The Derivation of Spatially Referenced Ecological Databases for Ecosystem Mapping and Modeling in the Rinker Lake Research Area, Northwestern Ontario

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FILE REPORT

1.0 Introduction

Ecosystem management requires that attention be paid to ecological information outside of the narrow focus of conventional operational concerns. It is critical that ecological entities that exist on the landbase be properly identified, and that the relative values of the various landscape components be carefully weighed for both resource extraction and conservation purposes. In principle, this necessitates an interdisciplinary approach to developing a total inventory of ecological resources and processes within an area of operational interest.

Ecosystems are complex entities of multiple ecological dimensions; they also come in various sizes and shapes that may overlap on the ground, depending upon the scale of investigation and the manner in which they are described. Consequently, ecological inventories should be capable of distinguishing various properties of ecosystems and defining their relationships at various spatial scales. Scale issues are particularly important when spatially referenced ecological information is being compiled. Local, large-scale inventories should be nested within the context of smaller-scale, regional ecological units as defined within ecologically-based land classification systems.

Spatially referenced, ecological information will increasingly be used to construct or calibrate predictive, dynamic ecosystem models, at a variety of scales, for management purposes. As they are developed and tested, such models will be seeking to derive spatial information on critical ecosystem characteristics that are not directly interpretable from primary data sources. Examples of ecological parameters that may be modelled include the spatial distribution of primary environmental regimes such as radiation, ground water, and nutrients; potential ecological ranges for various biological communities and species populations; temporal, successional responses of vegetation communities to natural or anthropogenic disturbances; indices of biodiversity; specific regional effects of climate change and pollution; as well as dynamic linkages between local-level ecological conditions and responses to resource management activities at various scales. The accuracy of any modeling efforts depends upon the input of spatially reliable estimates of environmental attributes.

For northwestern Ontario, spatially referenced ecological data is limited in both its thematic coverage and the scales at which it is available. The data are typically outdated and do not therefore, accurately represent existing landscape features, particularly vegetation conditions. Existing spatial databases, such as the Ontario Land Inventory (OLI), Northern Ontario Engineering Geology and Terrain Survey (NOEGTS), and Forest Resource Inventory (FRI), are useful for some, but not all applications. For operational forest management, both the OLI and NOEGTS databases lack sufficiently detailed data required to support local management decisions. While FRI information is provided at an operational scale (i.e., 1:15 000 to 1:20 000 scale), it lacks ecological scope by detailing, for a moment in time, only the characteristics of the forest canopy in terms of tree species composition and potential timber volumes. In order to achieve ecologically-based forest management, existing databases may need to be modified and/or new databases will have to be created, at appropriate scales, to represent the spatial distribution of all types of ecological parameters (soil, understory vegetation, etc.).

1.1 An Overview of the Rinker Lake Project

In Spring, 1992, a multidisciplinary and multiagency research project was initiated at the Rinker Lake Research Area in northwestern Ontario. A principal goal of this collection of studies was to assimilate and integrate the findings of various researchers into prototypes of spatially-based ecosystem models, or sets of models, (initially, static and descriptive; ultimately, dynamic and predictive) that could be applied in the context of resource management planning. Another goal was the elucidation and description of ecosystem components and processes at scales of 1:15 000 to 1:20 000, the current scale of operational forest management planning in northwestern Ontario.

The project served as a demonstration of the practical application of GIS technology for the purposes of resource inventory, ecosystem process modeling , and management planning. An analytical GIS approach was employed throughout the project in order to 1) integrate various ecological databases (e.g., FRI, landcover, soil, terrain); 2) construct and test ecosystem models; and, 3) develop several "case study" resource management applications that demonstrate the utility and application of the work.

In order to carry out the modeling work, data was required that provided spatial representation of both primary and derived ecological data. Primary spatial data used throughout the project included 9 digital topographic mapsheets from the Ontario Base Map (OBM) Series (1:20 000 scale), black and white aerial photographs (1:15 840 scale) acquired during summer 1985, colour infrared aerial photographs (1:10 000 scale) acquired in September, 1992 and September, 1994, and 2 Landsat Thematic Mapper (TM) images (bands 1-7) acquired June 20, 1992 and September 11, 1993. Additionally, various ecological ground survey data were collected at approximately 550 georeferenced points across the Research Area according to the following breakdown: 1) approximately 250 points at which ground truth observations were noted for mapping the Quaternary geology features in the Rinker Lake Research Area; 2) approximately 100 10 m x 10 m plots at which full descriptions of soil, site, and vegetation conditions were collected according to Northwestern Ontario Forest Ecosystem Classification (NWO FEC) protocols (Sims *et al.* 1989); 3) approximately 200 ground truth points at which soil textures were determined along with abbreviated site and vegetation descriptions.

Spatial databases describing fundamental ecological characteristics of the Rinker Lake Research Area were subsequently derived from these primary spatial and ground survey data. A digital elevation model was constructed from the OBM topographic contour data. Quaternary geology of the Research Area was mapped using aerial photo-interpretation and ground truth observations at some 250 survey points throughout the Research Area. Soil texture coverages were derived by reclassifying the Quaternary geology polygons according to ground observations of soil texture at approximately 200 points across the Research Area. Land cover classifications were derived from the 1992 and 1993 TM images. As well, coverages of roads and cutovers were updated as forest management activities proceeded during the study period.

The techniques for deriving these spatial databases constitute the focus of a NODA Note (see NODA Note #). The primary databases described in this report (terrain, soils, and land cover) are currently being used in ongoing modeling efforts to predict the spatial distribution of primary environmental regimes, and biological responses to physical and temporal characteristics within the Rinker Lake Research Area. The database development and modeling work being carried out for the Rinker Lake Research Area at an operational scale (1:20 000) parallels and complements similar modeling work for the province of Ontario at a landscape scale (approximately 1:250 000) (Mackey and McKenney 1994; McKenney et al. 1996).

The Ontario Ministry of Natural Resources (OMNR) is currently updating the provincial silviculture guidelines to address a new requirement to employ standard, mappable site types, and ecosite terminologies in the forest management planning process. Databases for the Rinker Lake Research Area have provided important background information for the development of these new guidelines. The techniques that have been tested in the Rinker Lake Research Area, as well as techniques from several other prototype ecosite mapping locations in northwestern Ontario, are helping to shape the future of Ontario's forest management planning process.

1.1.1 Linkages and Co-operators:

Research activities in the Rinker Lake Research Area involved investigators from a number of federal and provincial agencies, universities, forest industry and private contractors. Research coordination was provided by the Canadian Forest Service, Ontario. The two primary funding sources for the work were the federal/provincial cost-shared Northern Ontario Development Agreement (NODA), and the federal government's Green Plan, although additional funding sources assisted some individual studies.

Agencies and groups participating in the project included:

Canadian Forest Service (CFS) - Ontario Region, Department of Natural Resources Canada
Ontario Ministry of Natural Resources (OMNR):
- Science & Technology Unit, NW Region
- Provincial Remote Sensing Office
- Land Resource Information Division
- Centre for Northern Forest Ecosystem Research
- Provincial Fire and Aviation Branch

Ontario Geological Survey, Ontario Ministry of Northern Development and Mines
Australian National University
Institute for Space and Terrestrial Studies, University of Waterloo / York University
Canadian Wildlife Service - Ontario Region, Department of National Heritage Canada

Surveys, Mapping and Remote Sensing Sector, Department of Natural Resources Canada
Abitibi-Price Inc.
EROS Data Centre, United States Geological Survey
Geomatics International Inc.
Mitig Forestry Services Ltd.
University of Toronto

There are several important linkages for the Rinker Lake ecosystem mapping / modeling work:

1. Other collaborative/cooperative studies at the Rinker Lake Research Area, which provide some of the background data for resource modeling, bird habitat investigations, remote sensing imagery interpretations, etc.. that are going on concurrently.

2. Other forest ecosystem related activities that are ongoing in Ontario and elsewhere. This Rinker Lake work serves as an important prototype for making the essential linkages between ground-based forest ecosystem classification and mappable spatial units.

   For example, research tie-ins exist to:

   - Forest ecosystem classification prototype mapping which is now underway in the Northeast Region of Ontario.
   - The development of a forest ecosystem classification for Manitoba forests
   - The development of a photo-interpretation guide for northwestern Ontario forest ecosystem classification units (an ongoing study being supported by the Northern Ontario Development Agreement)

3. The "Bioenvironmental Indices Project" (BIP) which is being conducted at a regional scale. The Rinker Lake Study Area serves as a prototype test-area for larger scaled applications of BIP outputs and activities. Mapping of the Rinker Lake ecosystem serves as an important prototype for testing the potential for operational use of digital elevation models for forestry applications in Ontario.

4. Mapping of the Rinker Lake ecosystem provides a unique basis for describing modeled/predicted parameters of vegetation, soils and other features in relationship to a very detailed ground-truthed database of ecological features. Ground surveys have now been completed at over 300 plots, all of which have detailed ecological information linked to globally positioned locations. A forest ecological database of this detail and accuracy for the express purpose of landscape-level spatial study is not available elsewhere. Results from the Rinker Lake Study Area ecosystem mapping work should help to guide future provincial

strategies for ecologically-based land classification, mapping, and inventory.

1.2 The Rinker Lake Research Area

Located about 110 km north of Thunder Bay, Ontario, the 900 sq km (i.e., 30 km by 30 km) Rinker Lake Research Area (Figure 1) encompasses 9 Ontario Base Map (OBM) mapsheets at 1:20 000 scale. Latitude / longitude co-ordinates of the approximate center of the Research Area are 49° 10′ N; 89° 20′ W. The Research Area is bounded by Lac des Iles in the northwest, Poshkokagan Lake in the northeast, and Eaglehead Lake in the southeast. It is accessible from Thunder Bay via provincial Highway 527, a drive of approximately 1.5 hr. It lies wholly within the Lake Nipigon Ecoregion of the Boreal Shield Ecozone (Ecological Stratification Working Group 1995). The humid to perhumid, moderately cool, boreal climate of this Ecozone is generally characterized by warm, rainy summers and cold, snowy winters. Specifically, the Research Area receives in the order of 75 cm of total precipitation annually, approximately 50 cm of which occurs as rainfall (Environment Canada 1982b). Annual snowfall averages over 250 cm (Environment Canada 1982b), but the average snow depth rarely exceeds 75 cm throughout the winter. The mean annual daily temperature for the area is about 0°C; mean annual daily minimum temperature is approximately -6°C and mean annual daily maximum is around 6.5°C (Environment Canada 1982a).

Landscape features of the Rinker Lake Research Area constitute a heterogeneous mosaic of both surface and subsurface conditions. Hundreds of waterbodies and rivers cover some 103.4 sq km (11.5%) of the 900 sq km Research Area. The physiography of the Research Area is primarily bedrock-controlled, characterized by undulating hills of low to moderate relief, and by low parallel ridges oriented in a northeast to southwest direction. Elevations range between 360 m above sea level (asl) and 560 m asl, with the majority of the relief (over 80% of the area) occurring between 440 m asl and 500 m asl. Highest elevations occur in the northwest and southeast sectors of the Research Area (Figure 2). The underlying bedrock includes Archean "greenstones" and granites as well as diabase and unmetamorphosed shales and limestones from the Proterozoic Era.

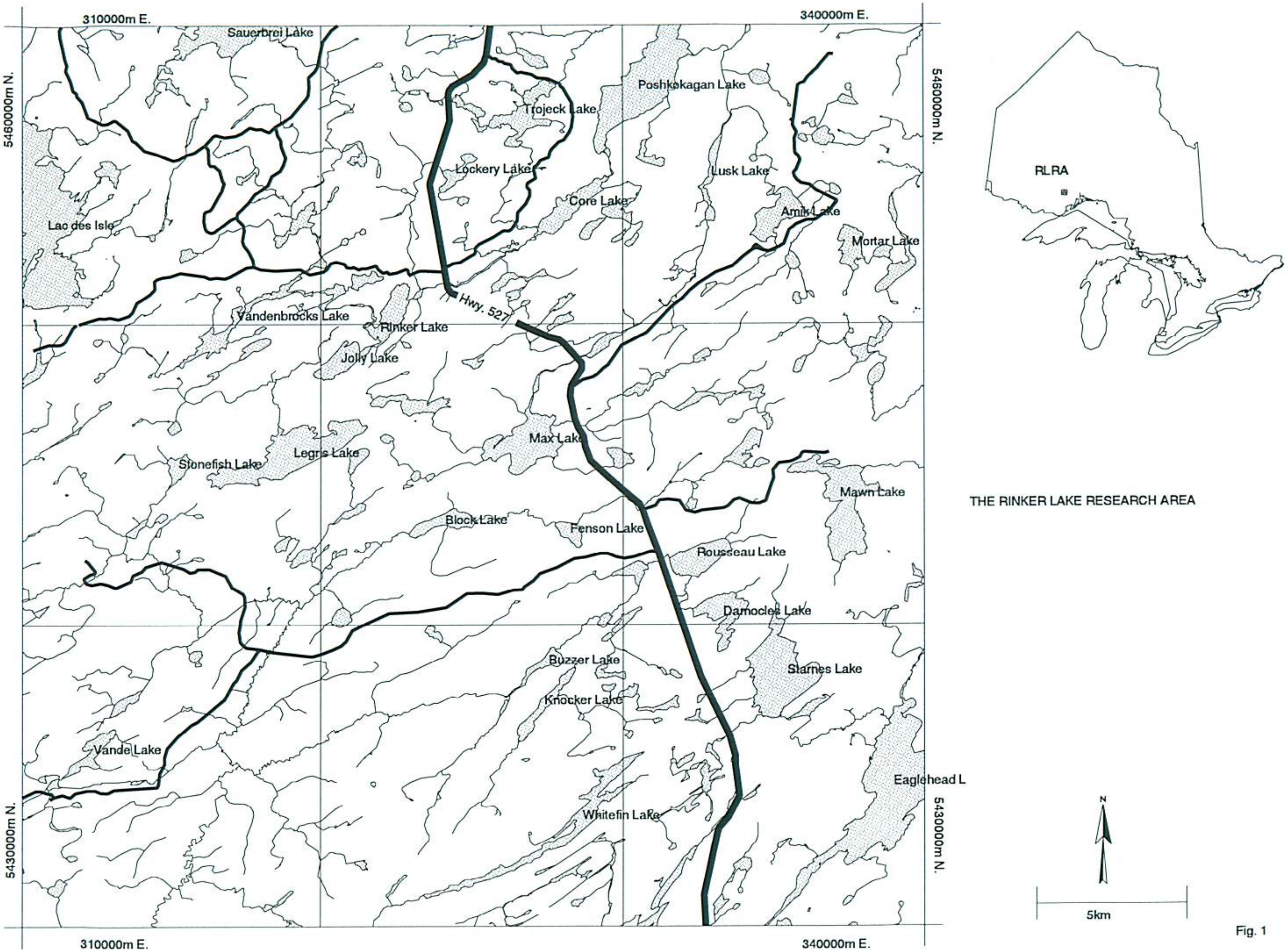
Surficial materials in the Research Area are predominantly of glacial origin, although some post-glacial deposits of recent origin also occur. These deposits range in thickness from a thin veneer (<1m) to more than 30m, but on average are probably less than 5m thick. Glacial till is the most common surface sediment, covering 68% of the terrestrial portion of the Research Area. Approximately 17% of the land area is covered by glaciofluvial deposits, comprising flat outwash plains and positive relief, ice-contact features, such as eskers and kames. There are also limited expanses of fine-grained, mostly silt-sized, glaciolacustrine sediments, which were deposited in local glacial lakes. Recent materials include organic deposits, covering about 12% of the land area; sandy alluvium; and coarse, angular talus.

Soil parent materials in the study area vary in texture from silt to sand to gravel with only a minor clay component (<10%). The till matrix mostly contains 30 to 60% sand (mostly fine and very fine sand fractions), generally with <2% clay, and textures fall in the sandy loam and silt loam classes. Glaciofluvial sediments are generally classed as gravelly sands. Most of the glaciofluvial deposits throughout the Research Area contain high fractions of fine and very fine sand, although many of the eskers in the southwestern part of the area are composed mainly of open framework gravel with very poor water retention capacity. The fine-grained glaciolacustrine deposits are classed as either silt loams or silty clay loams. Soil profiles throughout the Research Area, regardless of depositional origin, are commonly characterized by a cap of silty sediment overlying the genetic parent material.

The Rinker Lake Research Area is located within the Boreal Forest Region of Canada (Rowe 1972). This Region is characterized by extensive conifer forests of black (*Picea mariana* [Mill.] BSP.) and white spruce (*Picea glauca* [Moench] A. Voss), jack pine (*Pinus banksiana* Lamb.) and balsam fir (*Abies balsamea* [L.] Mill.), as well as mixed stands of conifer and northern hardwood species such as trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.). In overview, the mature forests of the Rinker Lake Research Area are a diverse combination of pure and mixed stands comprising all of the major tree species listed above. The most common stand composition consists of a mixture of black and white spruce, balsam fir, white birch, and trembling aspen; the second most frequent cover type comprises a mixture of black spruce and jack pine. According to interpreted landcover from a Landsat TM image dated June 20, 1992, mature, closed canopy forest covered about 82% (approximately 655.3 sq km) of the land portion of the Research Area at that time. Of this total, conifer and conifer-dominated mature forests were estimated to cover about 48% (383.0 sq km) of the land portion of the Research Area, while hardwood and hardwood-dominated mixedwoods covered about 34% (272.3 sq km). About 7.5% of the landbase was accounted for by wetlands, alder thickets, sparse vegetation cover (e.g., associated with shallow soils) and other minor vegetation features.

The Research Area lies within the bounds of the Spruce River Forest Management Agreement with Abitibi-Price Inc. Although timber harvesting has been conducted within the Research Area over the past 40 years, the majority of industrial activity has occurred since 1985. As a consequence, a range of stand age classes is represented within the area, from recently harvested, regenerating stands (aged 0-10 years) to intact, mature forest (aged >100 years). According to interpreted land cover from the June 20, 1992 Landsat TM image, young (0-10 years) cutovers covered about 66 sq km (approximately 8.0% of the land portion of the Research Area) and existing road networks (*see* Figure 5) accounted for an additional 19 sq km, or about 2.3% of the land area. The relative areal proportions of mature forest to young, regenerating forest are changing rapidly as timber harvesting operations proceed in the area.

All of the timber production from Company operations is in tree length form. One hundred percent of the wood is cut mechanically by feller bunchers and grapple skidded to roadside. It is then mechanically delimbed. At roadside, the tree lengths are either cut into 2.5 m or 5.1 m lengths (pulpwood and sawlogs, respectively) by means of mobile slashers. Hydraulic loaders



THE RINKER LAKE RESEARCH AREA

Fig. 1

then load the truck and trailer units with approximately 55 m^3 of wood. Much of the harvested aspen is chipped at the roadside directly into trailers for transport. All wood is delivered to the various mills in Thunder Bay; haul distances for Company and third party vehicles vary between 90 and 180 km.

The Ontario Ministry of Natural Resources maintains a forward attack fire-fighting base at the northeastern end of Rinker Lake, near the centre of the Research Area. The camp provided an excellent base of operations for research staff, and its use was an important factor in the success of field work.

2.0 A Digital Elevation Model for the Rinker Lake Research Area

A digital elevation model (DEM) is an ordered array of numbers that represents the spatial distribution of elevations above some base datum (e.g., mean sea level) in the landscape (Moore *et al.* 1991). Spatial referencing typically uses coordinates defined by latitude and longitude or Universal Transverse Mercator (UTM) grid intersections. A good DEM contains accurate, digital, topographic data that can then be used as the basis for reliable, spatially referenced estimates of local and regional climatic regimes, and numerous terrain-related ecological attributes of the landscape (Mackey *et al.* 1994).

A DEM for the Rinker Lake Research Area was developed at a 20 m grid resolution (Figure 2), using the ANUDEM procedure (Hutchinson 1989) and digital input data from the Ontario Base Map topographic series. OBM digital topographic data (1:20 000 scale) are available for a significant portion of the commercially-forested land area in northwestern Ontario. These data comprise lake polygons, stream vectors, spot heights, and elevation contours at intervals of 10 m. Base maps encompassing the Research Area included the following nine mapsheets: 16 3100 54300 to 54500, 16 3200 54300 to 54500, and 16 3300 54300 to 54500. Contour, lake, and stream data were interpolated using the ANUSPLIN procedure (Hutchinson 1987), following computational procedures as described by Mackey *et al.* 1994.

The DEM provides a digital representation of the topography of the landscape within the Research Area. Figure 2 shows the northeast - southwest orientation of the bedrock ridges underlying the central portion of the Research Area. Also clearly illustrated are the heights of land associated with outcrops of the Nipigon diabase formation in the northwestern and southeastern portions of the Research Area.

The DEM also constitutes a database upon which interpretive climatic and terrain analyses can be conducted. By fitting climatic surfaces to the DEM (Mackey et al. 1996), values for a range of climatic and bioclimatic variables were estimated at point locations in the Research Area where field data had been collected, thereby enhancing the ecological descriptions of these sample plots. A radiation model (Wilson and Gallant 1996) has been calibrated for the Research Area in order to provide estimates of parameters associated with solar radiation for these same sample plots. Statistical terrain analyses also make use of the DEM and other spatial data in order to establish empirical relationships between topographic landscape attributes and primary environmental regimes within the Research Area.

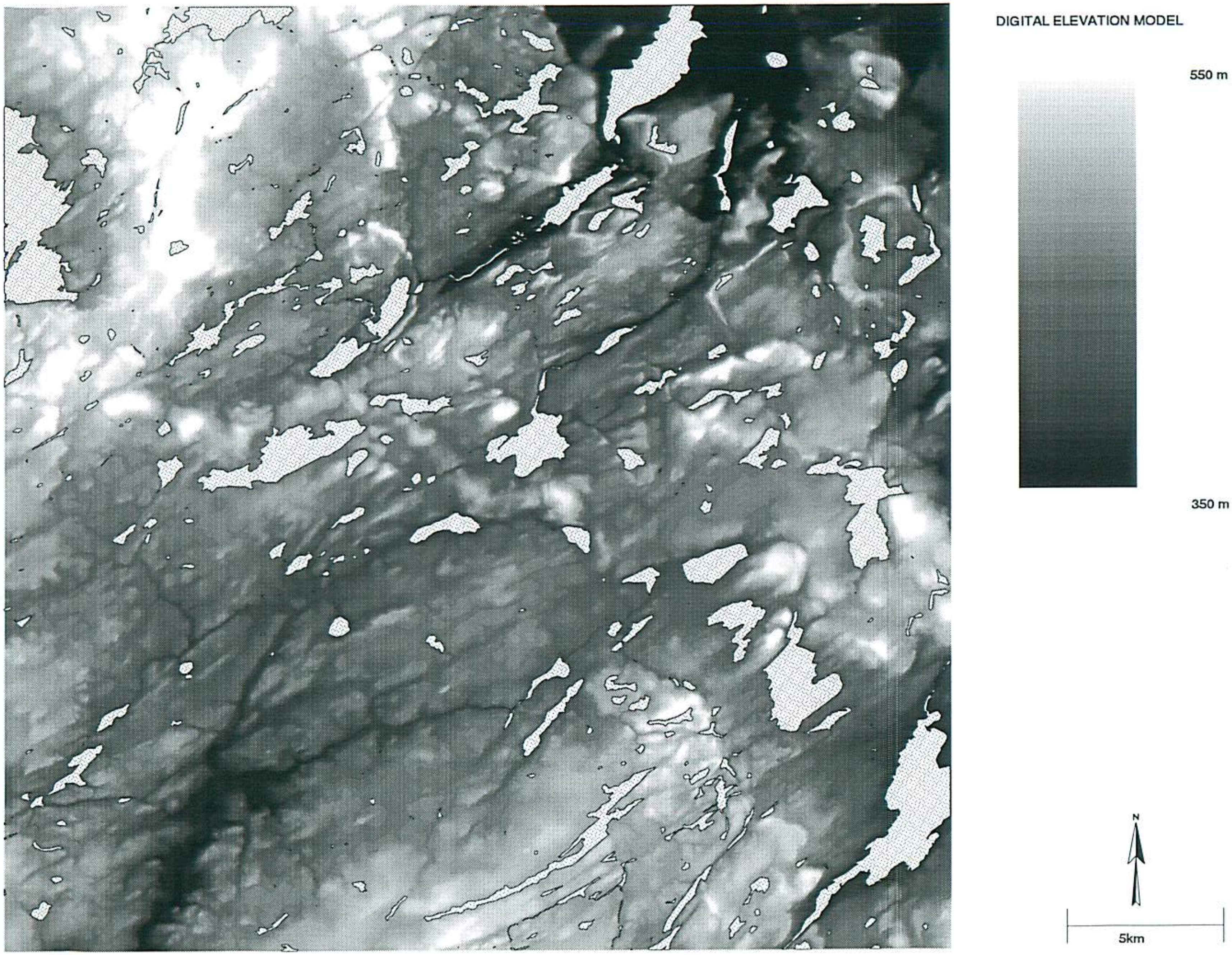


Fig. 2

3.0 Geology and Soils of the Rinker Lake Research Area

The expression of the ecological character of a region is the result of interactions, over time, between climatic, biological, and geological factors. Weathering of bedrock and soil parent materials results in the development of mineral soils which, in turn, provide the physical substrate within which most vegetation communities evolve. Genetic characteristics of geological materials are very influential in determining both the physical and chemical nature of mineral soils that develop in an area. The distribution and productivity of vegetation communities respond, in part, to the characteristics of soil substrates upon which they grow.

Detailed spatial data on the distribution of soil attributes within the Rinker Lake Research Area are essential for the construction of integrated ecosystem models. These data, in conjunction with the DEM, offer a comprehensive description of the physical landscape of the Research Area. At the outset of the Rinker Lake Project, existing spatial data for the substrate characteristics of the area consisted mainly of incomplete coverages of mapped bedrock and Quaternary geology features at scales no larger than 1:100 000 (e.g., Mollard and Mollard 1981). Some interpreted coverage of soil attributes was available for the entire area, in the Ontario Land Inventory series at a scale of 1:250 000. Consequently, in order to have spatially referenced soil data for the Research Area, at a nominal scale of 1:20 000, a database had to be constructed using primary sources.

This work was overseen by John Ford of the Ontario Geological Survey and was completed in 2 stages. Initially, a map of the Quaternary geology of the Research Area (Figure 3) was developed using conventional photo-interpretation of black and white aerial photographs (1:15 840 scale), supplemented by color infrared aerial photography (1:10 000 scale). This was augmented by field observations of both bedrock and surficial landform characteristics, collected at approximately 250 georeferenced ground points. Twenty-two surficial geology classes were identified (Table 1), and the resulting map layer was line digitized, with polygon boundaries rasterized to a 20 m grid spacing at a nominal scale of 1:20 000. Distribution of soil texture (Figure 4) was subsequently derived by reclassifying polygons from the Quaternary geology data layer using a reclassification matrix (Table 2) developed from ground survey data, including soil samples collected at over 300 georeferenced field plots that were submitted for laboratory texture analyses. The texture reclassification was verified against both surface (0-25 cm) and deep (C horizon) soil strata using an independent set of field data.

Results of this work provide a detailed description of both the bedrock and Quaternary geological features of the Rinker Lake Research Area. Additionally, an intimate understanding of the structural and chemical characteristics of soils occurring within the Research Area has been developed as a result of intensive field observations. Relationships between soil attributes and genetic Quaternary classes have been elucidated and the spatial distribution of soil textures within the Research Area can be predicted with greater than 70% accuracy.

Table 1. Listing of the 22 Quaternary geology landform classes recognized for the Rinker Lake Research Area. A thematic map of the Quaternary geology of the Research Area is presented in Figure 3. Areal extent for each class is given in square kilometers.

Class	Definition	
1	Colluvium / talus (0.3 sq km)	
2	Organic deposits: peat, muck (79.1 sq km)	
3	Alluvial deposits (1.1 sq km)	
4	Glaciolacustrine deposits: general	
5	"	: silt, clayey silt, silty sand (5.4 sq km)
6	"	: as in classes 4 & 5, with up to 1m organic overlay (1.0 sq km)
7	Glaciofluvial outwash	: general (19.4 sq km)
8	"	: sand, gravelly sand (14.8 sq km)
9	"	: gravel, sandy gravel (8.9 sq km)
10	"	: lag boulder deposits (0.5 sq km)
11	Glaciofluvial ice contact stratified drift: general (35.7 sq km)	
12	"	: sand, gravelly sand (19.9 sq km)
13	"	: gravel, sandy gravel (8.0 sq km)
14	"	: esker (2.2 sq km)
15	Glacial till deposits	: general (82.8 sq km)
16	"	: silty sand to silt till, up to 10% clasts (93.0 sq km)
17	"	: stony sand to silty sand till (14.0 sq km)
18	Bedrock-drift complex	: general (33.9 sq km)
19	"	: mainly till cover (122.6 sq km)
20	"	: mainly glaciofluvial sand and gravel cover (9.1 sq km)
21	"	: organic cover (1.6 sq km)
22	Precambrian bedrock (74.9 sq km)	


QUATERNARY GEOLOGY
Colluvium
Organic Deposits
Alluvial Deposits: gravel, sand, silt
Glaciolacustrine Deposits
silt, clayey silt
silt with < 1m of organic cover
Glaciofluvial Outwash
undifferentiated sand, gravel
sand, gravelly sand
gravel, sandy gravel
lag deposits: boulders
Glaciofluvial Ice-Contact Stratified Drift
undifferentiated sand, gravel, boulders
sand, gravelly sand
gravel, sandy gravel, boulders
Glacial Till Deposits
undifferentiated till
silty sand to sandy silt till
stony sand to stony silty sand till
Bedrock/Drift Complex
variable or unknown drift type
drift is mainly till
drift is mainly sand, gravel
bedrock with organic deposits
Precambrian Bedrock
N
5km

Fig. 3

Table 2. Reclassification matrix for conversion of Quaternary geology classes to C horizon soil texture classes.

Soil Texture Class (*see* Table 5)	Quaternary Classes (*see* Table 1)
1	1, 10, 22
2	9, 14
3	3
4	7, 8, 11–13, 15–20
5	4, 5
6	4, 5
7	2, 6, 21

3.1 Surficial Geology Overview

The Canadian Shield in Ontario is a broad region of generally low to moderate relief underlain by a wide variety of rocks of Archean and Proterozoic age. This is a glaciated terrain and soil parent materials are almost exclusively transported sediments, deposited mainly by glacial, glaciofluvial, and glaciolacustrine processes during the last major episode of glaciation. This drift cover is typically fairly thin (<5 m) and the physiography of much of the shield is bedrock-controlled.

Northwestern Ontario includes the extensive Glacial Lake Agassiz basin, with its thick sequences of glaciolacustrine silts and clays and associated sandy glaciofluvial deposits. Several large end moraines - composed of sand, gravel, and stony till - trend roughly northwest-southeast across the region, with local relief in places of almost 100 m. Interlobate moraines and major eskers are roughly perpendicular to the trend of the end moraines. Glacial till, with a sandy loam to silt loam matrix, is the predominant surficial sediment outside of the former glacial lake basins.

The Rinker Lake Research Area lies outside of the major glacial lake basins and straddles the boundary between two major subdivisions of the Shield: the Archean Superior Province and the Proterozoic Southern Province. Rocks underlying the area include an Archean "greenstone" assemblage of metavolcanic and metasedimentary rocks, granites, unmetamorphosed shales and limestones of the Proterozoic Sibley Group, and diabase. Each of the major rock types has a distinctive influence on the generally bedrock-controlled physiography of the area. The youngest rock in the area, the Nipigon diabase, forms prominent ridges, knobs, cuestas, and mesas throughout much of the area and underlies the extensive uplands to the west of Lac des Iles.

3.1.1 Physiography

The physiography of the Rinker Lake Research Area is largely bedrock-controlled and its variable nature clearly reflects the influence of the different major rock types. This can be clearly seen by comparing published bedrock maps of the area with the DEM or topographic maps. The most prominent features are ridges, knobs, cuestas, and mesas, formed on resistant Nipigon diabase, which are common through much of the area and have up to 80 m of local relief. Diabase underlies the extensive, relatively well-drained upland area in the northwestern part of the Research Area, which contrasts sharply with an adjacent terrain of low granite outcrops and intervening wet, organic soils. Areas underlain by Archean supracrustal rocks have low to moderate relief with northeasterly trending ridges. Unmetamorphosed sedimentary rocks of the Sibley Group underlie an area of low relief in the extreme southeastern corner of the Research Area.

Eskers and esker-kame complexes are the most common, distinctly glaciogenic landforms in the Research Area. They are present in all parts of the area, but are most prominent in the northeastern and southwestern portions, where sections of the landscape are drift-dominated.

Eskers range from <3 m to about 10 m in height and the largest observed kames are about 8 to 10 m high. Crevasse fill ridges, usually transverse to the last major ice flow direction, are common in ice contact, stratified drift complexes.

Outwash plains are common, but are generally less extensive than the esker-kame complexes. The smaller outwash systems are generally bedrock-controlled. The most extensive outwash plain is between Mawn Lake and Highway 527. The only erosional terraces on outwash recognized in the Research Area are west of Lusk Lake.

Streamlined whaleback ridges, formed by glacial abrasion, are common on the metasedimentary rocks in the southwestern part of the Research Area, where major ice flow was roughly parallel to the strike of the rocks. These features are up to 6 m high and 20 m to 30 m long. Similar ridges are also developed on massive amphibolitic metavolcanic rocks north of Max Creek, and even on diabase in a few locations. Drift cover on these features is generally absent or very thin. A few of the diabase knobs in the area form the bedrock cores of crag-and-tail features. No moraines of any size were recognized in the Research Area.

There are no major rivers within the Research Area and drainage is mainly to the northeast, toward Lake Nipigon via several small creeks and rivers. Southward flowing Block Creek drains the southwest part of the Research Area. Many scattered bogs and fens indicate poor local drainage in many parts of the area.

3.1.2 Bedrock Geology

The Rinker Lake Research Area lies entirely within the Canadian Shield and straddles the boundary between the Wabigoon Subprovince of the Superior Province and the Nipigon Embayment of the Proterozoic Southern Province. The northeast-trending boundary of the Wabigoon and Quetico subprovinces crosses the southeast corner of the Research Area.

The central and southern parts of the Research Area are underlain by an east-northeasterly striking belt of Archean supracrustal rocks. Massive mafic metavolcanic rocks predominate in the northern part of the belt, with subordinate pillowed and porphyritic mafic metavolcanic rocks and metamorphosed felsic to intermediate pyroclastic rocks. There are abundant clastic metasedimentary rocks in the southern part of the belt, mainly metawacke, but there are also polymictic, cobble to boulder metaconglomerate and minor meta-arkose. Metasedimentary migmatite (mainly metatexite) is present near the subprovince boundary in the southeastern corner of the Research Area. The regional metamorphic grade in the belt generally ranges from upper greenschist to lower amphibolite facies rank.

Late Archean felsic intrusive rocks flank the belt to the northwest and a small granitic stock cuts the supracrustal sequence about two kilometres east of Rinker Lake. Near Fenson Lake, there are a few thin sills of quartz feldspar porphyry within the metasedimentary sequence and an intermediate to mafic stock intrudes metasedimentary rocks south of Legris Lake. On the western margin of the Research Area, the Lac des Iles mafic-ultramafic complex intrudes gneissic tonalite and is contemporaneous with the younger granitoid rocks in the area (Sutcliffe *et al.* 1989). This intrusive complex hosts significant palladium-platinum deposits.

The relatively undeformed clastic and carbonate sedimentary rocks of the Mesoproterozoic Sibley Group have very limited exposure within the Research Area: Kaye (1969) reports Sibley Group rocks in two exposures below sills of Nipigon diabase, and a few small outcrops were found during the present study. Gently dipping brick red shale, exposed in a pit east of Starnes Lake, shows distinctive white "reduction" spots and is probably part of the Kama Hill Formation (*see* Franklin *et al.* 1980, Cheadle 1986). Flat-lying cream and pale green argillaceous dolostone outcrops north of Lime Creek in the northeastern corner of the area; it probably belongs to the Rossport Formation. It is thought that rocks of the Sibley Group underlie the extreme southeast and northeast corners of the Research Area.

The numerous bodies of tholeiitic diabase ('Nipigon diabase') in the area are mainly remnants of sills intruded within the Sibley Group and along the Archean-Proterozoic unconformity (Sutcliffe 1991). Pye (1968) mapped three diabase dikes that cross cut Archean rocks. The diabase is generally uniform and medium-grained, with typical "diabasic" textures visible even on weathered outcrops; however, coarsely crystalline to pegmatitic phases were seen at a few locations. Diabase is probably the most common single rock type in the Research Area and plays an important role in defining the physiography.

3.1.3 Ice Flow Directions

Wisconsinan ice flow is recorded in the Research Area by striations, chattermarks, crag-and-tail features, whaleback ridges, and a single drumlin. The two most prominent ice flow directions average azimuths of 220° and 240° (younger) and are roughly parallel to the general strike of the supracrustal rocks in the area. Striae also record ice movement toward azimuths of 180° and 265°, but the significance and relative timing of these events are unknown. Outcrops of diabase and Archean supracrustal rocks have the best preserved striations and hence were the best sources of ice flow data.

3.1.4 Drift Thickness

Drift thickness varies from zero to more than 40 m but, generally, it tends to be rather thin (<3 m) over much of the Research Area. Information about drift thickness is very limited; there are very few vertical exposures of more than 4m and no useful bore hole records. Locally, the thickness of drift cover can be estimated using the height of positive relief landforms, such as eskers. Road cuts and borrow pits generally yield only local minimum thickness information. Known areas of relatively thick drift are in deposits of ice contact stratified drift, most notably the high kame terrace in the northeast corner of the Research Area.

3.1.5 Till deposits

Till is probably the oldest and most widespread Pleistocene sediment in the Research Area. It is generally present at surface in upland areas as a mantle over the bedrock and does not display distinctive geomorphology. Matrix textures range from sand to predominantly silt, and clast content varies from <5% to more than 30%. Two till lithofacies were recognized for mapping purposes.

The first till facies (Class 16, Table 1; Figure 3) generally has a fairly uniform silty sand to sandy silt matrix with up to 10% clasts, mainly in the granule to small cobble range. This till facies commonly displays weakly to well developed fissility and is usually moderately compact to compact. The colour is typically olive grey in the C horizon and yellowish brown to dark brown in the B horizon. A brown to greyish brown BC transition zone, 20 cm to 40 cm thick, is fairly common and the B horizon proper (Bm) generally ranges from 30 cm to 70 cm thick. Maximum observed thickness is about 3 m, but good vertical exposures of this till facies are limited.

Table 3 summarizes textural data for this facies. Note that the mean values for the B horizon samples indicate a higher silt content than is found in the C horizon. This relationship is present in most pairs of samples analyzed and it was observed in the field at sites throughout the Research Area. It is assumed that this textural variation is the result of pedogenic processes; mineralogical studies may shed some light on this phenomenon.

In some parts of the Research Area, particularly in the northeast, C horizon material of this till facies reacts moderately to 10% hydrochloric acid (HCl) and there are noticeable clasts of carbonate rock derived from the Sibley Group. In the southeastern part of the Research Area, the till matrix has a distinct reddish cast and there are abundant clasts of reddish brown and maroon shale, also derived from rocks of the Sibley Group. In this area of reddish till, there is a single drumlin, with an orientation of 215°, just southeast of Rhamey Lake.

The second till facies (Class 17, Table 1; Figure 3) is stonier and tends to have a coarser-grained matrix than the first (see Table 4). This is particularly notable in the area just east of Lac des Iles where the till matrix is quite sandy and the stone content is as high as 40%. This facies is also less uniform and locally has a vaguely substratified appearance. The matrix composition varies from predominantly fine sand to silty sand and its colour is similar to the first till facies. Clasts are generally angular, with sizes ranging from granules to boulders; clast content locally exceeds 30%, but 20% to 25% is more typical. This facies is typically less compact than the other and cohesion is generally poor. Maximum observed thickness was 7 m. As in the first facies, the B horizon of this facies tends to have a higher silt content than the C horizon. From a textural classification standpoint, C horizon matrix samples of this facies are typically sandy loams and loamy sands. Many of the B horizon samples fall in the silt loam texture class.

Table 3. Textural data for the silty sand to sandy silt till facies with up to 10% coarse fragment content.

	SAND	SILT	CLAY	Median	Mean	St. dev.
mean overall	52.26	45.85	1.89	3.87	3.85	1.88
st. dev.	14.61	13.52	2.52	0.68	0.63	0.24
B hor: mean	47.16	50.55	2.29	4.08	4.03	1.90
st. dev.	16.48	15.57	2.62	0.77	0.70	0.26
maximum	74.26	75.32	7.64	2.61	2.87	2.42
minimum	17.78	25.73	0.0	5.33	5.37	1.30
C hor: mean	56.46	41.97	1.57	3.69	3.70	1.86
st. dev.	11.24	10.02	2.38	0.53	0.52	0.22
maximum	71.17	72.08	11.02	3.03	3.03	2.62
minimum	23.49	28.81	0.0	5.74	5.33	1.54

Note: the sand, silt, and clay values are in weight percentage; median, mean, and standard deviation are in phi units. The sand-silt boundary is 4 phi (62.5 microns) and the silt-clay division is 8 phi (3.9 microns), which is consistent with the Wentworth scale (from which the phi scale is derived) but varies somewhat from the respective USDA scale values of 50 and 2 microns.

Table 4. Textural data for the silty sand to sandy silt till facies with >10% coarse fragment content.

	SAND	SILT	CLAY	Median	Mean	St. dev.
mean	67.91	31.64	0.45	2.94	3.07	1.89
st. dev.	10.15	10.09	0.39	0.57	0.44	0.24
B hor: mean	63.70	35.94	0.36	3.11	3.21	1.94
st. dev.	12.51	12.65	0.51	0.74	0.54	0.27
maximum	76.25	74.32	0.76	2.57	2.73	1.77
minimum	24.92	23.73	0.0	4.78	4.82	1.26
C hor: mean	69.71	29.8	0.49	2.87	3.01	1.88
st. dev.	8.32	8.09	0.31	0.46	0.38	0.23
maximum	85.11	39.68	0.75	2.02	1.51	2.06
minimum	59.62	14.89	0.0	3.48	3.50	1.51

The mapped extent of this till facies within the Research Area is limited, with the most notable areas lying between Rinker Lake and Lac des Iles, and to the west of Core Lake. Because of the apparent lack of distinguishing geomorphology or characteristic tree cover, there is no way to recognize areas on aerial photos that are underlain by till of the stony facies. It may be the predominant surface material in some areas mapped as till of the silty facies that were not traversed on the ground.

3.1.6 Glaciofluvial deposits

Glaciofluvial deposits are formed by sedimentation from running glacial meltwater, either beyond the margin of a glacier (outwash), or on the surface of, within, or at the base of a glacier or a mass of stagnant ice (ice contact stratified drift). Typically, sand and gravel are the predominant materials in glaciofluvial deposits, but silt may be present in outwash. Silt, clay, and till are often found in sequences of ice contact stratified drift.

Deposits of glaciofluvial ice contact stratified drift are common throughout most of the Research Area, in the form of eskers, crevasse fills, kames, and kame terraces. Sediment texture and degree of sorting in these deposits are quite variable. Moderately well-sorted to well-sorted sand and gravelly sand are predominant in most of the exposures examined in eskers and in the kame terrace north of Lime Lake. However, most of the eskers in the southwestern part of the Research Area appear to be composed mainly of gravel, cobble and small boulder-sized material with infilling of sand and fine pebbles.

There is a prominent zone of nearly continuous ice contact stratified drift deposits that transects the area from northeast to southwest (Figure 3). Eskers and esker complexes are the most common landforms within this zone, but there are numerous kames, some crevasse fill ridges, and at least one kame terrace. For about 5 km to the east of Hwy 527, the zone is marked by a broad, round-crested ridge of silty sand and gravel that contains a few outcrops of metaconglomerate. In the northeastern part of the Research Area, the zone broadens into an extensive complex of eskers and kames, and includes a sandy kame terrace which is up to 40 m thick. Other areas with significant ice contact stratified drift deposits include the Vandenbrooks Lake area, the Poshkokagan River between Rinker Lake and Core Lake, and the area west and north of Trojeck Lake.

Glaciofluvial outwash is less abundant in the Rinker Lake Research Area than ice contact stratified drift; many of the outwash deposits are spatially associated with the latter. In general, outwash deposits in the Research Area are well bedded fine sands and gravels and display good to excellent sorting; descrete beds or lenses of fine-grained material are uncommon. Outwash bodies typically have roughly planar surfaces which slope gently toward the direction of meltwater flow. Erosional terraces, caused by major changes in stream dynamics, were identified only on the outwash west of Lusk Lake.

The most extensive outwash deposits are in the northeastern part of the Research Area, where sandy outwash plains flank a large area of ice contact stratified drift, and to the west of Mawn Lake, in the southeastern part of the Research Area. There is very little information available on the thickness of these deposits. Although fairly large in area, much of the gravelly outwash west of Mawn Lake appears to be a fairly thin (<4 m) mantle over bedrock. Most of the smaller outwash deposits are topographically constrained by bedrock.

There are lag deposits of boulders and large cobbles at several sites in the Research Area. Most of these are small and are indicated on the Quaternary map only by symbols, but the boulder lag at the north end of Vandenbrooks Lake is large enough to delineate as a polygon. The boulders in this deposit are subrounded, up to 1 m in diameter, and are almost entirely medium to coarsely crystalline granite of local provenance. Most of the area of this deposit is well vegetated and it is not readily discernable on aerial photos.

3.1.7 Glaciolacustrine Deposits

The Rinker Lake Research Area lies outside of the basins of the major postglacial lakes, such as glacial lakes Agassiz and Kelvin. However, parts of the Research Area were affected by local proglacial ponding and by a lake that extended into the area from the south. Only fine-grained sediments have been found in the Research Area - no shoreline features or deposits are present. This reflects quiet water conditions that must have prevailed in the narrow, bedrock-controlled water bodies.

Mappable glaciolacustrine deposits are largely restricted to the shallow valleys of Block Creek and a few of its tributaries in the southwestern part of the Research Area. The sediments are mainly compact silt, sandy silt, and clayey silt, and locally are more than 7 m thick. These massive-looking silts probably indicate rapid sedimentation. Silt-clay rhythmites (varves) were found at only one site (322422E 5437278N) along a Block Creek tributary. Approximately 1.8 m of fine-grained material overlies bedrock at this station with silt-clay couplets, 2-3 cm thick, clearly visible in the lower metre (C horizon). Block Creek flows to the south and the lake associated with these sediments was most likely an extension of a lake dammed by the Dog Lake Moraine southwest of the Research Area.

Fine-grained lacustrine sediments were also found near the Poshkokagan River just east of Highway 527, and also to the south of Amik Lake. The sediments near Amik Lake are about 90% silt and 8% clay and have a moderate to strong HCl reaction. These compact silts have very faint horizontal laminations and tend to split into 0.5 cm thick plates. Dense, brown clayey silt was found at two sites, near the Poshkokagan River, that are spatially associated with a prominent esker. These fine-grained sediments were probably deposited in one or more short-lived proglacial lakes. Poshkokagan and Lusk lakes and the Poshkokagan River lie in a basin that could have been readily dammed by an ice front receding to the northeast.

3.1.8 Recent Deposits

Sedimentary deposits of Recent age in the Research Area include alluvium, organic deposits, and talus. Alluvial deposits in the area consist of sand, gravel, and silt, but mappable deposits are very limited due to the small size of the streams. These deposits reflect the nature of the upstream source area; for example, the sandy alluvium along Shelby Creek in the southwestern part of the Research Area is derived from deposits of ice contact stratified drift that are in the vicinity.

Organic deposits form an important and distinctive class of soil materials. These flat-lying deposits are found throughout the Research Area in many bogs, fens, and swamps, and show a range of humification that spans the von Post scale. The most extensive areas of organic accumulation are in the southwestern part of the Research Area, where they have a crude linear pattern that displays the topographic control of northeasterly-striking supracrustal rocks. On the Quaternary map, significant organic deposits less than one metre thick are shown as subunits of the underlying material. For example, map class 6 comprises <1 m of organic material overlying a fine-grained lacustrine deposit.

Accumulations of talus are common on slopes below steep faces of diabase. This angular debris ranges in size from pebble to large boulder, and commonly displays gravity sorting (i.e., the largest rock fragments are found near the bottom of the talus slope). Most of the talus deposits recognized in the Research Area are too small to delimit as polygons on the Quaternary map and are represented by symbols. However, there are three bounded areas of talus shown between Rousseau and Starnes lakes and two others southwest of Amik Lake. In some places, the colluvial material is fairly stable and supports tree growth.

3.2 Reclassification of Quaternary Geology Landform Classes to Soil Texture Classes

Soils can be described in terms of both physical and chemical attributes. Physical attributes, such as texture of the soil matrix, content of coarse fragments (clasts), stratification features, and degree of compaction or cementation, influence soil characteristics such as structural stability, susceptibility to erosion, cation retention capabilities, and permeability to water, nutrient, and root penetration. Within a landscape, soils constitute an integral, enduring ecosystem component, influencing many biological and hydrological processes. Distribution of 2 primary environmental regimes, moisture and nutrients, is largely affected by characteristics of the soil resource.

Matrix texture is the most useful single attribute for predicting moisture and nutrient retention characteristics of a soil. In conjunction with spatial information on local terrain conditions and the chemical attributes of soil parent materials, knowledge of soil texture can offer predictive insight into the distribution of soil moisture and nutrients across the landscape. For the Rinker Lake Research Area, spatial estimates of C horizon soil texture were obtained by reclassifying landform classes from the Quaternary geology map (Figure 3, Table 1) into soil texture groupings (Table 5). A reclassification matrix (Table 2) was developed in which relationships between Quaternary landform classes and soil texture characteristics were incorporated. These relationships were elucidated from field observations and laboratory texture analyses of samples collected at over 300 ground survey points throughout the Research Area. Once the reclassification matrix was constructed, it was used to reclassify polygons on the Quaternary geology map to generate a soil texture map and spatial data layer (Figure 4). This new data layer was assessed for spatial accuracy using independent ground survey validation data collected at 212 points.

Difficulties associated with this exercise in the Rinker Lake Research Area were twofold: i) on the ground, soil conditions within each Quaternary landform class exhibited considerable spatial heterogeneity, and ii) soil profiles, regardless of the genetic origin of parent material, were often stratified, with a cap of silty sediment overlying the parent material. Reclassification inaccuracies associated with difficulty i) were largely unredeemable after the completion of the Quaternary map. Ground truth efforts in 1993 and 1995 were directed at refining the polygons of the Quaternary map to reflect an acceptable degree of map accuracy at a scale of 1:20 000. At this scale, a certain proportion of ground level heterogeneity was inevitably subsumed into the map units. This error factor is a property of the landscape which is being mapped. Inaccuracies associated with difficulty ii) were initially dealt with by treating the soils within the Research Area as universally stratified and generating a 2-part reclassification matrix - part one for the C horizon, on the premise that it would spatially reflect genetic influences, and part two for the surface horizons which would acknowledge the silty nature of surface soils throughout the Research Area. When these two reclassifications were assessed for spatial accuracy against ground truth data, it was noted that distributions of both surface and C horizon textures were better predicted by the surface algorithm. Consequently, this single reclassification is presented here (Table 2; Figure 4).

The soil texture classes employed in this reclassification were customized to address the textural characteristics of the soils within the Rinker Lake Research Area. Upland mineral soils, which constitute approximately 85% of the soil cover in the Research Area, typically contain very little (<5%) clay; matrix texture essentially comprises a mixture of silt and sand. The majority of the tills (covering approximately 68% of the land portion of the Research Area) comprise between 30% and 70% sand - often very close to a 50:50 mixture. The conventional Canadian soil texture classification (Working Group on Soil Survey Data 1978; Ontario Institute of Pedology 1985) splits these soils between silty sand and silt loam classes, segregated at the point of 50% sand content. For the Rinker Lake Research Area, due to the high silt content in the soils, it was deemed desirable to define a texture class which encompassed the silty sand / sandy silt characteristics of the upland till (and some glaciofluvial) deposits, thus recognizing textural similarities within map polygons of similar genetic origin. Consequently, 7 texture classes were defined (Table 5): a shallow soil class, 2 classes of sands (coarse and fine), a silty sand / sandy silt class, a silt class, a clay / fine loam class, and an organic soil class. The textural definitions of these classes differ somewhat from the conventional thresholds represented on the texture

Table 5. Definitions of the 7 classes of soil texture employed in the development of a thematic map of C horizon soil texture for the Rinker Lake Research Area. Areal extent for each class is given in square kilometers.

Class	Definition
1	≤ 20cm soil overlying bedrock (78.5 sq km)
2	coarse sandy (≥ 70% medium and/or coarse sand) (114.9 sq km)
3	fine sandy (≥ 70% fine sand) (15.2 sq km)
4	silty sand / sandy silt (clay < 20% *and* 30% < all sand < 70%; *or* very fine sand ≥ 70%) (332.4 sq km)
5	silt (clay < 20% *and* silt ≥ 70%) (5.4 sq km)
6	fine loamy / clayey (clay ≥ 20%) (0 sq km)
7	organic (≥ 40 cm Of, Om, Oh) (81.8 sq km)

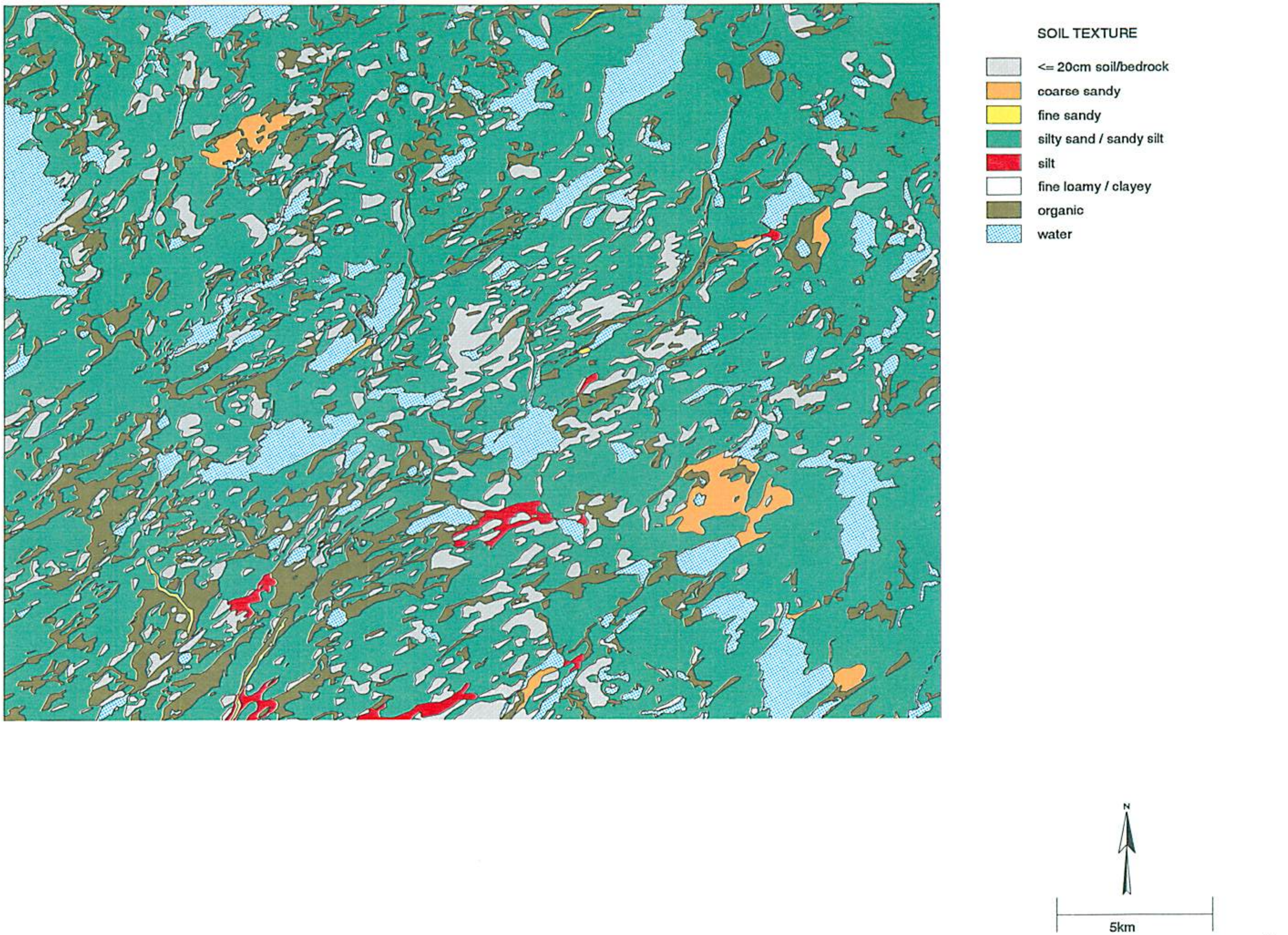

SOIL TEXTURE
<= 20cm soil/bedrock
coarse sandy
fine sandy
silty sand / sandy silt
silt
fine loamy / clayey
organic
water
N
5km

Fig. 4

triangle (Ontario Institute of Pedology 1985), however, they are intended to reflect the distribution of particle sizes as observed in the soils of the Rinker Lake Research Area and to, hopefully, distinguish among textural entities which actually occur on the landscape.

3.2.1 Accuracy Check of the Derived Soil Texture Data Layers

As noted above, 2 algorithms were tested for reclassifying Quaternary classes to C horizon soil texture. In order to test the spatial accuracy of the proposed soil texture data layers, independent validation data were obtained from 212 georeferenced ground survey points within the Research Area in August, 1995. Soil samples were collected from surface (0-25 cm) and C horizons at each survey point and submitted for laboratory texture analyses. From each proposed reclassification, predicted C horizon texture classes were obtained at coordinates matching the locations of the survey points. For each reclassification, 2 sets of values, comprising predicted texture classes from the reclassified Quaternary map and reference texture classes from the ground truth survey, were cross-tabulated in an error matrix (Janssen and van der Wel 1994). The error matrix was used to test the spatial accuracy of each proposed C horizon reclassification.

The validation dataset contained 144 C horizon observations. Thus, the accuracy check for the soil texture predictions consisted of 144 observations in a 7 class x 7 class error matrix (Table 6). Two reclassification algorithms were tested for their effectiveness in predicting the spatial distribution of C horizon texture from classes of Quaternary landform. Within this verification sample, the more accurate algorithm correctly predicted C horizon soil texture 73% of the time. A Kappa statistic (Rosenfield and Fitzpatrick-Lins 1986) suggested an accuracy of 44%, considering the potential for random successes. This reclassification is presented in Figure 4 as a map of soil textures for the Research Area.

Errors of commission (Janssen and van der Wel 1994) for the C horizon texture reclassification were highest for texture classes 1 (0.57), 2 (1.0), and 7 (0.75) (*see* Table 6), indicating that the reclassification algorithm predicted the occurrence of these classes more frequently than they were observed on the ground. All were only rarely encountered in the ground truth survey. For classes 1 and 7, these are primarily mapping errors, reflecting the spatial heterogeneity of both shallow and organic terrain in the Research Area. The error for class 2 relates to the difficulty of predicting the occurrence of coarse sands in glaciofluvial deposits within the Research Area.

Errors of omission (Janssen and van der Wel 1994) for the C horizon texture reclassification were highest for texture classes 2 (1.0), 3 (1.0), 5 (0.47), and 6 (1.0) (*see* Table 6). These errors indicate occurrences of observed texture classes that were predicted otherwise. For classes 2 and 3, the majority of misclassifications was to texture class 4, reflecting the assignment of glaciofluvial deposits in the classification algorithm to silty sands rather than sands. Misclassifications of fine-textured soils, represented by classes 5 and 6, can be interpreted more

Table 6. Error matrix: observed C texture vs. predicted surface texture.

Predicted surface texture		Observed C texture								
		1	2	3	4	5	6	7	Total	Commision Error
	1	6		2	6				14	0.57
	2				1	1			2	1.0
	3									
	4		6	4	86	6	2		104	0.17
	5					10	2		12	0.17
	6									
	7		1		6	2		3	12	0.75
	Total	6	7	6	99	19	4	3	144	
	Omission Error	0	1.0	1.0	0.13	0.47	1.0	0		0.73

as mapping errors, reflecting spatial heterogeneity of glaciolacustrine deposits in the Research Area.

This reclassification algorithm assigns glaciofluvial classes to silty sands rather than coarse sands. Typically, glaciofluvial sediments are relatively coarse-textured sands and gravels. Although this condition was encountered in the Rinker Lake Research Area, most glaciofluvial-derived soils in the area exhibited high matrix fractions of silt or very fine sand in the upper 50 cm to 100 cm of the soil profile, the zone of maximum rooting for boreal plant species. Nevertheless, some glaciofluvial deposits in the Rinker Lake Research Area have relatively high clast contents, which influence soil characteristics such as permeability and moisture retention. Since soil texture classes reflect only the matrix textures and do not account for the clast content in the soil, it may be appropriate to consider these soils to be better drained than their matrix textures would suggest.

4.0 Land Cover and Vegetation of the Rinker Lake Research Area

4.1 Land Cover Overview

The Rinker Lake Research Area lies toward the northern edge of the climatic range of continuous forest in North America, i.e., the potential climax vegetation, as natural land cover, is a closed canopy forest. Specifically, the Research Area is situated between the Superior and Nipigon Sections of the Boreal Forest Region of Canada (Rowe 1972). Natural forest conditions are variable, but mixed forests comprising various species combinations of trembling aspen, white birch, white and black spruce, balsam fir, and jack pine are prevalent on well-drained, upland soils. Lowlying, wetland forests are dominated by eastern white cedar (*Thuja occidentalis* L.), tamarack (*Larix laricina* [Du Roi] K. Koch), and black spruce.

The Rinker Lake Research Area lies within the Canadian Shield and, as is typical for most areas of the Shield, the landscape is dominated by bedrock-defined terrain features (*see* Section 3.1.1). Numerous lakes and ponds occupy bedrock depressions, covering 11.5% of the total 900 sq. km surface area within the Research Area. Only a small proportion (approximately 3%) of the land cover within the Research Area is defined by human-constructed features. Permanent human structures include cottages on Max Lake, Mawn Lake, and Starnes Lake; a mining camp on the southeast shore of Lac des Iles; a government fire-fighting base on Rinker Lake; and an extensive network of forest access roads. The balance of land cover (about 97%) within the Research Area is natural forest vegetation, although human activities have extensively modified both the physiognomy and species composition of the forest cover.

Timber harvesting activities have been conducted within the bounds of the Research Area for approximately 40 years. Prior to 1985, most of the harvesting had occurred to the east of Hwy 527 and in the vicinity of Whitefin Lake, on the south-central edge of the Research Area. The current forest cover of these areas comprises a mixture of stand conditions, with ages ranging between 20 and 50 years. In 1985, intensive timber harvesting commenced to the west of Hwy 527 and east of the highway in the northeast portion of the Research Area. Forest cover in these areas has changed rapidly since 1985, and continues to change, as the road network is expanded to provide industrial access to larger proportions of the landbase. Extensive areas in these portions of the Research Area are being converted from closed canopy, mature forest cover into young, regenerating forest in a series of clearcut patches.

4.2 Forest Resource Inventory

The provincial Forest Resource Inventory (FRI) provides mapped coverage of most of the commercially forested area of Ontario. FRI map coverages, at either 1:15 840 or 1:20 000 scale, provide some detailed information on forest cover types, species mixes and potential wood volumes. Additional spatial files typically associated with the FRI include current road networks, harvesting schedules, historical forest practices, and lake/stream coverages. These maps are a primary database for foresters throughout northwestern Ontario for forest management planning activities. FRI coverage for the Rinker Lake Research Area was made available as a digital database by Abitibi-Price Inc.

4.3 Satellite Derived Land Cover Classification for the Rinker Lake Research Area

Imagery (season, multitemporal) from satellites (mainly Landsat and SPOT) is readily available but, curiously, is not widely used for forestry-related operational activities or planning, despite many studies which show this product's widespread utility for such purposes (*see* Treitz and Howarth 1996). Researchers from University of Waterloo and the Institute for Space and Terrestrial Studies, working at the Rinker Lake Research Area, are investigating the potential to map forest ecosystems from remotely sensed images at various scales (Kalnins *et al.* 1993). Within the Rinker Lake Research Area, satellite imagery was used to develop a digital database describing land cover conditions.

Land cover information, including relative proportions for various classes, presented in this section is derived from 2 classified Landsat Thematic Mapper (TM) satellite images dated June 20, 1992 and September 11, 1993. The land cover classification was developed in conjunction with personnel from the Institute for Space and Terrestrial Studies, University of Waterloo and Geomatics International, Inc. Additional digital data encompassing the Research Area that were employed in development of the classification included 9 Ontario Base Map (OBM) Series topographic mapsheets (1:20 000 scale); 9 Forest Resource Inventory (FRI) mapsheets, interpreted from 1985 black and white aerial photography (1:15 840 scale); ground survey ecological plot data; and colour infrared aerial photographs acquired in September 1992 (1:10 000 scale).

Unsupervised clustering of spectral bands 2, 3, and 4 from the TM data was conducted using the ISODATA clustering algorithm from the EASI/PACE image analysis software package (PCI 1993). Ultimately, a set of 16 land cover classes was defined (Table 7) using results from the spectral analysis in conjunction with information derived from ground survey data and photo-interpretation of the infrared aerial photographs (Figure 5). To refine the image classification, polygons representing roads and cutovers were manually outlined using a graphic overlay constructed from aerial photographs and the unclassified spectral data; polygon distributions for alder thickets and other wetland classes were derived from digital FRI data; and road and water vectors were extracted from FRI and OBM databases. Mature, closed canopy forest was spectrally discriminated into 5 broad canopy classes, ranging from pure conifer to pure hardwood. Two classes of cutover, as well as 3 classes of open canopy forest and non-forest, were distinguished on the basis spectral signatures. Classification results were filtered using a 3 x 3 mode filter and then sieved with a connectiveness criterion of 8 to remove any polygon less than 2 hectares in size.

Table 7. Listing of the 16 land cover classes recognized for the Rinker Lake Research Area. A thematic map of the land cover of the Research Area is presented in Figure 5. Areal extent for each class is given in square kilometers.

Land Cover Class	Legend
1	Water (103.4 sq km)
2	Roads (19.2 sq km)
3	Closed Canopy Mature Forest - Conifer (290.2 sq km)
4	Closed Canopy Mature Forest - Conifer Dominated Mixedwood (93.0 sq km)
5	Closed Canopy Mature Forest - Approximately 50/50 Mixedwood (38.7 sq km)
6	Closed Canopy Mature Forest - Hardwood Dominated Mixedwood (156.3 sq km)
7	Closed Canopy Mature Forest - Hardwood (77.5 sq km)
8	Alder-dominated Thicket Swamp (15.3 sq km)
9	Recent Cutover (<10 yr.) (47.2 sq km)
10	Older Cutover (≥10 yr.) (18.9 sq km)
11	Non-treed Wetland (9.8 sq km)
12	Treed Wetland ((14.2 sq km)
13	Miscellaneous Open Non-forested Sites (e.g., gravel pits, roadside clearings) (7.7 sq km)
14	Open Canopy Forest - Hardwood (5.0 sq km)
15	Shadow (0.2 sq km)
16	Open (Sparse) Canopy Forest - Conifer (2.1 sq km)

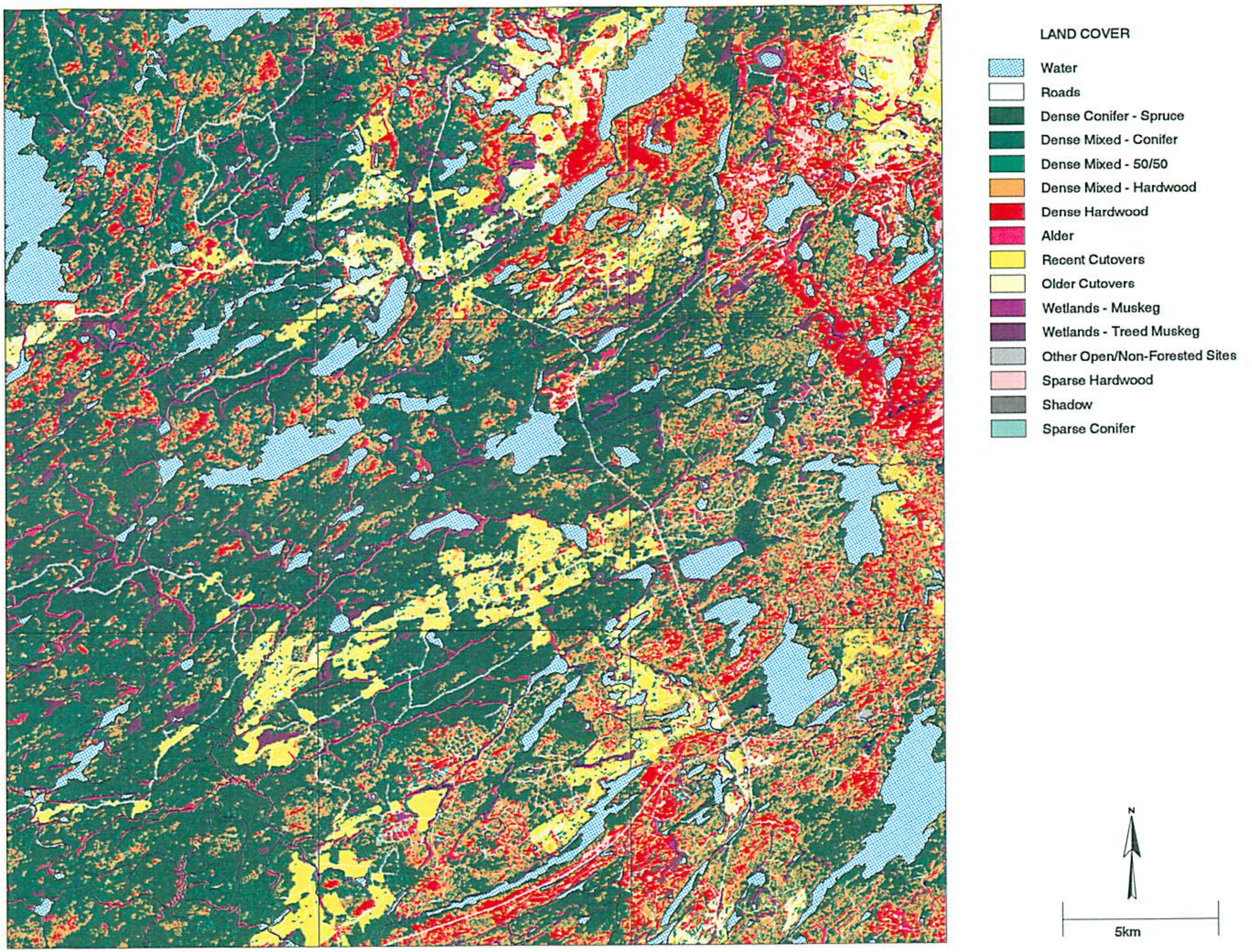

LAND COVER
Water
Roads
Dense Conifer - Spruce
Dense Mixed - Conifer
Dense Mixed - 50/50
Dense Mixed - Hardwood
Dense Hardwood
Alder
Recent Cutovers
Older Cutovers
Wetlands - Muskeg
Wetlands - Treed Muskeg
Other Open/Non-Forested Sites
Sparse Hardwood
Shadow
Sparse Conifer
N
5km

Fig. 5

Spatial accuracy of the spectral classification was tested on a systematically sampled grid using photo- interpreted land cover from the 1:10 000 infrared aerial photographs as validation data. An error matrix was constructed for the spectrally defined forest classes (classes 3-7, 13, 14, 16; Table 7) in each of the 1992 and 1993 satellite images (Tables 8 and 9). Road, cutover, and wetland classes, which were derived from FRI and OBM data or aerial photos (classes 2, 8-12; Table 7), were checked by visual inspection on the classified images and by re-registration against the FRI and OBM digital data. Spectrally derived water polygons (class 1; Table 7) were assessed against OBM water coverages and found to be 100% accurate. For the 1992 and 1993 images, class to class matching accuracies were 69.7% and 65.2%, respectively. Accuracy within a 1 class range of association (i.e., accepting assignment to adjacent classes) jumps to 90.9% and 81.8%, respectively. For this classification, the latter accuracy rating is probably acceptable, given the general nature of the forest cover classes and the intrinsic, fine-scaled spatial and compositional heterogeneity of forests in the Research Area. At the landscape scale of 1:20 000, this classification is only intended to map broadly differentiated classes of forest cover. Finer distinctions, at the stand level, must be derived from other data sources.

4.4 Vegetation Cover Summary

Vegetation cover within the Rinker Lake Research Area can be grouped into 5 main categories:

1. Wetlands - treed and non-treed
2. Mature hardwood dominated forests (pure or mixed)
3. Mature conifer dominated forests (pure or mixed)
4. Second growth forests (20-50 years old)
5. Recent cutovers (10 years old or younger)

Wetlands are ecological units with permanently elevated water tables that select for the occurrence of plant and animal communities adapted to wet environments. They can be broadly classified into 5 categories, based upon characteristics of hydrology and vegetation (Harris *et al.* 1996): open water marsh, marsh, fen, bog, and swamp. Numerous wetlands, representing all 5 categories, are scattered throughout the Rinker Lake Research Area. Open water marshes and marshes are associated with standing or slow-moving water, typically occurring along lakeshores and slow streams throughout the Research Area. These wetland types are characterized by submerged, floating, and emergent aquatic vegetation and, sometimes, graminoid communities. Fens, bogs, and swamps are semi-terrestrial wetlands with accumulated organic peat comprising some or all of the soil substrate. These features are not necessarily associated with apparent water bodies, often occupying small topographic depressions where drainage is restricted and water accumulates. Swamps, fens, and bogs occur widely in the Research Area and constitute the majority of the approximately 12% of land cover attributed to wetlands. Swamps are characterized by vegetation communities that are dominated by tree or tall shrub species. In the Rinker Lake area, thicket swamps dominated by speckled alder (*Alnus rugosa* [Du Roi] Spreng.) are common along streamcourses (land cover class 8; Table 7, Figure 5). Treed conifer swamps,

Table 8. Error Matrix for June 1992 satellite image.

	Airphoto interpreted class									
Predicted Class	Land cover classes	3	4	5	6	7	13	14	16	Totals
	3	21								21
	4	5	10	4						19
	5			4						4
	6		2	1	7	1	1			12
	7				2	1		2		5
	12							1		1
	13						1			1
	14							1		1
	16								2	2
	Totals	26	12	9	9	2	2	4	2	66
	%	80.8 %	83.3%	44.4%	77.8%	50.0%	50.0%	25.0%	100.0%	
	Percent of correctly identified classes (excluding water, roads, wetlands, older cutovers, and shadow)									69.7%
	Percent of correctly identified classes within 1 class									90.9%

Table 9. Error matrix for September 1993 satellite image.

	Airphoto interpreted class									
	Land cover classes	3	4	5	6	7	13	14	16	Totals
Predicted Class	3	21	2	2						25
	4	4	8	1					1	14
	5		1	5						6
	6		1	1	7	1	1		1	12
	7				1	1		3		5
	9	1								1
	12							1		1
	13						1			1
	14				1					1
	16									0
	Totals	26	12	9	9	2	2	4	2	66
	%	80.8%	66.7%	55.6%	77.8%	50.0%	50.0%	0.0%	0.0%	
	Percent of correctly identified classes (excluding water, roads, wetlands, older cutovers, and shadow)									65.2%
	Percent of correctly identified classes within 1 class									81.8%

dominated by black spruce, tamarack, and/or eastern white cedar, are extensive along Hwy 527 north of Max Lake and in the southwest quadrant of the Research Area. Since these wetland classes are characterized by a conifer overstory, some are included in the conifer forest land cover classes in Figure 5 and Table 7 (land cover classes 3 and 4), as well as in land cover class 12 (treed wetlands). Bogs and fens are numerous but relatively small in individual area within the Research Area. These are wetlands with relatively deep deposits of peat. Vegetation communities may be treed or not, and are characterized by *Sphagnum* mosses, graminoid species, and low shrubs. In Figure 5 and Table 7, bogs and fens are included in land cover classes 11 and 12.

Mature upland forest cover in the Rinker Lake Research Area constitutes a heterogeneous mosaic of mixed forest conditions across the landscape (Figure 5); overall, there are very few single-species stands in the Research Area. In the northern half of the Research Area, mature upland forests are largely dominated by trembling aspen (land cover classes 6 and 7; Figure 5, Table 7). Mixed, aspen-dominated stands contain black spruce, balsam fir, jack pine, white birch and sometimes white spruce in the overstory. Sizeable stands of relatively pure aspen also occur in this portion of the Research Area. Aspen-dominated stands often have well developed understories, with abundant shrub and herb cover. In particular, dense layers of mountain maple (*Acer spicatum* Lam.) and beaked hazel (*Corylus cornuta* Marsh.) are common in these stand types within the Research Area. Aspen stands within the northern part of the Research Area range in age from 80-100 years and are notable for their high proportion of unusually large, well-formed trees (especially, aspen, jack pine, and white spruce) that are free of heart rot. In the southwestern section of the Research Area, mature upland forests tend to be dominated by conifers, especially black spruce (land cover classes 3 and 4; Figure 5, Table 7). In this area, pure stands of black spruce occur occasionally on upland sites. More frequently, this species forms mixtures with jack pine, balsam fir and/or white spruce and, to a lesser extent, with trembling aspen and/or white birch. Understories in these stands are variable, ranging from rich shrub and herb strata to open understories dominated by a ground cover of feathermoss.

Over the past 50-100 years, forest disturbance regimes within the Rinker Lake Research Area have primarily included insect infestation, wind throw and breakage, and anthropogenic disturbances. Although much of the current mature forest originated after catastrophic fire, there have not been extensive wildfires in the Research Area during the last 100 years. Recurring spruce budworm (*Choristoneura fumiferana* Clem.) and forest tent caterpillar (*Malacosoma disstria* Hbn.) outbreaks have resulted in defoliation and mortality of certain tree species, occasionally with attendant changes in the species composition of the forest overstory. Tent caterpillar attacks trembling aspen in this area, causing complete defoliation of trees, but little mortality, during peak years. The population cycle for this insect species extends over approximately 10 years, with the last outbreak ending in 1993. Spruce budworm populations oscillate over an approximate 35 year cycle in this part of northwestern Ontario. Budworm feeds preferentially on the buds and new foliage of balsam fir and white spruce in this area and, at outbreak levels, populations are capable of causing widespread mortality in these tree species. Relative proportions of susceptible tree species often decline in the overstory of mixed forest stands following budworm outbreaks. Canopy gaps develop as dead fir and spruce decompose from the overstory. This process opens stands to increased light levels, typically resulting in physiognomic changes such as increased density of shrubs and the release of surviving understory fir and spruce. Much of the balsam fir in the Research Area was killed in the late 1980's and early 1990's by an outbreak of spruce budworm which is currently in its final stages. In mature boreal forest stands, wind damage typically creates small canopy gaps subject to the processes described above. In the Research Area, trembling aspen seems to be most susceptible to stem breakage due to wind, while trembling aspen and jack pine are most commonly affected by windthrow.

Major anthropogenic disturbance in the Research Area dates to the 1940's, when road access was established along the route which is now Hwy 527. Early timber harvesting (circa 1950) occurred to the east of the current highway, along access roads near Mawn Lake and to the east of Max Lake (Camp 45 Road). Further harvesting took place in the early 1980's along the highway, to the north of Max Creek, and in the vicinity of Whitefin Lake. Extensive, industrial forest management activities did not commence for the main portion of the Research Area (i.e., the area west of the highway) until 1985. Since that time, virtually all of the territory to the west of the highway has been accessed by an extensive road network, with primary access provided via roads to the north of Rinker Lake and to the west of Mawn Lake.

The oldest harvested areas, such as those near Mawn Lake, were manually logged, with horse or early mechanical skidding, and regenerated naturally after the disturbance. These areas are now characterized mainly by second growth forest, aged between 30 and 40 years. Stand canopies throughout this portion of the Research Area comprise a mixture of balsam fir, black spruce, white birch, white spruce, and trembling aspen (land cover classes 5, 6, and 7; Figure 5, Table 7). Some remnant mature stands still exist, often as protected forest reserves (PFR).

Cutovers dating to the early 1980's were logged manually, with mechanical skidding, and have been artificially regenerated by planting jack pine and black spruce seedlings, with attendant spraying of herbicides. Vegetation in these areas currently comprises shrub communities dominated by broadleaf species such as trembling aspen, white birch, raspberry (*Rubus idaeus* L. var. *strigosus* [Michx.] Maxim.), bush honeysuckle (*Diervilla lonicera* Mill.), blueberry (*Vaccinium* spp.), and beaked hazel. Balsam fir is the most common naturally occurring conifer shrub. These areas are primarily represented on Figure 5 by land cover classes 6 and 7.

Recent harvesting (since 1985) has resulted in large, contiguous patches of clearcut on the Rinker Lake Research Area landscape (land cover classes 9 and 10; Figure 5, Table 7). Currently, wood is cut mechanically by feller bunchers and trees are skidded by machine to the roadside. Much of the wood is being chipped on site and transported to the mill in chip form. Cutovers are site-prepared and artificially regenerated by planting mostly black spruce seedlings. Vegetation communities on the recent cutovers are dominated by herb and low shrub species such as blueberry, Labrador tea (*Ledum groenlandicum* Oeder), raspberry, bush honeysuckle, wild rose (*Rosa acicularis* Lindl.), fireweed (*Epilobium angustifolium* L.), wild sarsaparilla (*Aralia* *nudicaulis* L.), large-leaved aster (*Aster macrophyllus* L.) and various graminoid species. Balsam fir seedlings and vegetative sprouts of trembling aspen and white birch are also abundant.

5.0 Ground Survey Data

Ground survey data were employed in both the development and the verification of spatial databases and ecosystem models for the Rinker Lake Research Area. Table 10 outlines information contained in 3 ground survey databases which were constructed between 1992 and 1995 during field work in the Research Area. All plots were georeferenced using a global positioning system (GPS) and readings were differentially corrected to a fixed base station in order to obtain accuracy levels in the range of 2–5 m (x,y) and <15 m (z).

Observations from 249 georeferenced field locations played an important role in the development of the Quaternary geology map (*see* Section 3.0) by providing ground information for reference during the air photo interpretation. These sampling locations were selected to represent the range of landform conditions occurring in the Rinker Lake Research Area and to provide adequate geographic coverage of samples to support subsequent Quaternary geology map production. Soil texture data obtained during this survey were used to develop an understanding of relationships between Quaternary landforms in the Research Area and their characteristic soil matrix textures. Another database was developed by sampling at intervals along transect lines that were located along slope gradients on the range of landform classes in the Research Area. Summary vegetation and soil observations, including soil texture samples, were recorded at 237 georeferenced points. The data from this independent ground truth survey were used to check the accuracy of various proposed algorithms for predicting soil texture from the Quaternary landform classes. (*see* Section 3.2.1).

In addition to these surveys, intensive ecological sampling was completed on 99 10 m X 10 m forest plots. Using sampling methodologies developed for the northwestern Ontario Forest Ecosystem Classification program (Sims *et al* 1989), detailed quantitative descriptions were compiled on vegetational composition and abundance, tree growth, forest floor cover and humus characteristics, physical and chemical soil attributes, local drainage patterns and site moisture status, as well as other site/soil/stand features.

These detailed ecological plot descriptions have provided critical reference data for the ecosystem mapping and modeling work in the Rinker Lake Research Area. Soil texture data were pooled with those obtained in the geological ground survey to establish textural characteristics of the Quaternary landform classes. Vegetation descriptions from these plots assisted in developing the land cover classification for the Landsat TM images. Site data, such as percent slope, aspect, and topographic position, were employed in checking the Research Area's DEM and are being used in ongoing terrain analyses. Forest mensuration data (tree heights, diameters, and ages) are an important component of site productivity modeling efforts. Additional ground data that were collected by other project collaboraters, on the distribution and abundance of a variety of songbird, reptile, and amphibian species have been used in fine-scaled habitat mapping and to model species ranges in relation to climatic gradients in Ontario (e.g., McKenney *et al.* 1996). Survey plots were distributed across a range of landform features and along major topographic gradients, making it possible to use the ecological plot descriptions to

Table 10. Summary of the ecological attributes contained within three ground survey databases collected for the Rinker Lake Research Area.

Data Attributes	**Ground Survey Database**		
	Geological Field Survey	Ground Truth Survey	Forest Ecology Plots
geoposition (GPS)	x	x	x
landform feature	x	x	x
slope	x	x	x
aspect	x	x	x
topographic position	x	x	x
soil depth	x	x	x
soil texture	x	x	x
soil chemistry[1]	x	x	x
soil moisture / drainage		x	x
humus condition			x
forest floor cover			x
overstory vegetation description		x	x
understory vegetation description		x	x
tree growth (mensuration)[2]			x
sub-catchment area			x
NWO FEC classification[3]		x	x

---

[1] Soil samples were analyzed for total and exchangeable cations, pH, and nitrogen, organic matter, iron, and aluminum contents.

[2] Data collected included DBH, height, age, and basal area.

[3] V-type and S-type determined following Sims et al. 1989.

construct several toposequence models for the Research Area.

5.1 Common Toposequence Models within the Rinker Lake Research Area

Toposequence models are schematic representations of site relationships between landform, soil, and vegetation units along topographic gradients in a particular landscape (Corns and Annas 1986; Meades and Moores 1989; Baldwin *et al.* 1990; Zoladeski *et al.* 1994). Toposequence models can be constructed from ground survey data collected along topographic gradients on representative examples of landform features within a geographic area. Relationships between soil or vegetation characteristics and topographic position are elucidated from the data, and then generalized into toposequence models. Since fundamental ecological processes in a defined geographic area are relatively constant (Tuttle 1970; Daubenmire 1968, 1974), these models can be considered to be representative within that area wherever general climate, geomorphology, and vegetation potential remain within locally normal ranges (Van Cleve and Yarie 1986).

Toposequence models succinctly portray common vegetation and soil / site patterns in relation to landscape topography. Good toposequence models encapsulate information on basic vegetation conditions and their relationships with common soil / landform complexes within a geographic area. Once developed, toposequence models are useful tools for the recognition, interpretation, and prediction of site-specific, topographically influenced, soil and vegetation characteristics (Houseknecht *et al.* 1986). Since they illustrate the ecologically significant transitions across topographic features, toposequence models can be helpful in the development and refinement of aerial photo interpretation keys (Johnson and Walsh 1997). Such keys can be used to identify forest ecosystem attributes, assess site productivity or stand susceptibility to insect damage and to develop timber harvest and regeneration strategies.

Toposequence modeling can be applied to any land-based interpretive exercise requiring an understanding of site-related properties. Such diverse management activities as pre-harvest timber surveys, wildlife habitat assessment, and integrated management planning can benefit from the preparation of toposequence models. In mapping exercises, toposequence models can foster an understanding of the spatial distribution of soil and vegetation conditions.

During intensive field sampling within the Rinker Lake Research Area, forest ecology plots were situated along topographic gradients across a variety of landform classes. Site, soil, and vegetation data from these plot series were compiled, summarized and graphically organized into toposequence illustrations, in order to clarify the individual toposequences that were sampled. The toposequence models presented in Figures 6 to 9 were selected from these sampled toposequences on the basis of their ecological representativeness for the landscape of the entire Research Area.

Toposequence models for the Rinker Lake Research Area are presented in Figures 6 to 9 as cross-sectional landscape profiles with accompanying, interpretive descriptions. Schematic diagrams, as well as tabular summaries, relate specific trends in vegetation and soil / site conditions to individual plot locations along the toposequence profiles. This information can be noted by reading vertically above and below each topo-position on the cross-sectional diagrams. Species acronyms are defined in Appendix B; vegetation and soil types are from the northwestern Ontario Forest Ecosystem Classification (Sims *et al.* 1989); humus type is from Sims and Baldwin (1996).

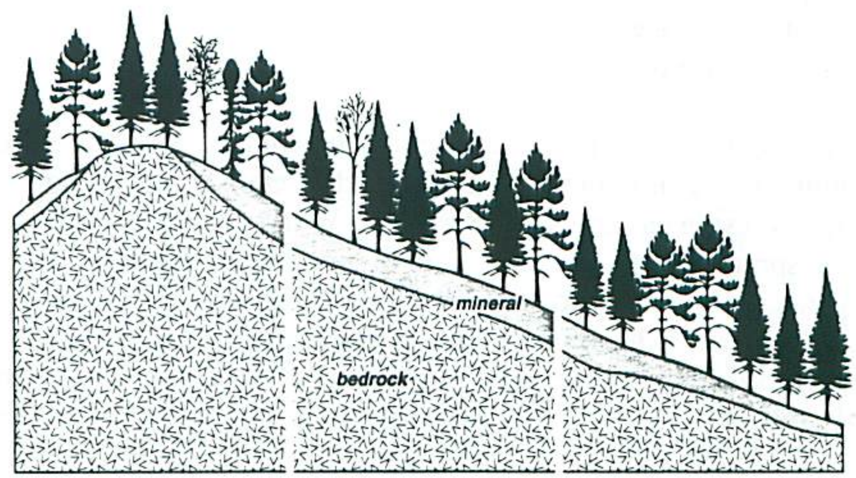
Figure 6. Bedrock Ridge (Shallow Till) / Balsam Fir Mixedwood

As is the case for most of the Canadian Shield, bedrock controlled terrain dominates the physiography of the Rinker Lake Research Area. A mantle of glacial drift (generally <3 m thick) overlies the bedrock, but topographic expression is dictated by the configuration of underlying bedrock features (*see* Section 3.1.1). The most common surface sediment in the Research Area is a glacial till of mixed supraglacial and subglacial origins, which typically comprises matrix textures of silty, fine or very fine sand with clast content varying between 5% and 30% by volume. This is one of 2 till lithofacies recognized during the Quaternary mapping phase of the Rinker Lake Project (*see* Section 3.1.5).

This toposequence model is characterized geologically by a thin veneer (<1 m) of glacial till overlying a long bedrock slope. The bedrock is diabase, a common intrusive igneous rock of Mesoproterozoic age, known in this region as the Nipigon diabase. Most of the prominent bedrock controlled landform features in the Research Area, such as ridges, mesas, knobs, and cuestas, are composed of diabase. In this sequence, the crest position of the slope exhibits a very thin (<5 cm thick), discontinuous layer of organic material without mineral horizons (SS1). The soils downslope are moderately deep (SS6), comprising poorly sorted, silty fine sand with very low clast content. Soil moisture regimes grade from dry (SMR θ) at the crest to moderately fresh (SMR 1) at the midslope position.

Balsam fir is a common component of the mixedwood forests of the Rinker Lake Research Area. It is especially prevalent in the northern and eastern portions of the Research Area, where it occurs on all but the shallowest upland sites. Balsam fir is a shade-tolerant species, often forming a secondary canopy in stands dominated by trembling aspen. In second-growth stands within the Research Area, especially to the east of Hwy 527, balsam fir represents a main canopy element, in association with black spruce, white spruce and white birch. In this toposequence model, younger balsam fir forms a secondary overstory stratum under a dominant canopy of jack pine. Understory conditions reflect a topographic gradient, as shrub and herb abundances increase downslope, compared with extensive feathermoss ground cover upslope. This trend can, in part, be attributed to enhanced downslope soil moisture conditions due to lateral seepage along the bedrock surface. Toward the lower slope sections, hardwood species such as trembling aspen and white birch become less abundant in the overstory.

Overstory	Bf 40 Pj 30 Pot 25 Sb 22	Bf 50 Pj 28 Bw 7	Bf 56 Pj 29
Shrubs	Bf 7 Dierlon 3	Bf 12 Bw 8 Acerspi 4 Dierlon 1	Bf 9 Acerspi 37 Dierlon 4
Herbs and Graminoids	Aralnud 8	Maiacan 2	Clinbor 5 Maiacan 2 Aralnud 1
Moss/Lichen	Fmoss 32	Fmoss 47	
Vegetation Type	V16	V16	V24



Slope Position	crest	upper	middle
% Slope	12	15	15
Humus Type	Mycelial fibrimor	Subhumic fibrimor	Subhumic fibrimor
% Coarse Fragments	< 5	< 5	< 5
Soil Type	SS1	SS6	SS6

Soil Horizon Summary

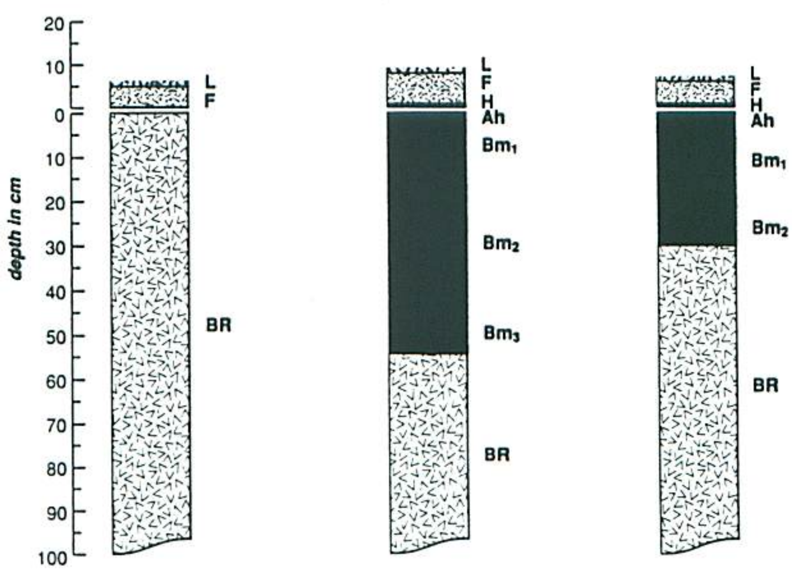


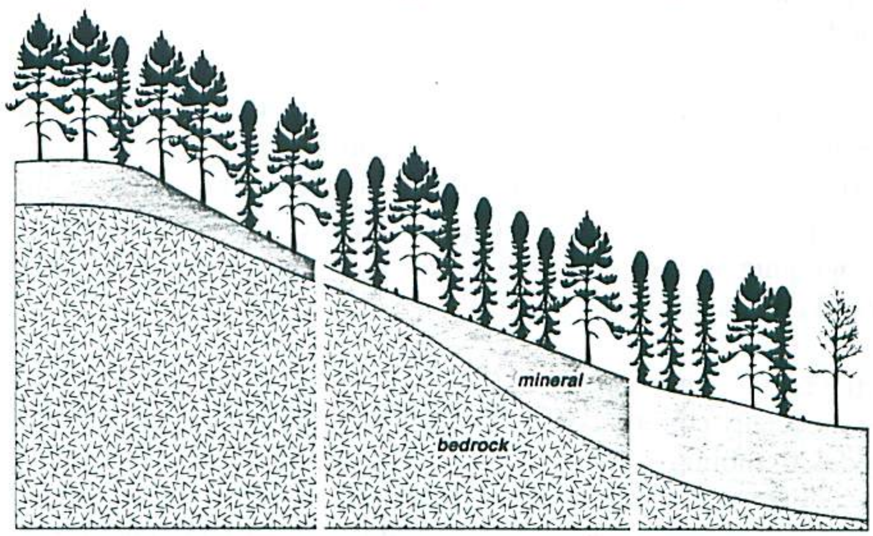
Fig. 6. Bedrock ridge (shallow till) / balsam fir mixedwood.

Figure 7. Shallow Till Overlying Bedrock / Jack Pine - Black Spruce

This toposequence model is similar to that described in Figure 6, also representing a shallow mantle of silty, fine sandy, glacial till overlying bedrock. This is a shorter slope, however, with the sequence extending between crest and lower slope topo-positions. Soil depth is shallow at the upper two positions, but exceeds 1 m at the base of the slope. Clast content varies significantly between the upper two positions (<20%) and the lower one (20%-35%). The high clast content at the lower slope position suggests that post-depositional processes, such as slope wash, may have removed some of the matrix material. A gradient of soil moisture regime is evident downslope, ranging from moderately fresh (SMR 1) at the crest to very fresh (SMR 3) at the lower slope position.

In this toposequence model, the vegetation comprises a mature jack pine - black spruce forest community. This community type is a characteristic, fire-originated land cover element of the boreal forest in eastern North America. Within the Rinker Lake Research Area, these jack pine - black spruce forests are common in the southwest quadrant. The relative abundance of jack pine is greatest at the crest position, declining downslope, while black spruce shows exactly the opposite trend. This reflects the topographic soil moisture gradient noted above. Other vegetation indicators, such as the presence of *Sphagnum* moss and balsam poplar (*Populus balsamifera* L.), suggest elevated moisture status at the lower slope position.

	V31	V32	V34
Overstory	Pj 58 Sb 5	Sb 54 Pj 25	Sb 28 Pj 13 Pob 2
Shrubs	Bw 10, Vaccmyr 1 Sb 4, Linnbor 1 Ledugro 3, Acerspi 1 Alnucri 1	Bw 4 Sb 3 Alnucri 1 Ledugro 1	Sb 9, Linnbor 2 Ledugro 4, Bw 2 Gaulhis 3, Rubupub 1 Bf 2
Herbs and Graminoids	Astemac 15, Corncan 2 Lycoann 14, Gaulhis 2 Copttri 4, Lycoobs 1 Maiacan 2, Aralnud 1	Maiacan 1 Corncan 1	Maiacan 5, Carebru 2 Violren 4, Lycoann 2 Athyfil 4
Moss/Lichen	Fmoss 41	Fmoss 59	Fmoss 72 Sphagnum 14
Vegetation Type	V31	V32	V34



Slope Position	crest	middle	lower
% Slope	2	20	4
Humus Type	Mycelial fibrimor	Mycelial fibrimor	Mycelial fibrimor
% Coarse Fragments	5 - 20	< 5	20 - 35
Soil Type	SS6	SS6	S3

Soil Horizon Summary

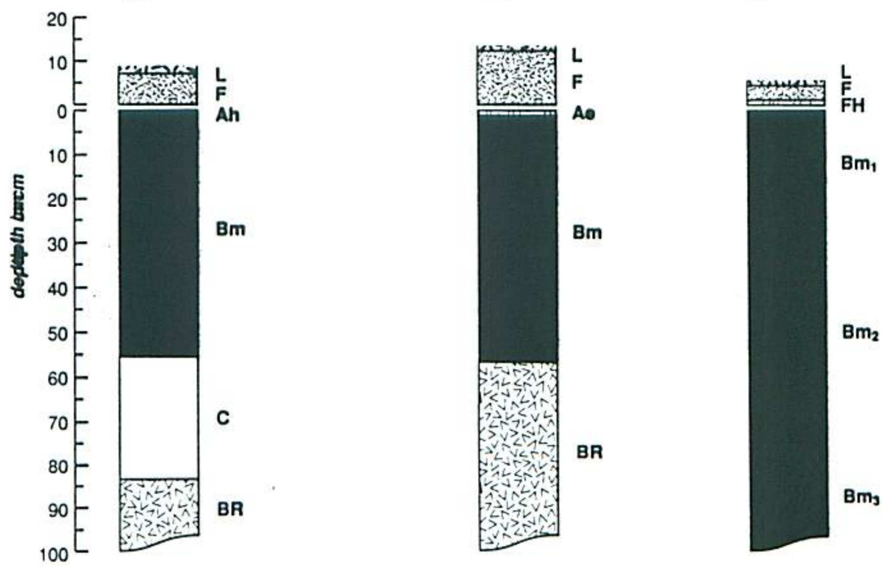


Fig. 7. Shallow tilll overlying bedrock / jack pine - black spruce.

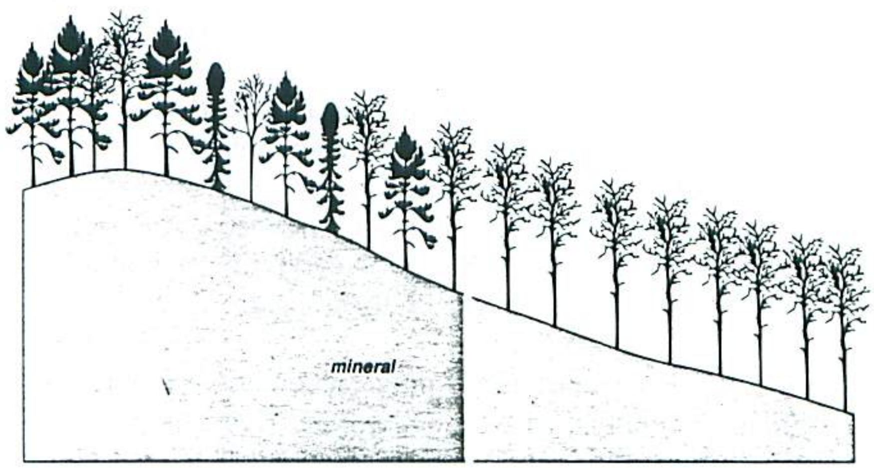
Figure 8. Deep, Stony Supraglacial Till / Trembling Aspen

In the northern portion of the Rinker Lake Research Area, particularly the northwest quadrant near Lac des Iles, glacial till differs in composition and appearance from the till lithofacies described in Figures 6 and 7. This till facies (*see* Section 3.1.5) is substratified in appearance and contains a high proportion of gravel- to boulder-sized clasts (often >30% by volume). It is probably entirely of supraglacial origin, compared to a combination of supraglacial and subglacial genetic environments attributed to the more widespread till facies described in Figures 6 and 7.

In this toposequence model, drift thickness is sufficient to obscure the local expression of all but the most significant bedrock features; soil depths of up to 7 m were observed during ground reconnaissance. In the top 50-100 cm, matrix texture is high in silt (S3, S4), although the fraction of coarse sand increases with depth. Clast content is very high (typically >30%). Soils in upland topographic positions are well to rapidly drained, with moderately fresh (SMR 1) to fresh (SMR 2) soil moisture regimes.

In the northern portion of the Research Area, mature forest stands dominated by trembling aspen are especially common on fresh, well-drained, mid-slope topo-positions. In this toposequence model, trembling aspen is the principal overstory species, occurring in association with jack pine, white birch, and black spruce. Elsewhere, balsam fir is also an important component of aspen-dominated mixedwoods (Figure 6). Abundance of conifer species in the overstory increases toward the crest and lower slope positions of this toposequence, while aspen tends to prevail at mid-slope. Understory vegetation is species-rich, with well-developed shrub and herb strata.

Overstory	Pj 28 Pot 8 Sb 8 Bw 3		Pot 73	
Shrubs	Acerspi 112 Corycor 42 Lonican 4	Rubupub 3 Dierlon 3	Corycor 67 Acerspi 31 Salidis 13	Alnucri 9 Dierlon 22 Rubupub 7
Herbs and Graminoids	Aralnud 31 Clinbor 30 Astemac 9 Maiacan 6	Streros 3 Corncan 2 Violren 1	Astemac 41 Aralnud 11 Clinbor 3 Maiacan 2 Corncan 2	Epilang 1 Streros 1 Violren 1 Cinnlat 1
Moss/Lichen				
Vegetation Type	V17		V5	



Slope Position	crest	middle
% Slope	3	12
Humus Type	Typical fibrimor	Subhumic fibrimor
% Coarse Fragments	20 - 35	> 50
Soil Type	S3	S4

Soil Horizon Summary

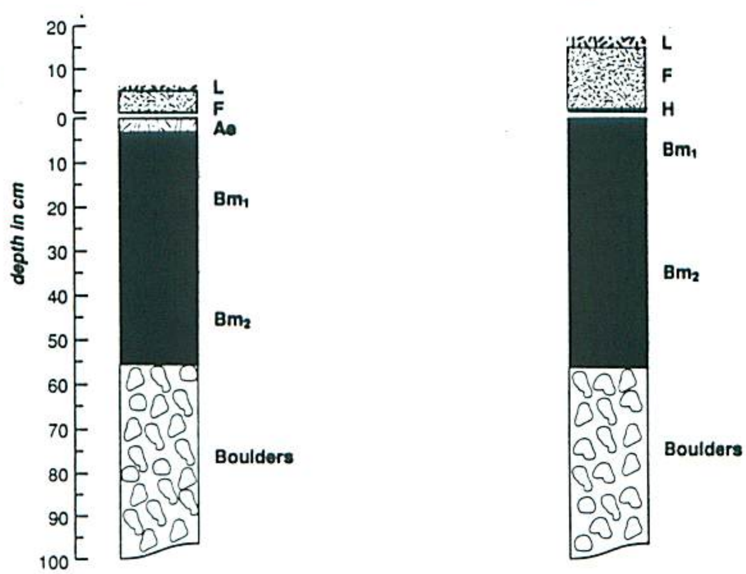


Fig. 8. Deep, stony supraglacial till / trembling aspen.

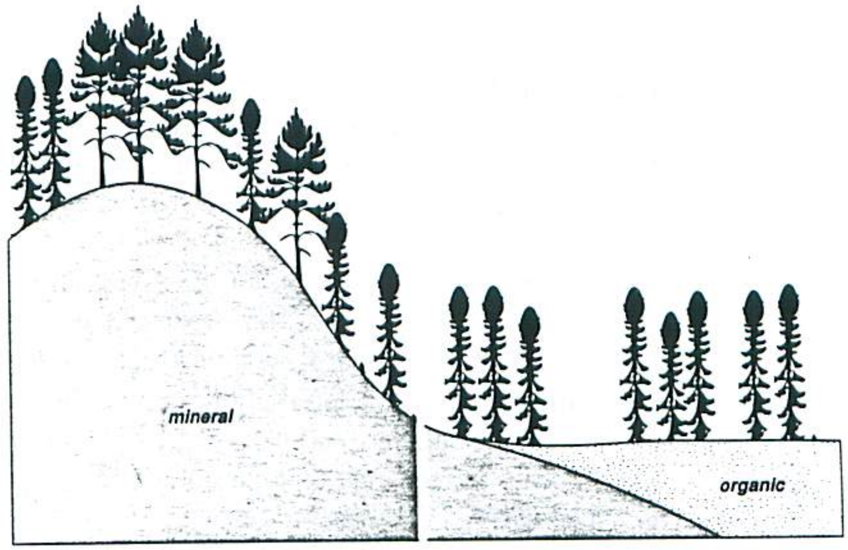
Figure 9. Deep, Sandy Glaciofluvial - Ice Contact / Jack Pine - Black Spruce

Approximately 17% of the land area within the Rinker Lake Research Area is covered by glaciofluvial sediments, the majority of which were deposited in near-glacier ice contact environments. Ice contact deposits form positive relief landform features such as eskers, kames, and crevasse fills. They typically comprise relatively coarse-textured materials, i.e., sands, gravels, and cobbles, which exhibit some degree of internal sorting. Within the Research Area, ice contact features occur across a broad range of forms and scales (*see* Section 3.1.6). Sediment texture and degree of sorting are extremely variable in ice contact stratified drift within the Research Area, ranging from well-sorted fine sand to poorly sorted gravel, cobbles, and boulders.

This toposequence model represents a short slope extending from the crest of an esker, composed of glaciofluvial sand and gravel (S1), to an adjacent topographic depression, where a perennially elevated water table has promoted the development of a thick peat deposit (S12S). The soil profile on the esker is characterized by well-defined strata, consisting of coarse and medium sands with a very high (up to 50% by volume) proportion of gravel and cobbles. These soils are moderately dry (SMR 0) and very rapidly drained.

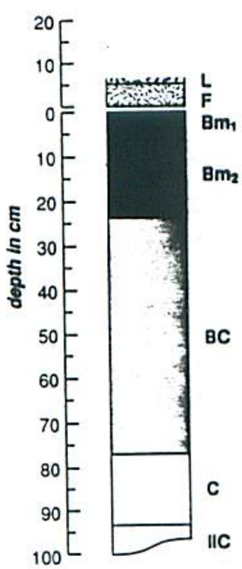
Due to dramatic differences in hydrological conditions along this toposequence, a distinct ecological discontinuity is evident in the vegetation conditions. Two separate vegetation communities occur, with only a truncated ecotone at the slope toe. On the esker, an upland jack pine - black spruce stand (V32) is found, with an extremely depauperate shrub and herb flora. On the peatland, a lowland black spruce community (V35) occurs. Ground cover contrasts are evident, with feathermoss dominating on the esker and *Sphagnum* spp. in the peatland. The relatively well-developed shrub and herb strata in the peatland community suggest nutrient enrichment from telluric water seepage.

Overstory	Pj 35 Sb 35	Sb 27
Shrubs	Sb 13 Ledugro 3 Linnbor 2	Alnurug 25 Ledugro 50 Sb 12
Herbs and Graminoids	Corncan 6	Equisyl 2 Caretri 2
Moss/Lichen	Fmoss 88	Sphagnum 86
Vegetation Type	V32	V35



Slope Position	crest	depression
% Slope	3	0
Humus Type	Typical fibrimor	Fibric peatymor
% Coarse Fragments	35 - 50	-
Soil Type	S1	S12S

Soil Horizon Summary



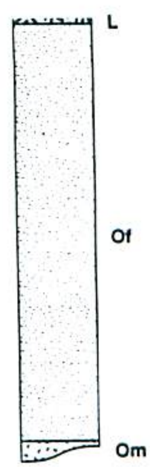


Fig. 9. Deep, sandy glaciofluvial - ice contact / jack pine - black spruce.

6.0 Summary and Future Applications

The principles of ecosystem management necessitate a detailed awareness of ecological values occurring within a management unit. Knowledge is required, not only of what ecological attributes are present within the ecosystems to be managed, but also of where they are currently located within the management unit and what dynamic processes link them together. At the initiation of the Rinker Lake Projcet, there was limited coverage of the ecological attributes characterizing the Research Area at spatial scales suitable for operational considerations. The Project sought to acquire and/or create digital spatial databases of primary ecological parameters, which could then be used in the development and testing of a range of ecosystem models. Ultimately, the Rinker Lake Project intended to offer a model for ecosystem management at an operational scale, in a selected landscape.

This report has summarized some key outputs of the first phase of the project, the development of integrated, spatially referenced databases that serve as a baseline inventory of primary ecological parameters in the Rinker Lake Research Area. These databases were interpreted from a variety of primary sources, including aerial photographs, satellite images, topographic maps, and ground survey data. Each database has been digitized and registered to a common basemap scale and projection in order to facilitate manipulation and analysis within a geographic information system. The derived databases significantly augment existing spatially referenced inventory data available for the Area (e.g., forest resource inventory). The techniques described in this report are intended to be used in conjunction with local or regional tools for ecoregionalization (e.g., Hills 1961; Ecological Stratification Working Group 1995), ecosite mapping (e.g., Harris et al. 1996; Racey et al. 1996), and ground-based ecological site classification (e.g., Sims et al. 1989).

The second phase of the project should provide an improved understanding of spatially distributed, ecological relationships in boreal forest areas through the development of spatially predictive ecosystem models that utilize these ecological databases. Efforts are currently underway to develop spatial models that will facilitate the prediction of various derived ecological attributes from the primary databases described in this report. Ongoing work includes development of a spatially distributed model for soil moisture regime in the Rinker Lake Research Area, using soil texture data and terrain indices derived from the digital elevation model. The biological response of vegetation communities to environmental regimes within the Research Area is being investigated by ecological domain analyses. The degree to which the current spatial distribution of recognizable vegetation types can be explained on the basis of distribution of critical ecological attributes such as topographic position, soil texture, and soil moisture will determine the likelihood of predicting future vegetation distribution across the landscape following disturbance. Succession models, encompassing temporal dynamics of various vegetation types, will be coupled to the domain analyses to further refine the capability for predicting potential vegetation distributions. Other work in progress involves the modeling of site productivity for several tree species using terrain and climate factors derived from the DEM.

Following are some recommendations regarding implementation of ecosystem management and the development of ecological inventories:

- A well-developed, ecologically-based classification system for forest site conditions at the very local level is a required precursor for ecological inventory and mapping (e.g., FEC).

- The ecological resources of the forest are not just the trees and the greater vegetation; they also include the geology, surficial deposits, soils, climate, etc. When we talk about an ecological inventory we include all of the above, as well as synthesized ecological units such as Ecoelements and Ecoregions.

- Ecosystems are complex, of various sizes and shapes, and may be overlapping depending upon the scale at which they are described, sensed or mapped.

- Scale is important!

- Efficient forest land management requires the best use of the total landscape to maximize the sustainable production of forest products, both timber and non-timber.

- To be able to decide between alternative uses of forest stands, the land manager needs to know the relative value of different forest types and to be able to identify landscape components that are critical for conservation purposes.

- Accuracy of spatial data must be assessed in the context of its proposed uses.

- There is a need for data modeling and the synthesis of data layers; not just a need for organizing data.

- For a defined management area, it may be essential to collect information on the basic ecological fabric and to generate the management entities such as broad ecological units (analogous to the forest resources inventory (FRI) stands).

- We must make the best possible use of existing spatial databases such as Ontario Base Map (OBM) elevation data, Ontario Land Inventory (OLI) maps, Northern Ontario Engineering Geology Terrain Study (NOEGTS) maps, Forest Resource Inventory (FRI) maps, etc.

- We must develop the most efficient methodologies to help fill the remaining information gaps (e.g., detailed surficial mapping or large-scale soils information).

- Ecological mapping and inventory is an interdisciplinary task that involves a great deal of cooperation among agencies and divisions. The developmental work includes foresters, biologists, geologists, remote sensing experts, field technicians, statisticians, modelers, etc.

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Appendix A. Glossary of Geological Terms

Archean - refers to the earlier part of Precambrian time which ended about 2.5 billion years before present (BP).

carbonate rocks - rocks composed mainly of carbonate minerals, such as calcite and dolomite, that are generally of sedimentary origin, but, strictly speaking, also include certain uncommon igneous rocks known as carbonatites. Limestone and dolostone and the metamorphic counterparts (marbles) are the major common types of carbonate rocks.

clastic - refers to sediment derived from pre-existing rocks, particularly non-carbonate rocks. Clastic sedimentary rocks include shade, sandstone, and conglomerate.

diabase - a mafic intrusive rock common in shallow intrusive bodies, most frequently in the form of sills and dikes. It is composed principally of clinopyroxene and calcium-rich plagioclase feldspar. It is chemically and mineralogically equivalent to basalt (volcanic) and gabbro (plutonic).

esker - a sinuous ridge of sand and gravel formed by glaciofluvial sedimentation in tunnels within or at the base of glacier ice.

felsic - refers to igneous rocks with a large component of light coloured mineral such as feldspars, quartz, feldspathoids, and muscovite mica. Granite and rhyolite are examples of felsic rocks.

glaciofluvial - refers of processes and deposits associated with streams of glacial meltwater.

glaciolacustrine - an adjective that refers to processes and sedimentary deposits of glacial lakes.

granite - a type of felsic intrusive rock that, in the strict modern definition, is composed of 20 to 60% quartz with alkali feldspars (potassium and high sodium types) making up at least 65% of the feldspar component. The terms granite and granitic are more loosely applied to a broad range of felsic intrusive rocks.

greenstone belt - elongate or belt-like areas of deformed supracrustal rocks within granite-greenstone subprovinces of the Shield. Metamorphic grade is low to medium and the name "greenstone" is an old field term that come from the dark green appearrance of metabasalt at these metamorphic grades. Most greenstone belts are dominated by mafic metavolcanic rocks, with subordinate felsic metavolcanic and clastic metasedimentary rocks.

ice-contact stratified drift - sediments deposited mainly by running water in contact with glacier ice. Sedimentation may occur on the ice surface, within crevasses and moulins, in tunnels within or at the base of the ice, or between the ice margin and adjoining high gound. Sand and gravel make up the bulk of ICSD deposits, but fine-grained sediments deposited in ponds on the ice surface and flow till layers may also be present. Usually the ice is stagnant, i.e. no long moving under the influence of gravity. Ice stagnation maybe widespread or occur in a narrow zone at the nose of an ice mass. These deposits are often characterized by a variety of deformation structures that develop as the supporting ice melts away.

igneous rocks - rocks that originate by the solidification of molten or partially molten material (magma). Examples include volcanic rocks, such as basalt and andesite, and granitic rocks.

intrusive rocks - igneous rocks formed by the emplacement of magma into pre-existing rocks. Rocks emplaced at fairly shallow depths in the crust are often referred to as subvolcanic or hypabyssal rocks; the rocks in deeper seated intrusions are known as plutonic rocks.

mafic - refers to igeous rocks which contain a large proportion of dark-coloured minerals rich in iron and magnesium. These "ferromanesian" minerals include pyroxenes, amphiboles, dark micas, and olivine. Examples of mafic rocks are gabbro and basalt.

magma - mobile rock material, either a liquid or a liquid-solid mixture, from which igneous rocks are thought to be derived by solidification and related processes. Magmas are generated by the melting of rock in the earth's mantle and lower crust.

meta - this prefix to a rock name indicates that that the rock has been metamorphosed, eg. metabasalt, metawacke, etc. Generally, the original rock can still be recognized.

metamorphic grade - the intensity or degree of metamorphism, characterized by the difference between the original rock and the metamorphic rock. Low grade rocks usally retain many of the features of the original rock (the "protolith" in geologese), whereas in high grade rocks original structures are generally completely obliterated.

metamorphic rocks - rocks derived from pre-existing rocks by mineralogical or structural changes that take place in the solid state in response to changing thermal and/or pressure conditions. Chemical changes are mainly limited to the addition or removal of water. Metamorphism occurs below the zone of surface weathering and erosion.

outwash - glaciofluvial sediments deposited in braided streams that drain melt water away from a glacier. Sand and gravel are the main components, but there may also be silt and even minor amounts of clay.

phi (ϕ) scale - a simple logarithmic transformation of the Wentworth grain size. scale. It is the base 2 log of the reciprocal of the grain size in millimeters. For example, the reciprocal of 1/8 is 8 (2^3)and its base 2 log is 3, hence 3ϕ is equal to 0.125mm .

Proterozoic - the latter part of Precambrian time, roughtly 2.5 billion years BP (before present) to about 600 million years BP.

Quaternary - a period of geological time that began about 1.8 million years BP and continues to the present day. It is divided into two epochs: the Pleistocene, which ended 10,000 years BP; and the Recent or Holocene.

sedimentary rocks - rocks that originate through the hardening (lithification) of accumulations of sediment - debris dervied from the breakdown of pre-existing rocks or material that has been chemically precipitated in water.

sorting - refers to the degree of similarity between particles in a sediment, usually in terms of size. In a well sorted sediment, most of the grains fall into a fairly narrow size range. Standard deviation can be used as a statistical measure of sorting in a grain-size distribution.

supracrustal - at the surface of the earth. Supracrustal rocks are those that form at the earth's surface, that is, volcanic rocks and sedimentary rocks.

texture - refers to the grain-size characteristics of a sediment or sedimentary rock.

till - sediment that has been transported and deposited by or from glacier ice with little or no sorting by water. Tills are generally poorly sorted, that is they have a wide range of grain sizes, with a bimodal distribution. The modal peaks represent the matrix fraction - the "fine" component with material ranging from clay to coarse sand - and the clast or coarse fragment fraction, which is composed of material larger than 2mm in diameter.

ultramafic - refers to igneous rocks that are composed almost exclusively of ferromagnesian minerals (*see* mafic). Examples are pyroxenite, peridotite, dunite, etc.

volcanic rocks - igneous rocks that result from volcanic avtivity at or near the earth's surface. They can be either be explosively ejected or extruded as lava. These rocks are generally fine-grained or glassy and form stratified sequences similar to sedimentary rocks. They are also known as extrusive rocks. Metamorphosed volcanic rocks are common in Archean greenstone belts.

Wentworth scale (or Udden-Wentworth scale) - the most commonly used scale of grain size in geology. It is based on simple on simple fractions of nominal grain diameter in millimeters and can easily be converted to a whole number scale (the phi scale) using a simple logarithmic transformation (*see* phi scale).

Name	Size in millimetres	Size in phi units
boulders	> 256	< -8
cobbles	64 – 256	-6 – -8
pebbles	4 – 64	-2 – -6
granules	2 – 4	-1 – -2
sand - very coarse	1 – 2	0 – -1
coarse	0.5 – 1	1 – 0
medium	0.25 – 0.5	2 – 1
fine	0.125 – 0.25	3 – 2
very fine	0.0625 – 0.125	4 – 3
silt	0.002 – 0.0625	9 – 4
clay	< 0.002	> 9

Appendix B. List of plant species acronyms, latin and common names.

Acronym	Latin Name	Common Name
Tree species:		
Bf	*Abies balsamea*	balsam fir
Bw	*Betula papyrifera*	white birch
Pj	*Pinus banksiana*	jack pine
Pob	*Populus balsamifera*	balsam poplar
Pot	*Populus tremuloides*	trembling aspen
Sb	*Picea mariana*	black spruce
Shrub species:		
Acerspi	*Acer spicatum*	mountain maple
Alnucri	*Alnus crispa*	green alder
Alnurug	*Alnus rugosa*	speckled alder
Corycor	*Corylus cornuta*	beaked hazelnut
Dierlon	*Diervilla lonicera*	bush honeysuckle
Gaulhis	*Gaultheria hispidula*	creeping snowberry
Ledugro	*Ledum groenlandicum*	labrador tea
Linnbor	*Linnaea borealis*	twinflower
Lonican	*Lonicera canadensis*	Canada fly honeysuckle
Rubupub	*Rubus pubescens*	dwarf raspberry
Salidis	*Salix discolor*	pussy willow
Vaccmyr	*Vaccinium myrtilloides*	velvet-leaf blueberry

Acronym	Latin name	Common name
Herb / Graminoid species:		
Aralnud	*Aralia nudicaulis*	wild sarsaparilla
Astemac	*Aster macrophyllus*	large-leaved aster
Athyfil	*Athyrium filix-femina*	lady fern
Carebru	*Carex brunnescens*	brownish sedge
Caretri	*Carex trisperma*	three-fruited sedge
Cinnlat	*Cinna latifolia*	drooping wood reed
Clinbor	*Clintonia borealis*	blue bead lily
Copttri	*Coptis trifolia*	goldthread
Corncan	*Cornus canadensis*	bunchberry
Epilang	*Epilobium angustifolium*	fireweed
Equisyl	*Equisetum sylvaticum*	woodland horsetail
Lycoann	*Lycopodium annotinum*	stiff clubmoss
Lycoobs	*Lycopodium obscurum*	ground pine
Maiacan	*Maianthemum canadense*	wild lily of the valley
Streros	*Streptopus roseus*	rose twisted stalk
Violren	*Viola renifolia*	kidney-leaved violet
Moss species:		
Fmoss	includes: *Pleurozium schreberi, Hylocomium splendens, Ptilium crista-castrensis*	feathermosses
Sphagnum	*Sphagnum* spp.	Sphagnum mosses