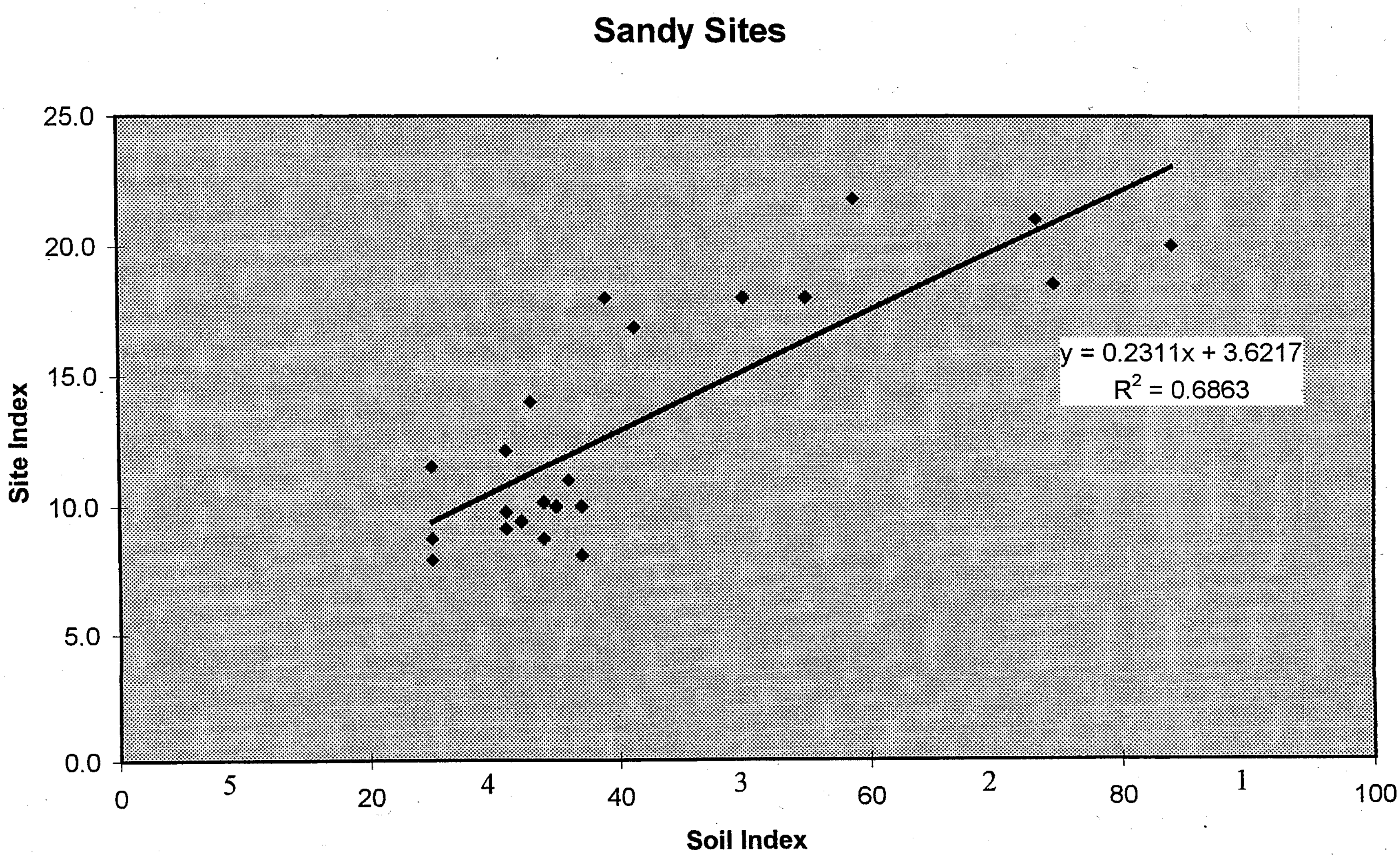

Figure 19. Relationship between site index and soil capability class for sandy sites.

Source: Sandy sites from among 80 permanent sample plots and 7 natural sandy sites from current research project (Moskal).

9.5 SOIL CAPABILITY EXAMPLE PROFILES

Soil Capability (S) **Location:** Suncor (KNS) Orthic Gray Luvisol on Till. TS=SL; US=CL; LS=SCL **Surveyor:** Leskiw & Pluth **Date:** July 1995

	Value	Interim Deduction		Final Deduction
1. Profile AWHC (m)				
$50 - \left(\frac{TS\ 28 + US\ 51 + LS\ 75}{3}\right) =$	50 - (51)		= (a)	0
2. Topsoil Factors				
Physical: *Choose D plus most limiting of F or O*				
– structure / consistence (D)	friable	0		
– organic equivalent (F)	55 t/ha	0		
– peaty surface (O)	-	0	= (b)	0
Chemical: *Choose most limiting*		% deduction		
– acidity (V)	6 ($CaCl_2$)	0		
– salinity (N)	-	0		
– sodicity / saturation % (Y)	-	0		
– nutrient retention (K)	high	0		

c = (80 -(a) 0 -(b) 0) (V, N, Y, or K 0 %) = (c) 0

Basic Soil Rating d = 80 -(a) 0 -(b) 0 -(c) 0 = (d) **80**

	Value	Deduction
3. Upper Subsoil Factors - *Choose most limiting*		
– structure (D)	sbk, firm	0
– acidity (V)	6.3 ($CaCl_2$)	0
– salinity (N)	-	0
– sodicity / saturation % (Y)	-	0

Upper subsoil deduction = 0 % of (d) x 0.67 = (e) 0

	Value	% deduction
4. Lower Subsoil Factors - *Choose most limiting*		
– structure (D)	massive, firm	0
– acidity (V)	7.4 (H_2O)	10
– salinity (N)	0.39	0
– sodicity / saturation % (Y)	1.8	0

Lower subsoil deduction 10 % of (d) x 0.33 = (f) 2

Interim Soil Rating = (d) 80 - (e) 0 - (f) 2 = (g) 78

5. Edaphic Grid (R)
– moisture 5
– nutrients medium

Edaphic Grid multiplier = (h) 1.0

FINAL SOIL RATING (S) = (g) 78 **x (h)** 1.0 = 78

Class	**Subclass**
2	R

Subclass, denoted by Uppercase letter codes (e.g., M, D, Y), when ≥15 point deduction in (a), (b), (c), (e), (f), and (h if < 1.25).
If more than two subclasses use S, or SR if R is a limitation.

Landscape Capability (L)

	Value			Point Deduction
1. Slope (T)				
• slope steepness %	15%			= (a) 12
Basic Landscape Rating =	**100−**	**(a)** **12**		**= (b)** **88**

			% deduction		
2. Exposure (X)					
• position	upper	+ aspect na	= 0		
			(0)	x (b)	= (c) 0

(position to be deducted on slopes >10%)
(aspect to be deducted on slopes >20%)

3. Stoniness (P)				
• % volume to 1 m	5%			
Stoniness deduction =		0	% x (b)	=(d) 0

		% deduction		
4. Erosion (E)				
• estimated volume loss in gullies	none			
• years since reclamation	na			
• annual gully erosion	na			
Erosion deduction =		0	% x (b)	= (e) 0

FINAL LANDSCAPE RATING (L) = (b) **88** -(c) **0** -(d) **0** -(e) **0** = **88**

= 1 (Class) ____ (Subclass)

Subclass, denoted by Uppercase letter codes (e.g., T, X, P), when ≥20 point deduction in (a), (c), (d), or (e). If more than two subclasses use L.

FINAL COMBINED RATING

	Index	Class	Limiting	Factors
S=	78	2		
L=	88	1		

Index	Class
81 - 100	1
61 - 80	2
41 - 60	3
21 - 40	4
0 -20	5

Soil Capability (S) **Location:** Forest Scenario 1: 20 cm peat-mineral mix over 80 cm plus nonsaline, nonsodic sandy clay loam overburden

	Value	Interim Deduction		Final Deduction
1. Profile AWHC (m)				
$50 - \left(\frac{TS\ 34 + US\ 45 + LS\ 75}{3}\right) =$ 50 -	(51)		= (a)	0
2. Topsoil Factors				
Physical: *Choose D plus most limiting of F or O*				
– structure / consistence (D)	peat mix	0		
– organic equivalent (F)	>80 t/ha	0		
– peaty surface (O)	-	0	= (b)	0
Chemical: *Choose most limiting*		% deduction		
– acidity (V)	5.0-7.0 (H_2O)	0		
– salinity (N)	0.7	0		
– sodicity / saturation % (Y)	SAR <4	0		
– nutrient retention (K)	high	0		

c = (80 -(a) 0 -(b) 0) (V, N, Y, or K 0 %) = (c) 0

Basic Soil Rating d = 80 -(a) 0 -(b) 0 -(c) 0 **= (d) 80**

3. Upper Subsoil Factors - *Choose most limiting*	Value	Interim Deduction
– structure (D)	2-10, firm	20
– acidity (V)	7.5 (H_2O)	10
– salinity (N)	EC <2	0
– sodicity / saturation % (Y)	SAR <4	0

Upper subsoil deduction = 20 % of (d) x 0.67 = (e) 11

4. Lower Subsoil Factors - *Choose most limiting*	Value	% deduction
– structure (D)	2-10, firm	20
– acidity (V)	7.5 (H_2O)	10
– salinity (N)	EC <2	0
– sodicity / saturation % (Y)	SAR <4	0

Lower subsoil deduction 20 % of (d) x 0.33 = (f) 5

Interim Soil Rating = (d) 80 - (e) 11 - (f) 5 = (g) 64

5. Edaphic Grid (R)

– moisture 5

– nutrients medium

Edaphic Grid multiplier = (h) 1.0

FINAL SOIL RATING (S) = (g) 64 x (h) 1.0 = 64

	Class	Subclass
	2	**D, R**

Subclass, denoted by Uppercase letter codes (e.g., M, D, Y), when ≥15 point deduction in (a), (b), (c), (e), (f), and (h if < 1.25).
If more than two subclasses use S, or SR if R is a limitation.

Landscape Capability (L)

1. Slope (T) — Value — Point Deduction
   - slope steepness % — 8% — = (a) 0

   Basic Landscape Rating = **100–** **(a)** **0** **= (b)** **100**

2. Exposure (X) — % deduction
   - position upper + aspect na = 0
     (0) x (b) = (c) 0

   (position to be deducted on slopes >10%)
   (aspect to be deducted on slopes >20%)

3. Stoniness (P)
   - % volume to 1 m — 5%

   Stoniness deduction = 0 % x (b) =(d) 0

4. Erosion (E) — % deduction
   - estimated volume loss in gullies — 30 m^3/ha
   - years since reclamation — 5
   - annual gully erosion — 6

   Erosion deduction = 10 % x (b) = (e) 10

FINAL LANDSCAPE RATING (L) = (b) **100** -(c) **0** -(d) **0** -(e) **10** = **90**

= 1 (Class) ____ (Subclass)

Subclass, denoted by Uppercase letter codes (e.g., T, X, P), when ≥20 point deduction in (a), (c), (d), or (e). If more than two subclasses use L.

FINAL COMBINED RATING

	Index	Class	Limiting	Factors
S=	64	2		
L=	90	1		

Index	Class
81 - 100	1
61 - 80	2
41 - 60	3
21 - 40	4
0 -20	5

10.0 GLOSSARY

A horizon: A mineral horizon formed at or near the surface in the zone of removal of materials in solution and suspension, or maximum accumulation of organic carbon, or both.

Ae: An horizon that has been eluviated of clay, iron, aluminum, or organic matter, or all of these.

Ah: An horizon in which organic matter has accumulated as a result of biological activity.

Ap: An horizon markedly disturbed by cultivation or pasture.

acid soil: A soil having a pH of less than 7.0.

aggregate: Many fine soil particles held together in a single cluster, such as a clod or crumb. Many properties of an aggregate differ from those of an equal mass of unaggregated soil.

alkaline soils: Any soil that has a pH greater than 7.0.

arable: Tillage; agricultural production based on cultivation practices; land that is cultivated or capable of being cultivated. Arable is used as a comparison to agriculture based on grazing (non-cultivated) systems.

available water holding capacity: See water holding capacity.

B horizon: A subsoil horizon characterized by one of:

a) an enrichment in clay, iron, aluminum, or humus (Bt or Bf).
b) a prismatic or columnar structure that exhibits pronounced coatings or staining associated with significant amounts of exchangeable sodium (Bn or Bnt).
c) an alteration by hydrolysis, reduction, or oxidation to give a change in colour or structure from the horizons above or below, or both (Bm).

bedrock: The solid rock underlying soils and the regolith or exposed at the surface.

Brunisolic: An order of soils whose horizons are developed sufficiently to exclude them from the Regosolic Order but lack the degrees or kinds of horizon development specified for soils in other orders. They always have Bm or Btj horizons.

bulk density (soil): The mass of dry soil per unit bulk volume.

C horizon: A mineral horizon comparatively unaffected by the pedogenic processes operative in the A and B horizons except for the process of gleying (Cg) or the accumulation of calcium carbonate (Cca) or other salts (Csa). A naturally calcareous C horizon is designated Ck.

calcareous soil: Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1N hydrochloric acid.

capability: Focuses on the nature and degree of limitations imposed by the physical characteristics of a land unit for a certain use.

capability class (soil): The class indicates the general suitability of the soils for forestry use. It is a grouping of subclasses that have the same relative degree of limitation of hazard. the limitation or hazard becomes progressively greater from Class 1 to Class 5.

capability subclass (soils): This is a grouping of soils with similar kinds of limitations and hazards. It provides information on the kind of conservation problem or limitation. The class and subclass together provide the map user with information about the degree and kind of limitation for broad land use planning and for the assessment of conservation needs.

cation: An ion carrying a positive charge of electricity; the common soil cations are calcium, magnesium, sodium, potassium, and hydrogen.

cation exchange capacity (CEC): A measure of the total amount of exchangeable cations that can be held by the soil; it is expressed in terms of cmol (+) per kg of soil (formerly me/100g).

Chernozemic: An order of soils that have developed under xerophytic or mesophytic grasses and forbs, or under grassland-forest transition vegetation, in cool to cold, subarid to subhumid climates. The soils have a dark-coloured surface (Ah, Ahe or Ap) horizon and a B or C horizon, or both, of high base saturation. The order consists of the Brown, Dark Brown, Black and Dark Gray great groups.

classification (soil): The systematic arrangement of soils into categories and classes on the basis of their characteristics. Broad groupings are made on the basis of general characteristics and subdivisions on the basis of more detailed differences in specific properties.

clay: As a particle-size term: a size fraction <0.002 mm equivalent diameter.

coarse fragments: Rock or mineral particles >2.0 mm in diameter.

coarse texture: The texture exhibited by sands, loamy sands, and sandy loams except very fine sandy loam. A soil containing large quantities of these textural classes.

consistence: (i) The resistance of a material to deformation or rupture. (ii) The degree of cohesion or adhesion of the soil mass. Terms used to describe moist soils are - loose, very friable, friable, firm, very firm, compact, very compact, and extremely compact. Terms used to describe dry soils are - loose, soft, slightly hard, hard, very hard and extremely hard.

control section: The vertical section of soil upon which the classification is based.
For mineral soils in general, the control section extends either from the mineral surface to 25 cm below the upper boundary of the C or IIC, or to a depth of 2 m, whichever is less. Exceptions are: (i) if the upper boundary of the C or IIC is less than 75 cm from the mineral surface, the control section extends to a depth of 1 m; (ii) if bedrock occurs at a depth of less than 1 m, the control section is from the surface to the lithic contact.

disturbed land: Land on which excavation has occurred or upon which overburden has been deposited, or both.

drainage: Soil drainage refers to the frequency and duration of periods when the soil is not saturated. Terms used are - rapidly, well, moderately, imperfectly, poorly and very poorly drained.

droughty soil: Sandy or very rapidly drained soil.

electrical conductivity (EC): A physical quantity which measures the readiness with which a medium conducts electricity. EC can be related to the soluble salt content of saturated soil extracts, and is expressed as dS/m or (mmhos/cm) at 25 degrees C.

eolian: Material that has been deposited by wind action.

erosion: The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.

exchangeable sodium percentage (ESP): The degree of saturation of the soil cation exchange complex with sodium. It may be calculated by the formula:

$$ESP = \frac{\text{Exchangeable Sodium}}{\text{Cation Exchange Capacity}} X\ 100$$

Units are usually expressed as milliequivalents per 100 g soil.

fine texture: Consisting of or containing large quantities of the fine fractions, particularly or silt and clay.

first lift: The uppermost layer of undisturbed soil materials removed and segregated during surface mining to be respread as topsoil.

flood plain: The land bordering a stream, built up of sediments from overflow of the stream and subject to inundation when the stream is at flood stage.

fluvial: Material that has been transported and deposited by streams and rivers. Also alluvial.

friable: A consistency term pertaining to the ease of crumbling of soils.

groundwater: That portion of the total precipitation which at any particular time is either passing through or standing in the soil and the underlying strata and is free to move under the influence of gravity.

Gleysolic: An order of soils developed under wet conditions and permanent or periodic reduction. These soils have low chromas, or prominent mottling, or both, in some horizons. The great groups Gleysol, Humic Gleysol and Luvic Gleysol are included in the order.

horizon (soil): A layer of mineral or organic soil or soil material approximately parallel to the land surface that has characteristics altered by processes of soil formation. It differs from adjacent horizons in properties such as colour, structure, texture, and consistence, and in chemical, biological, and mineralogical composition. The other layers are either nonsoil layers such as rock and water or layers of unconsolidated material considered to be unaffected by soil-forming processes.

hydraulic conductivity: The rate of flow of water through a given cross section of area under hydraulic gradient at the prevailing temperature.

immature soil: A soil with indistinct or only slightly developed horizons.

impeded drainage: A condition which hinders the movement of water through soils under the influence of gravity.

impervious: Resistant to penetration by fluids or by roots.

indicator plants: Plants characteristic of specific soil or site conditions.

infiltration: The downward entry of water into the soil.

lacustrine: Material deposited in lake water and later exposed.

land: terrestrial, semi-aquatic and aquatic landscapes when the term is used in the definitions of "land capability" and "equivalent land capability".

land capability: the ability of the land to support a given land use, based on an evaluation of the physical, chemical and biological characteristics of the land, including topography, drainage, hydrology, soils and vegetation.

landscape: All the natural features such as fields, hills, forests, water, etc., which distinguish one part of the earth's surface from another part. Usually that portion of land or territory which the eye can comprehend in a single view, including all its natural characteristics.

landscape capability: The evaluation of the landscape factors as they affect general tree growth, including: slopes, position, aspect, stoniness, and erosion.

leachate: A solution obtained by leaching, for example, water that has percolated through soil containing soluble substances and that contains amounts of these substances in solution.

leaching: The removal of materials in solution by the passage of water through the soil.

loam: See soil texture. A mixture of sand, silt and clay.

loose: A soil consistency term.

Luvisolic: An order of soils that have eluvial (Ae) horizons, and illuvial (Bt) horizons in which silicate clay is the main accumulation product. The soils developed under forest of forest-grassland transition in a moderate to cool climate. The Gray Luvisol great group is the most common in western Canada.

map unit: A mappable portion of the soil landscape with attributes varying within narrow limits that are determined by the intensity of survey and its objectives such as land use planning and management requirements.

moder: A zoogenous forest humus form made up of plant remains partly disintegrated by the soil fauna (F layer), but not matted as in raw humus. It is transitional to a zone of spherical or cylindrical microdejections of arthropods that is permeated by loose mineral particles in its lower part and often throughout. Although incorporation of organic matter is intense, it is shallow, because none of the organisms concerned with moder formation have important burrowing activity. The mixing of organic and mineral particles is purely mechanical. Organic carbon under the F layer varies from 23% to 29% but may exceed 35%. The C:N ratio is 20 to 25 and sometimes lower. Various subgroups can be recognized by their morphology and chemical characteristics.

mor: A nonzoogenous forest humus form distinguished by a matted F layer and a holorganic H layer with a sharp delineation from the A horizon. It is generally acid, having high organic carbon content (52% or more) and a high C:N ratio (25-35, sometimes higher). Various subgroups can be recognized by the morphology, and chemical and biological properties.

morphology (soil): The make up of the soil, including texture, structure, consistence, colour, and other mineralogical, physical and biological properties of the various horizons of the soil profile.

mull: This is a zoogenous, forest humus form consisting of an intimate mixture of well-humified organic matter and mineral soil that makes a gradual transition to horizon underneath. It is distinguished by its crumb or granular structure, and because of the activity of the burrowing microfauna (mostly earthworms), partly decomposed organic debris does not accumulate as a distinct layer (F layer) as in mor and moder. The organic matter content is 5-20% and the C:N ratio is 10-15. Various subgroups can be distinguished by the morphology and chemical characteristics. Ah horizon.

neutral soil: A soil in which the surface layer, at least to normal plow depth, is neither acid nor alkaline in reaction.

nonsoil: The aggregate of surficial materials that do not meet the definition of soil. It includes unconsolidated materials displaced by processes such as dumps of earth fill along a highway under construction, mineral or organic material thinner than 10 cm overlying bedrock, exposed bedrock, unconsolidated material covered by more than 60 cm of water year round, and organic material thinner than 40 cm overlying water.

nutrient: A chemical element or inorganic compound taken in by a green plant and used in organic synthesis.

Organic: An order of soils that have developed dominantly from organic deposits. The majority of organic soils are saturated for most of the year, unless artificially drained. The great groups include Fibrisol, Mesisol, Humisol and Folisol.

organic matter: The decomposition residues of biological materials derived from: (a) plant and animal materials deposited on the surface of the soils; and (b) roots and micro-organisms that decay beneath the surface of the soil.

overburden: Undisturbed consolidated or unconsolidated materials overlying a resource to be mined.

paralithic: Poorly consolidated bedrock which can be dug with a spade when moist. It is severely constraining but not impenetrable to roots.

parent material: The unconsolidated and more of less chemically weathered mineral or organic matter from which the solum of a soil is developed by pedogenic processes.

particle size: The effective diameter of a particle measured by sedimentation, sieving, or micrometric methods.

peat-mineral mix: is a mixture of peat and mineral material resulting in a “mineral” soil. It may be obtained by either overstripping peat into the mineral soil, or by placing peat material and then rotovating into underlying mineral material. Peat mineral mixes contain a ratio of peat:mineral ranging from 1:1 to 4:1 (vol.). Higher proportions of peat likely behave as an organic material.

percolation (soil water): The downward movement of water through soil. Especially, the downward flow of water in saturated or nearly saturated soil at hydraulic gradients of the order of 1.0 or less.

permeability: The ease with which water can pass through a bulk mass of soil or a layer of soil. This can be either a qualitative term, or a quantitative term if the rate of movement is specified.

pH (soil): The negative logarithm of the hydrogen-ion activity of a soil. The degree of acidity (or alkalinity) of a soil as determined by means of glass, quinhydrone, or other suitable electrode or indicator at a specified moisture content of soil-water ratio, and expressed in terms of the pH scale.

platy: Consisting of soil aggregates that are developed predominately along the horizontal axes, laminated, flaky.

perviousness: The potential of a soil to transmit water internally, as inferred from soil characteristics such as structure, texture, porosity, cracks, organic matter content, and shrink-swell properties. It is closely related to measures of permeability, percolation rate, and infiltration rate, but these are reserved for actual measurements using standard techniques.

1. Rapidly pervious - the capacity to transmit water vertically is so great that the soil will remain wet for no more than a few hours after thorough wetting. The horizons and soils have large and continuous or connecting pores and cracks that do not close with wetting.
2. Moderately pervious - the capacity to transmit water vertically is great enough that the soil will remain saturated for no more than a few days after thorough wetting. Most moderately pervious soils hold relatively large amounts of water against the force of gravity, and are considered good, physically, for rooting and supplying water to plants. Soil horizons may be granular, blocky, weakly platy or massive (but porous) if continuous conducting pores or cracks are present which do not close with wetting.
3. Slowly pervious - the potential to transmit water vertically is so slow that the horizon or the soil will remain saturated for long periods of a week or more after thorough wetting. The soil may be massive, blocky, or platy, but connecting pores that conduct water when the soil is wet are few, and cracks or spaces among peds that may be present when the soil is dry, close with wetting. Even in positions accessible to plant roots, roots are usually few or absent. When present, roots are localized along cracks.

porosity: The volume percentage of the total bulk not occupied by solid particles.

profile (soil): A vertical section of the soil through all its horizons and extending into the parent material.

productivity: Expression of tree growth by site index which is a measurement of tree growth expressed as height (m) at 50 years breast height.

reaction (soils): The degree of acidity or alkalinity of soil, usually expressed as a pH value.

reconstructed soil: A soil profile formed by selected placement of suitable overburden materials on reshaped spoils.

residual material: Unconsolidated and partly weathered mineral materials accumulated by disintegration of consolidated rock in place.

root zone: That part of the soil which is occupied by plant roots.

sodium adsorption ratio (SAR): A ratio for soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange relations with soil, where the ionic concentrations are expressed in milliequivalents per litre.

$$SAR = Na/[(Ca + Mg) / 2]^{1/2}$$

saline soil: A nonalkali soil containing soluble salts in such quantities that they interfere with the growth of most crop plants. The conductivity of the saturation extract is greater than 4 dS/m (formerly mmhos/cm), the exchangeable-sodium percentage is less than 15, and the pH is usually less than 8.5.

salinization: The process of accumulation of salts in soils.

sand: A soil particle between 0.05 and 2.0 mm in diameter.

saturation extract: The solution extracted from a saturated soil paste prepared using distilled water.

saturation percentage: The amount of water required to saturate a unit of soil (often correlated with sodicity).

second lift: The second layer of undisturbed soil material which underlies the first lift, and which is removed and segregated during surface mining to be replaced as subsoil.

silt: A soil separate consisting of particles between 0.05 to 0.002 mm in equivalent diameter.

sodicity: A measure of the amount of sodium on the exchange complex (often expressed as sodium adsorption ratio - SAR).

soil: The naturally occurring, unconsolidated mineral or organic material at least 10 cm thick, that occurs at the earth's surface an is capable of supporting plants. It includes disturbance of the surface by mans activities such as cultivation and logging but not displaced materials such as mine spoils.

soil capability: the nature and degree of limitations imposed by the physical, chemical and biological characteristics of a soil unit for forest productivity.

soil map: A map showing the distribution of soil types or other soil mapping units in relation to the prominent physical and cultural features of the earth's surface.

soil moisture: Water contained in the soil.

soil series: A soil series is a conceptual class that has defined limits of relatively detailed soil properties including horizon depth and expression, color, texture, structure, consistence, stoniness, salinity, pH and soil drainage. In soil mapping, the names of soil series are often used to name the map units.

soil structure: The combination or arrangement of primary soil particles into secondary particles, unit or peds. These secondary units may be, but usually are not, arranged in the profile in such a manner as to give a distinctive characteristics pattern. The secondary units are characterized and classified on the basis of size, shape, and degree of distinctness into classes, types, and grades, respectively. Common terms for kind of structure are - single grain, amorphous, blocky, subangular blocky, granular, platy, prismatic and columnar.

soil survey: The systematic examination, description, classification, and mapping of soils in an area. Soil surveys are ranked according to the kind and intensity of field examination.

soil type: In ecosite classification soil types are functional taxonomic units used to stratify soils based on soil moisture regime, effective soil texture, organic matter, thickness, and soil depth. The concept of the soil type is more general than that of a soil series in this context.

Solonetzic: An order of soils developed mainly under grass or grass-forest vegetative cover in semiarid to subhumid climates. The soils have a stained brownish or blackish solonetzic B (Bn, Bnt) horizon and a saline C horizon. The order includes the Solonetz, Solodized Solonetz and Solod great groups.

solum (plural sola): The upper horizons of a soil in which the parent material has been modified and within which most plant roots are confined. It consists usually of A and B horizons.

spoil: Overburden that has been disturbed and haphazardly mixed during surface mining.

subsoil: Although a common term it cannot be defined accurately. It may be the B horizon of a soil with a distinct profile. It can also be defined as the zone below the plowed soil in which roots normally grow. In this publication it refers to the soil material between 20 cm and 100 cm depth.

sustainability: the reclaimed plant communities establish and progress to maturation without the operators ongoing input of nutrients, water, seeds or seedlings. Furthermore, the reclaimed sites must be able to recover from infrequent, naturally occurring environmental disturbances such as fire, floods or drought at the same rate as similar natural areas.

sustained yield: the yields that a forest can produce continuously at a given intensity of management.

texture: The relative proportions of sand, silt and clay (the soil separates). It is described in terms such as sand (S), loamy sand (LS), sandy loam (SL), loam (L), silt loam (SiL), clay loam (CL), silty clay loam (SiCL) and clay (C). See textural triangle, Figure 17.

topsoil: The organo-mineral surface "A" or organic surface "O" horizon; dark-coloured surface soil materials, e.g., first lift. First lift materials are usually removed to the depth of the first easily-identified colour change, or to specified depth where colour change is poor, and contain the soil Ah, Ap, O, or Ahe horizon. Other horizons may be included in the first lift if specified.

unconsolidated material: Includes loose material as well as that compacted or cemented by soil-forming processes.

water-holding capacity: The ability of the soil (or spoil material) to hold water. Water content may be expressed as either gravimetric water or volumetric water. Gravimetric water is expressed as percentage of the weight of water per unit weight of oven-dry soil. Volumetric water is expressed as percentage of the volume of water per unit volume of soil or as depth of water per unit depth of soil.

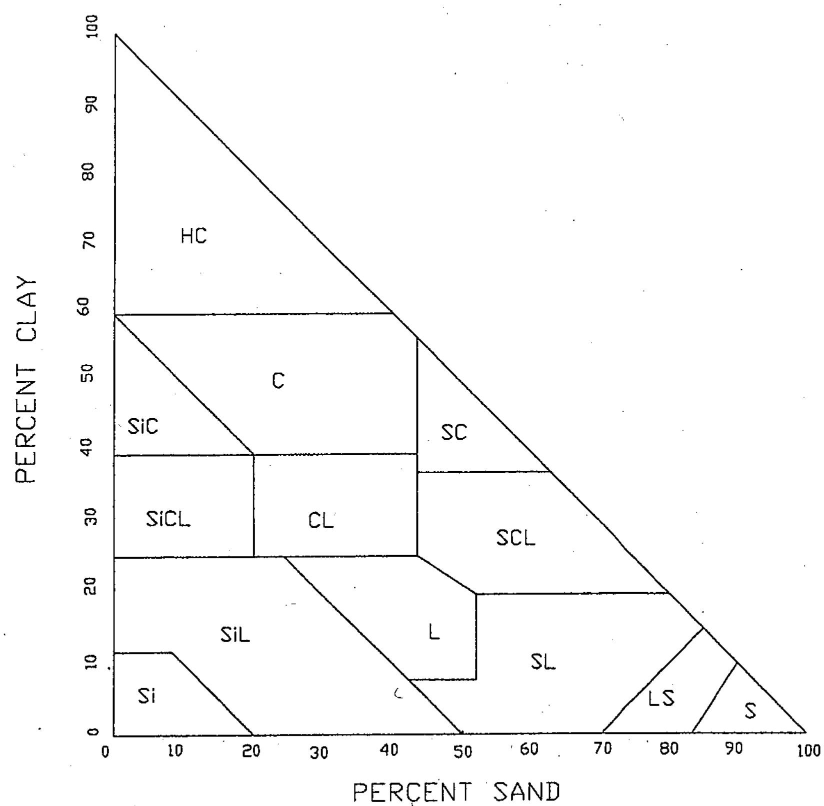

Figure 20. Soil textural triangle.