

**Building Aerial Photo Interpretation Keys  
to the  
NWO FEC S-types and V-types  
in the  
Roslyn Lake Study Area: A Case Study**

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## ABSTRACT

This report provides a case study description of the development of aerial photo interpretation (API) keys that may assist resource managers in the identification of the classification units ("soil types" and "vegetation types") of the Northwestern Ontario Forest Ecosystem Classification (NWO FEC) on 1:15 840 scale, black and white aerial photos. By developing approaches to photo interpret classification units on aerial photos, site classifications can be spatially applied while minimizing the amount of field sampling required to accurately describe forest ecosystems.

The first part of the report provides a brief historical overview of site classification activities in Ontario. The NWO FEC system, some of its current applications by the Ontario Ministry of Natural Resources (OMNR) and forest industry staff, as well as past efforts to photo interpret and map the classification units, are described. Basic techniques for interpreting landform, soil, and vegetation features on intermediate scale black and white aerial photos are presented. This background information is the foundation for photo interpreting NWO FEC vegetation types (V-types) and soil types (S-types).

The method of developing aerial photo interpretation keys in the Roslyn Lake case study is described in detail, including phases of data collection, photo interpretation, and key construction. In the final sections of the report, all aspects of the development of the keys are demonstrated, including a description of the Roslyn Lake Study Area's soil and vegetation characteristics, the creation of toposequence models, the framework for each key, and photo stereograms that illustrate a variety of interpreted features. In the interest of conserving space in the body of this report, each API key is introduced with an overview of its structure and how to use it. The full API keys are presented in a "stand-alone" format in the appendices of this report. Conventions used in the keys, tips for successfully applying them, and a limited glossary of terms are also provided.

Potential applications for the photo interpretation keys, with particular emphasis on mapping, are presented. Photo interpretability of the NWO FEC V- and S-types is assessed and the implications for forest resource management are discussed. Finally, some conclusions and recommendations are made based on this case study.



## RÉSUMÉ

À l'aide d'une étude de cas, ce rapport décrit une procédure pour élaborer des clés de photo-interprétation qui peuvent aider les responsables de la gestion des ressources à identifier les unités de classification (types de sol et types de végétation) utilisées dans la Classification des écosystèmes forestiers du nord-ouest de l'Ontario (système NWO FEC) sur des photographies aériennes noir et blanc à l'échelle de 1/15 840. Des méthodes de photo-interprétation adéquates permettent aux interpréteurs de situer dans l'espace des classifications de sites tout en limitant à un strict minimum la somme d'échantillonnage à exécuter sur le terrain pour décrire fidèlement les écosystèmes forestiers.

La première partie du rapport fait une courte rétrospective des travaux de classification de sites exécutés en Ontario. On y décrit le système NWO FEC, quelques-unes de ses applications au ministère ontarien des Richesses naturelles et dans l'industrie forestière, ainsi que les travaux qui ont été faits jusqu'à maintenant en photo-interprétation et en cartographie des unités de classification. Le rapport présente des techniques de base pour identifier les types de relief, de sol et de végétation sur des photos aériennes noir et blanc à échelle moyenne; il fournit en somme l'information de base sur laquelle s'appuient les interpréteurs pour distinguer les types de végétation et de sol dans le cadre du système NWO FEC.

Le rapport décrit en détail, étape par étape (collecte des données, interprétation des photos et construction des clés), la méthode qui a été utilisée dans le cas du lac Roslyn pour élaborer des clés de photo-interprétation.

Dans les dernières parties du rapport, les auteurs illustrent par des exemples concrets les divers aspects de l'élaboration des clés de photo-interprétation : description des propriétés du sol et de la végétation dans la région du lac Roslyn, création de modèles de toposéquences, cadre de chaque clé d'interprétation et stéréogrammes illustrant une grande variété d'objets d'interprétation. Par souci de concision, les auteurs se bornent dans le corps du texte à décrire brièvement la structure des clés et la façon de les utiliser, pour ensuite renvoyer le lecteur à des annexes dont chacune traite en détail d'une clé en particulier. Les annexes sont complétées d'une explication des conventions utilisées dans les clés d'interprétation, de divers conseils sur la bonne façon de les appliquer et d'un glossaire de termes choisis.

Le rapport nous renseigne également sur les applications possibles des clés de photo-interprétation, plus particulièrement dans le domaine de la cartographie. Il évalue la photo-interprétabilité des types de végétation et de sol reconnus par le système NWO FEC et ses implications pour la gestion des ressources forestières. Finalement, les auteurs nous livrent leurs conclusions et leurs recommandations à la lumière de l'étude de cas.



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## 1.0 INTRODUCTION

The purpose of this report is to provide a case study description of the development of aerial photo interpretation (API) keys that will aid in identifying the classification units ("soil types" and "vegetation types") of the Northwestern Ontario Forest Ecosystem Classification (NWO FEC) (Sims et al. 1989) on 1:15 840 scale, black and white aerial photos. The ability to photo interpret the classification units on aerial photos allows the classification to be spatially applied while minimizing the amount of field sampling required to accurately describe forest ecosystems.

### 1.1 Objectives

This technical report provides resource managers in northwestern Ontario with tools and techniques that will assist them with the identification and delineation of NWO FEC soil and vegetation types on intermediate-scale (1:15 840), black and white aerial photos. The specific objectives of this report are:

1. To describe the development of the aerial photo interpretation keys to the NWO FEC soil types and vegetation types as they exist in the Roslyn Lake Study Area.
2. To present the aerial photo interpretation keys to the NWO FEC soil types and vegetation types in the Roslyn Lake Study Area.
3. To provide example toposquence models that illustrate some of the main soil and vegetation complexes that occur in the Roslyn Lake area and that are utilized as aerial photo interpretation tools within the aerial photo interpretation keys.
4. To illustrate on select aerial photo pairs, examples of photo interpreted features that are part of the two keys.
5. To briefly discuss the photo interpretability of NWO FEC types and the implications thereof for forest/resource management.

### 1.2 Historical Overview of Site Classification in Ontario

Forest land management requires a comprehensive knowledge of the physical and spatial characteristics of the forest/land resource. Forest site classification and mapping can provide the framework for describing and quantifying the forest resource in ecological terms. Site classification is a method for reducing the many diverse features of the landscape to a few groups that have similar features. Forest ecosystem classifications, such as those produced by Jones et al. (1983) and Sims et al. (1989), provide a means for identifying and naming forest ecosystems on the ground; resulting classification units are

segments of the forest landscape that have similar climate, vegetation, and soil characteristics. Once an area has been classified, the spatial relationships of the classification units can also be illustrated on maps. Unquestionably, the practicality of any ecological classification system is greatly enhanced by the development of simple and reproducible methodologies for mapping and spatially extending the classification units.

Forest resource mapping has historically been accomplished by ground-level observations, by interpretation of aerial photos, or by a combination of both techniques. Ground surveys obviously provide the most accurate description of forest stand and site conditions. However, they can be very costly and difficult to complete in some areas because of intensive manpower and time requirements, problems with accessibility to the map area, and limited funding. Aerial photo interpretation minimizes the need for ground surveys and facilitates the creation of accurate forest ecosystem maps over extensive areas. A minimum amount of field survey will always be required to ground truth and thereby confirm aerial photo interpretations.

Other forest resource mapping techniques currently being investigated employ satellite or aerial-borne imagery (e.g., Treitz and Howarth 1996), digital elevation models (e.g., Sims and Mackey 1994), or other modeling approaches. These prospective methodologies will not be dealt with in this report.

The ecological approach to describing forest sites in Canada began in the 1950s with Hills' work in Ontario (Hills 1952, 1953, 1954) and Krajina's work in British Columbia (Krajina 1965). Both Hills and Krajina recognized the importance of considering all interacting factors of the forest site, including vegetation (at all strata—trees, shrubs, herbs, and bryophytes), soil/landform, and climate, and developed site classification systems that attempted to incorporate these ecosystem components. Krajina's classification considered the influence of topographic and climatic factors, and associated zonal vegetation conditions (Krajina 1965). Central to Hills' classification was the assessment of the productive capability of the land, initially for forestry, but subsequently for agriculture and a range of other potential resource uses (Burger 1972).

At all levels of the classification system for Ontario, Hills emphasized the need to map the classification units. Comprehensive mapping and land evaluation techniques were developed by Hills and his colleagues (e.g., Hills et al. 1960, Lynn and Zoltai 1965). These techniques continue to influence site classification and mapping work throughout Canada and the United States (Burger 1972, Bailey et al. 1978, Burger and Pierpoint 1990).



Since Hills' pioneering efforts in ecological site classification and mapping, numerous land classification programs have been developed throughout Canada. The Canada Land Inventory (CLI) and Ontario Land Inventory (OLI) programs were directly influenced by Hills' land evaluation techniques (Canada Department of Forestry 1965). The CLI and OLI were initiated in the mid 1960s to map the land base and show its assessed capability for agriculture, forestry, recreation, and wildlife. Mapped areas were primarily populated agricultural lands and adjacent forested lands (Burger 1972).

In the late 1960s, Lacate (1969) developed a biophysical land classification system for Canada that was comparable in its structure to Hills' forest site classification. The system was used to classify and map vast areas of Canada for the purposes of providing an overview of land resources and to serve as an ecological basis for land use planning (Burger 1972, Burger and Pierpoint 1990, Sims and Uhlig 1992).

In 1976, the Canada Committee on Ecological Land Classification (CCELC) was established for the purpose of developing and promoting the use of a uniform, national ecological land classification system that could be the basis for environmentally sustainable resource management and land use planning. Several working groups were responsible for developing a classification system for Canada's wetlands, promoting the integration of wildlife habitat management with other ecological land surveys, developing a national vegetation classification system, and determining and mapping ecoclimatic regions of Canada. The CCELC developed national standards, guidelines, and methods for ecologically classifying, inventorying, and evaluating natural resources. Its working groups addressed a variety of resource issues throughout Canada during the 1980s (Ironside 1989).

More recently, Burger (1993) has revised Hills' site classification of Ontario. Burger clarified some of the terminology associated with site type classification, created a new site region for the Hudson Bay shoreline, and updated the map and vegetation characteristics of Ontario's site regions. In the revised classification, the relationships between tree species and site type are emphasized. Other work to revise the regional ecological units for Ontario is continuing (Mackey et al. 1996; R. Sims, pers. comm.).

Aerial photo interpretation has always been an important component of land resource mapping, especially when extensive areas are being mapped. Techniques for identifying features on aerial photos have been developed, tested, and improved over the years. More recent advances in remote sensing technology have increased the utility of satellite images and computer-based geographic information systems (GIS) for mapping and describing the landscape. For now, however, interpretation of intermediate

scale aerial photos is still the basis for local and regional land management practices because satellite imagery is typically acquired at smaller resolutions that are more suited to broad, landscape-scale interpretation and application. The GIS is used increasingly as a powerful means of linking the different scales of information (large to small) obtained from different sources (point data collected in the field to satellite image analyses) (e.g., Goodenough et al. 1994, Kempka et al. 1994).

### 1.3 Forest Ecosystem Classification in Ontario

In the last decade, ecological classification systems for mature forest conditions have been developed for many different regions across Canada (e.g., Corns and Annas 1986, Meades and Moores 1989, Sims et al. 1989). Each system has been created for specific applications within a particular geographic area, but all provide frameworks for identifying and describing mature forest ecosystems. In Ontario, various forest ecosystem classification (FEC) systems have been or are being developed that are intended to facilitate the accurate and consistent description of forest ecosystems and to provide the framework for organizing and communicating forest management knowledge and experience (Sims and Uhlig 1992). Classification units vary in scale but typically represent ecoelements, at scales from 1:2 000 to 1:10 000 (e.g., Jones et al. 1983, Merchant et al. 1989, Sims et al. 1989, McCarthy et al. 1994), or ecosites, at scales from 1:10 000 to 1:20 000 (e.g., Jones et al. 1983, McCarthy et al. 1994, Racey et al. 1996). The ability to map the classification units has been an important consideration in the development of each of the classifications.

Ontario's regional forest ecosystem classification systems have been widely adopted by the Ontario Ministry of Natural Resources (OMNR) and forest industry staff who have incorporated the concepts into a variety of forest resource management applications. FECs provide a framework for assessing silvicultural suitability and/or limitations of the site (e.g., susceptibility to root rot or insect infestation, appropriate planting stock selection, opportunity for prescribed burning, etc.), for evaluating habitat conditions for a variety of wildlife species, and for considering a variety of forest management applications (e.g., pre-cut inventory surveys) (Racey et al. 1989). Many scientific studies have investigated the potential applications of these classifications: the productivity of jack pine (*Pinus banksiana* Lamb.) stands (Leblanc and Towill 1989); the potential for advance growth following logging (Groot 1984, Walsh and Wickware 1991); caribou (*Rangifer tarandus*) and moose (*Alces alces*) habitat preferences (Morash and Racey 1990, Jackson et al. 1991); the correlation of surficial landform features with FEC units (Sims and Baldwin 1991); and postharvest vegetation development (Walsh and Krishka 1991).



In order to make the FEC systems more relevant to current resource management practices, the classification units must also be readily mappable. Maps are a familiar and effective means of portraying inventory information about the areal extent and spatial distribution of the forest resource, and are, therefore, an integral part of forest management planning and decision making processes. When mapping FEC units, the ecological information that characterizes each unit can be represented within each map polygon. All of this spatially based site information can then be incorporated into the management process to ultimately result in wiser, ecologically sensitive management decisions.

### **1.3.1 Aerial Photo Interpretation of Site Classification Units**

Since the 1940s, aerial photo interpretation has been an important tool for mapping. Losee (1942) interpreted large-scale winter (1:9 600) and late summer/fall (1:7 200) black and white aerial photos to accurately map a range of forest site types at the Petawawa Forest Experiment Station in eastern Ontario. He made use of topographical and vegetational cover measurements on the photos to identify and delineate a total of 12 site types that occurred on ridge, dry, moist, and swamp conditions.

Jeglum and Boissonneau (1977) evaluated the photo interpretability of wetland classification units on black and white, 1:15 840 scale aerial photos of the Clay Belt area of northeastern Ontario. This wetland classification, based on vegetational physiognomy and dominance, was found to be well suited to aerial photo interpretation and mapping.

More recently, considerable effort has been applied to the development of mapping methodologies as part of the FEC programs, and aerial photo interpretation has been an important component. Both the northeastern (Clay Belt) (Jones et al. 1983) and northwestern Ontario FEC systems have been used to develop and test techniques for interpreting different ecosystem conditions on aerial photos.

#### **1.3.1.1 Aerial Photo Interpretation and Mapping of Clay Belt FEC Units**

Subsequent to the completion of the Clay Belt FEC in northeastern Ontario, guidelines were developed for mapping and photo interpreting "operational groups" (OGs), the management oriented ecosystem units defined in the classification system. Jones et al. (1983) stressed that the most important factor to be considered when developing a survey and mapping program is to clearly define the intended use of the map. This will influence map scale, survey intensity, and data requirements. As an aid to the aerial photo interpretation of the operational groups, Jones et al. (1983) described the general appearance of each OG

on 1:15 840 black and white aerial photos. Since a certain amount of variation can be expected among the stand conditions within each OG, Jones et al. (1983) recommend that individual mappers/photo interpreters develop localized keys of the diagnostic features for each OG that occurs within their own management unit/map area.

Addante (1989) reported on the utilization of the Clay Belt FEC by the Spruce Falls Power and Paper Co. Ltd. in Kapuskasing, Ontario. The company found that a satisfactory level of accuracy was achieved when they photo interpreted FEC OGs on conventional (1:15 840) black and white aerial photos. Success was attributed in part to the photo interpreters' familiarity with local forest conditions, their level of field experience and familiarity with the FEC, and their skill in aerial photo interpretation.

Work is currently underway, within the Abitibi Model Forest, to develop aerial photo interpretation and mapping techniques for the Northeastern Ontario Forest Ecosystem Classification units (G. Racey, pers. comm.)

#### **1.3.1.2 Aerial Photo Interpretation and Mapping of Northwestern Ontario FEC Units**

Since the publication of the NWO FEC in 1989 (Sims et al. 1989), several methods have been tested for utilizing aerial photo interpretation to map classification units and to reduce the amount of field sampling required. Aerial photo interpretation and mapping of the NWO FEC V-types and S-types has been tested in the Aulneau Peninsula (Wickware 1990); in the Thunder Bay (B. Wiltshire, pers. comm.) and Red Lake (R. Sidders, pers. comm.) districts of the OMNR; and in the Sapawe area (Wickware and Sims 1990), west of Thunder Bay.

Wickware (1990) reported on a project designed to develop a reliable method of interpreting the NWO FEC V-types and S-types on 1:15 840 black and white aerial photos. The Aulneau Peninsula, near Kenora, Ontario, provided the location for developing and testing the methodology. Separate keys were developed for the V-type and S-type classifications. Wickware suggested that the key to the V-types could be applied in other locations throughout northwestern Ontario. The key to the S-types was less reliable when used in other parts of northwestern Ontario, due to the wide range of physiographic conditions that exist throughout the region. Wickware stressed that an aerial photo interpretation key must be tested to confirm its applicability in different mapping areas.

The Thunder Bay Crown Management Unit (CMU) was classified and mapped using NWO FEC types (B. Wiltshire, pers. comm.). Landform types and general soil conditions were identified on 1:15 840 scale aerial photos of the area. Photo interpreted landform delineations were verified and adjusted through field inspections. NWO FEC V-types



were extrapolated from the FRI stand canopy descriptions. The aerial photo interpretation and field verification exercise resulted in an ecologically based resource inventory that was useful for forest management planning in the CMU.

In the Red Lake District, a recent timber management planning (TMP) process incorporated NWO FEC V-type and S-type classification (R. Sidders, pers. comm.). FEC typing on approximately 10 000 hectares was accomplished using a combination of aerial photo interpretation and field verification. The effort was applied to determine the most suitable sites for regeneration of commercially important tree species.

Keys to aid in identifying complexes of NWO FEC types on 1:15 840 black and white aerial photos were developed in a study designed to model stand vulnerability to spruce budworm (*Choristoneura fumiferana* [Clem.]) attack (Wickware and Sims 1990). The aerial photo interpretation keys facilitated mapping the NWO FEC types in the 10 000 hectare Sapawe study area, northeast of Atikokan, Ontario. Several models were developed and tested using GIS analytical techniques to assess stand susceptibility to budworm attack and damage. Two of the models incorporated V-type and S-type information about the stand as important factors in determining the degree of vulnerability to budworm damage. The ability to identify and spatially delineate V-types and S-types was a critical component of these GIS models since interpretive, predictive maps, which would be useful for forest management planning, could be produced and then updated over time (Wickware and Sims 1990).

In the wake of the development of an ecosite classification system for northwestern Ontario (Racey et al. 1996), a set of photo interpretation keys has been developed for identifying forested ecosites on black and white aerial photos (Ecological Services for Planning 1996). The keys will be tested and refined on an ongoing basis throughout 1996 (G. Racey, pers. comm.).

These mapping/aerial photo interpretation efforts have demonstrated various strategies that may be employed for different applications/purposes to interpret the NWO FEC V-type, S-type, and ecosite conditions in different parts of Ontario's Northwest Region. Methodologies that will assist the photo interpreter in identifying NWO FEC units on aerial photos should reflect local assemblages and distributions of NWO FEC types. The Roslyn Lake case study is an example of developing aerial photo interpretation keys for the NWO FEC V-types and S-types in the shallow soil, black spruce-dominated conditions that occur east of Lake Nipigon in north central Ontario.

## 1.4 Aerial Photo Interpretation Techniques

### 1.4.1 Aerial Photos

Aerial photos are ideal tools for identifying and mapping forest sites because, at appropriate scales and resolution, they can present accurate and detailed information about topography, landforms, forest crown cover, and other characteristics (Losee 1942, Westveld 1951). Successful interpretation of the information contained in aerial photos depends on the interpreter's ability to stereoscopically discern details, his/her training and experience, the nature of the objects being interpreted, and the quality of the photography (Zsilinszky 1966, Smelser and Patteson 1975). The art and science of aerial photo interpretation of forested landscapes involves recognition of directly observable ground features and an understanding of biophysical relationships that allows the interpreter to make inferences about nonvisible features. Regardless of the interpreter's capabilities, all aerial photo interpretation exercises should be verified by ground-level checks (Hills 1950, Westveld 1951, Zsilinszky 1966, Kuchler 1967, Smelser and Patteson 1975). Other sources of information (e.g., maps, reports about local conditions, point records, ground surveys, and other aerial or ground photography) may be employed to help verify aerial photo interpretations.

Stereoscopic coverage of an area is normally achieved by taking overlapping aerial photos along the line of flight. A stereo pair is created when two adjacent aerial photos have at least a 50 percent overlap. In the area of overlap, each photo in the pair shows the same portion of the ground surface but from slightly different viewpoints. When the stereo pair is viewed through a stereoscope, each eye views a different photo (thus a different image), but the area of overlap is perceived as a 3-dimensional stereo image (Lillesand and Kiefer 1979).

The amount of detail shown and the usefulness of the information on an aerial photo depends primarily on its scale. Scale defines the relationship between distance on the photo, the actual ground distance, and the focal length of the camera lens used to acquire the photo. Large-scale photos (1:12 000 or larger) are useful for monitoring specific items (e.g., surveys of plant disease, insect infestations, tree blowdown). Intermediate-scale photos (1:12 000 to 1:60 000) may be used for identification, classification, and mapping of tree species, vegetation communities, or soil type. Applications for small-scale photos (1:60 000 or smaller) include reconnaissance mapping, large area resource assessment, and management planning. In Ontario, Forest Resource Inventory (FRI) photos and maps are obtained at intermediate scales, 1:15 840 or 1:20 000. Larger-scale photography is sometimes flown over local areas to supplement the intermediate scale inventory photography.



Film type and filter combinations are also important factors in aerial photo interpretation. Aerial photos may be obtained using black and white, color, infrared, or other specialized film types. Selection of the appropriate film type will depend on the ultimate use of the photos and on an evaluation of the advantages and disadvantages of each type. Aerial photos for forestry purposes typically use black and white panchromatic film because it is usually adequate, in large- to intermediate-scale photos, for species identification when species composition is relatively simple. Black and white film is also preferred because the development process requires simple darkroom facilities and can be manipulated more readily to obtain quality photos. The cost of black and white photography is usually less than color or infrared photography (Sayn-Wittgenstein 1978).

Over the years, aerial photo interpretation techniques have evolved to suit a range of user needs. The literature abounds with reports on techniques for interpreting a variety of forestry-related features on aerial photos: including, recognition of tree species (Sayn-Wittgenstein 1960, 1961, 1978; Zsilinszky 1966); forest stand/vegetation mapping (O'Neill 1953, Aldred and Blake 1967, Kuchler 1967, Keser 1970, Bonnor 1977, Jeglum and Boissonneau 1977, Aldred and Lowe 1978); soils and landforms identification (Hills 1950, United States Soil Conservation Service 1966, Keser 1976, Sims and Baldwin 1991); forest damage from insect, disease, and other causes (Murtha 1972, Croft et al. 1982); and assessment of regeneration success (Goba et al. 1982).

Eight factors to consider when trying to identify an object on an aerial photo are: (1) shape, (2) stereoscopic or 3-dimensional appearance, (3) size, (4) pattern, (5) shadow, (6) tone, (7) texture, and (8) location. The usefulness of any of these factors will depend on the object being identified, the type and scale of photograph being used, and the time of year and of day that the photograph was recorded. Several authors have fully described these factors in relation to aerial photo interpretation (e.g., Kuchler 1967; Sayn-Wittgenstein 1961, 1978; Zsilinszky 1966; Barrett and Curtis 1976; Lillesand and Kiefer 1979). Their main roles are summarized here:

#### 1. Shape

Shape is the general form or outline of individual objects. Some objects have such distinctive shapes that they can be identified on this basis alone (e.g., crowns of certain tree species, lakes or rivers, and some landform features).

#### 2. Stereoscopic Appearance

A particularly powerful tool for the identification of some objects is their 3-dimensional shape or height.

Stereoscopic imagery is required to facilitate such 3-dimensional viewing.

#### 3. Size

Size of an object on the photo, in terms of length, breadth, height, area, and/or volume, must be considered in the context of the photographic scale. The size/scale of the object may be compared with familiar features in the scene (e.g., roads).

#### 4. Pattern

Pattern relates to the spatial arrangement of objects and may be diagnostic for some landscape features (e.g., linear arrangement of trees in plantation). Repetitive arrangements of both natural and cultural features are common and can aid the identification of complex landscape features.

#### 5. Shadow

Shadow detail may reveal the object's profile in silhouette, which may help to determine the object's true shape and height. Shadows may, however, hinder interpretation by reducing the visibility of some objects.

#### 6. Tone

Tone is the relative brightness or color of objects on the photo. Tonal differences result from the different reflectance properties of objects, and permit the discrimination of shapes, patterns, and textures. Terms such as light, medium, and dark are typically used to describe tone.

#### 7. Texture

Texture is the frequency of tonal change on the photo. Texture becomes important in smaller-scale photographs when individual objects become too small to distinguish. However, analysis of texture tends to be subjective and should not be the sole criterion used in the interpretation process. Terms such as smooth, rippled, or mottled are used to describe texture.

#### 8. Location

Location of the object in relation to terrain features or other objects can aid its identification. Often, the identification of one or more obvious features will lead to the recognition of other objects by virtue of their relative locations.

Location may also be considered in terms of broad geographic or biophysical area. For instance, conclusions may be made about species identification based on a knowledge of the generally accepted range for that species.



In any aerial photo interpretation exercise these factors must be carefully considered by the interpreter, although the importance of any single factor will vary with the nature of the available photography and the purpose of the interpretation. The accuracy of the photo-interpreted product (map or otherwise) depends on the ability of the interpreter to assess all of these factors, recognize relationships among interpreted objects, and, consciously or unconsciously, assimilate the information and develop the knowledge to identify the objects portrayed in the aerial photos.

Vegetation and landform features are frequently the most obvious and identifiable features on intermediate scale aerial photos of forested landscapes. Once certain vegetation and landform features have been identified, inferences can be made about a range of additional vegetation and soil/site conditions that may not be directly visible on aerial photos.

#### **1.4.2 Aerial Photo Interpretation of NWO FEC S-types**

Distinguishing and identifying soil conditions on intermediate scale, black and white aerial photos of forested landscapes is often difficult because the ground surface is typically covered with vegetation. Even if exposed soil is visible on an aerial photo, the characteristics used to describe soil (e.g., texture, moisture, depth) are usually not obvious from direct observation. In northwestern Ontario, the actions of successive glaciations, as well as dynamic postglacial processes, have resulted in a diverse mosaic of surficial landscape features.

There are 22 different S-types defined in the NWO FEC (Sims et al. 1989) (Table 1). The identification of NWO FEC S-types requires knowledge of the texture of the soil parent material, soil moisture condition, and soil depth. Determining these factors on the ground is quite straightforward. Field identification of soil texture involves a series of simple tests in which the soil sample is examined and manipulated (Bates et al. 1982). Similarly, determining soil moisture regime requires the assessment of soil texture and soil depth, and observation of mottles and gley colors that are indicative of seasonal water movement in the soil (Bates et al. 1982). Soil depth (within 1 m) is determined on the ground by digging or augering a hole in the soil to determine its thickness over bedrock. However, defining these characteristics from the appearance of the ground surface on aerial photos is somewhat more complicated. These less visible soil characteristics may be inferred from more readily identifiable features on aerial photos, such as landform, topography, and the overlying vegetation.

##### **1.4.2.1 Aerial Photo Interpretation of Landforms**

To the trained photo interpreter, landform and topographical features are usually obvious on intermediate and small scale aerial photos, since at this scale, the landscape can be seen in overview. Most landform features are distinguishable by their shape, size, and position on the landscape. Keser (1976) and Mollard and Janes (1984) have described and provided photo illustrations of the appearance, on intermediate scale aerial photos, of landform features that may be found throughout Canada. Sims and Baldwin (1991) describe the major landform features of northwestern Ontario. Table 2 summarizes the typical characteristic appearance of major landform features on intermediate scale black and white aerial photos. The reader should consult Keser (1976) or Sims and Baldwin (1991) to obtain more detailed information about the general appearance of landforms on aerial photos.

**Table 1.** NWO FEC soil types.

<b>Deep Mineral Soil Types</b>	
S1	Dry/Coarse Sandy
S2	Fresh/Fine Sandy
S3	Fresh/Coarse Loamy
S4	Fresh/Silty-Silt Loamy
S5	Fresh/Fine Loamy
S6	Fresh/Clayey
S7	Moist/Sandy
S8	Moist/Coarse Loamy
S9	Moist/Silty-Silt Loamy
S10	Moist/Fine Loamy-Clayey
S11	Moist/Peaty Phase
<b>Deep Organic Soil Types</b>	
S12F	Wet/Organic (feathermoss)
S12S	Wet/Organic (sphagnum)
<b>Very Shallow Soil Types</b>	
SS1	Discontinuous Organic Mat on Bedrock
SS2	Extremely Shallow Soil on Bedrock
SS3	Very Shallow Soil on Bedrock
SS4	Very Shallow Soil on Boulder Pavement
<b>Shallow to Moderately Deep Soil Types</b>	
SS5	Shallow-Moderately Deep/Sandy
SS6	Shallow-Moderately Deep/Coarse Loamy
SS7	Shallow-Moderately Deep/Silty-Fine Loamy-Clayey
SS8	Shallow-Moderately Deep/Mottles-Gley
SS9	Shallow-Moderately Deep/Organic-Peaty Phase



**Table 2.** Landform types, associated soil textures, and general appearance (location, texture/tone/pattern, drainage pattern) on black and white aerial photos (*after* Sims and Baldwin 1991).

Landform type	Commonly associated soil texture	General appearance on black and white aerial photos		
		Location	Texture/tone/pattern	Drainage pattern
Ground moraine	Sandy / coarse loamy	Flat to undulating topography, usually without abrupt or steep slopes	Mottled appearance: lighter tones on higher site positions and darker tones in depressions; pattern ranges from irregular feathery to relatively flat, uniform, featureless terrain	Disordered or random drainage patterns; many small, undrained, irregular-shaped depressions
Ablation till	Sandy / coarse loamy	Irregular and variable relief, often with a knob-and-kettle appearance	Lighter tones on higher ground, darker tones on lower ground; pattern is characteristic of knobs and closed hollows (kettles)	Disordered drainage pattern, usually with stagnant kettle pools
Shallow ablation till over bedrock	Sandy / coarse loamy; organic	Relief strongly controlled by surface bedrock, ranging from gently rolling to rugged and broken; exposed bedrock patches are common; small peatlands and water pools may develop, even on uplands, where bedrock impedes drainage	Rock outcrops usually have light tone and little or no vegetation cover; patterns are variable but underlying bedrock pattern is often evident, showing signs of direction of glacial movement	Drainage strongly controlled by bedrock; small water pools and peatlands are common; areas tend to be poorly or imperfectly drained
End moraine	Sandy / coarse loamy	Hummocky to irregular relief, sometimes with large, distinctive, steep-sided ridges; abrupt elevation changes	Usually mottled tones; irregular topography	Disordered drainage, with local ponds and poorly developed drainage networks
Esker	Coarse sandy / coarse loamy with gravel and cobbles	Sinusoid, low ridges, occurring alone or in complexes; may be continuous or discontinuous features; often flanked by swamps or kettle-hole features	Vegetational tones may differ from surrounding landscape due to different species, degree of crown closure, etc.	Excellent internal drainage, therefore no surface drainage is evident
Outwash deposits (valley trains, outwash plains)	Coarse sandy / coarse loamy (gravel)	Usually level or gently sloping terrain; landscape may appear pitted, covered with kettle holes	Tone is generally light, though dark areas indicate water infiltration, depressions, basins, or kettle holes; wormlike patterns indicate channel scars	Good internal drainage, with high soil infiltration; channel scars may be filled with organic deposits; streams and drainageways usually absent
Colluvium	Fragmented rocks	Most commonly talus material deposited by rock falls from cliff faces; also associated with moderate to steep slopes, cliffs, or riverbanks; often not vegetated	Tone is typically light though this may be affected by shadows and composition of talus material; distinctive shapes and forms, e.g., kidney-shaped scars, fans, or irregular-shaped mounds of debris	Very low water-retention capability for talus; seepage and springs may be present in fine-textured deposits
Organic terrain	Decomposing sphagnum and other mosses, sedges, woody materials	Flat and lowlying terrain; confined to small pockets and depressions in bedrock terrain	Pale tones, light colors, and smooth appearance are diagnostic; surface patterns may include hummocks, water tracks, or ribbed features	Stagnant to slow drainage; water table usually at or very near the ground surface for part of the year



#### 1.4.2.2 Aerial Photo Interpretation of Soil Texture

Auxiliary soil/site information can be inferred from the landform features identified on aerial photos. Associations exist between landform type, topographic position, and general soil texture. The processes related to the creation of landform features and the ongoing development of their soils tend to be similar across a geographic region. It is typical, therefore, for similar landform features to exhibit similar soil conditions regardless of the location of the feature within a discrete geographic area (Mollard and Janes 1984, Sims and Baldwin 1991).

Landform type is closely related to soil parent material. Broad soil textural classes (e.g., sandy, coarse loamy, etc.) can be associated with particular landform types as shown in Table 2. Thus, once a landform feature has been identified on the aerial photo, general soil textural information for that location can be inferred.

#### 1.4.2.3 Aerial Photo Interpretation of Soil Depth

Exposed bedrock, signifying extremely shallow (or non-existent) soils, is usually readily visible on 1:15 840 black and white aerial photos. However, where the bedrock is not exposed estimating soil depth requires interpretation of other, more visible features and patterns. Some of these include: surface expression of microtopography and macrotopography, the degree of visibility of fine geological surface features, shape and appearance of margins of water bodies, drainage patterns, degree of water infiltration, and erosional shapes.

Macrotopography refers to the surface expression of gross landscape and landform features that have a photo size of >2 cm on 1:15 840 scale aerial photos and a true, on-the-ground size that may span hundreds of meters. Such macrotopographic features include "ridge and swale" patterns in bedrock-controlled landscapes where areas of exposed bedrock alternate with areas where the bedrock is covered with a thick layer of overburden. Soil depth is correspondingly thin on bedrock knobs (look for patches of exposed bedrock), but tends to be deeper in "depressions" between rock knobs/outcrops.

Microtopography refers to the surface expression of finer, more localized landscape and landform features that have a photo size of <2 cm on 1:15 840 scale aerial photos and a true, on-the-ground size ranging from a few meters to tens of meters. Such features include the gouges, striations, and fractures that are typically found on the surface of Precambrian bedrock in northern Ontario.

Any soil overlying bedrock will tend to mimic the microtopographic patterns and shape of the underlying rock surface; the strength of the mimicry is inversely proportional to the depth of the soil. Bedrock surface

patterns and shape will be more obvious in thin soils than in thick soils. The relative thickness of the soil can therefore be estimated from the strength of the expression of microtopographic pattern and shape of the underlying rock surface. In northwestern Ontario, linear patterns are often apparent in the ground cover and reflect the linear striations and fracture patterns on the surface of the underlying bedrock.

Fine geological surface features include fractures, crevices, folds, glacial ice striations, and rock lamellae or folia in the surface of the bedrock. When bedrock is exposed, these features are often visible on 1:15 840 scale aerial photos.

#### 1.4.2.4 Aerial Photo Interpretation of Soil Moisture

A soil catena is defined as "a sequence of soils of about the same age, derived from similar parent material, and occurring under similar climatic conditions, but having different characteristics due to variation in relief and drainage" (Hausenbuiller 1978). Soil catenae are defined generally by soil textural groups. Within a catena, soil conditions may be arranged or sequenced according to their range of moisture conditions (drier to wetter), which are typically distributed across a topographic gradient. Soil conditions represented in these catenae may be expressed as NWO FEC S-types.

NWO FEC S-types can be aggregated into sequences that parallel many of the soil catena frameworks because the S-types are distinguished primarily according to texture and moisture conditions. Table 3 shows how NWO FEC S-types can be associated with different soil catenae.

**Table 3.** NWO FEC S-types within soil catenae.

Soil catena	Component S-types along moisture gradient (drier to wetter)
Deep Sandy	S1 - S2 - S7 - S11
Deep Coarse Loamy	S3 - S8 - S11
Deep Silty / Silt Loamy	S4 - S9 - S11
Deep Fine Loamy	S5 - S10 - S11
Deep Clayey	S6 - S10 - S11
Deep Peaty Organic	S11 - S12F - S12S
Very Shallow	SS1 - SS2 - SS3
Boulder Pavement	SS4
Moderately Deep Sandy	SS5 - SS8 - SS9
Moderately Deep Coarse Loamy	SS6 - SS8 - SS9
Moderately Deep Fine Loamy	SS7 - SS8 - SS9
Moderately Deep Silty	SS7 - SS8 - SS9
Moderately Deep Clayey	SS7 - SS8 - SS9



Soil conditions can be inferred on aerial photos from the following information: (1) correct identification of landform features; (2) an understanding of soil texture and landform relationships; (3) soil depth; (4) the use of soil catena concepts; and (5) relative topographic position of the point being viewed on the aerial photos. Correct identification of landform features yields information regarding associated soil textures. Soil depth can be estimated by interpreting the surface expression of bedrock microtopography and macrotopography. This information can be used to select a soil catena. Within the selected soil catena, the range of soil moisture conditions is represented along a topographic gradient, and finally the S-type may be identified that is most closely associated with the slope position observed on the aerial photo.

#### 1.4.2.5 Soil Toposequence Models

Soil toposequence models illustrate the relative positions of soil conditions across topographic gradients of landforms or landform complexes. The models may encompass the soil conditions associated with a single landform feature (i.e., one soil catena) or the range of conditions associated with landform complexes (i.e., many soil catenae). The relative position of soil conditions will be the same within each discrete landform (or landform complex). Thus the toposequence models can be used to extrapolate the soil conditions on similar landform features.

#### 1.4.3 Aerial Photo Interpretation of NWO FEC V-types

Vegetation cover is one of the most obvious features on aerial photos of any scale. The tree canopy is usually the most prominent vegetation feature on aerial photos of forested landscapes; understory vegetation is often obscured by the overstory trees. Direct and accurate identification of vegetation conditions on aerial photos tends to depend on the scale of the photo: at small scales (e.g., 1:100 000 or smaller), vegetation may only be identified at a gross level (e.g., forest cover types); at intermediate scales (e.g., 1:15 840), individual trees, clusters of shrubs, tree crown shape, canopy shape, vegetation communities and complexes, forest cover type, and some ground cover types may be identified; at large scales (e.g., 1:8 000 or more), individual trees, individual shrubs, and many ground cover types may be identified.

Thirty-eight V-types have been defined in the NWO FEC (Sims et al. 1989). There are three main groups of V-types: two mixedwood groups - Mainly Hardwood (11 types), and Mainly Conifer (9 types), and a group representing Pure Conifer Types (18 types). The V-types are listed in Table 4.

**Table 4.** NWO FEC vegetation types.

#### Mainly Hardwood Vegetation Types

- V1 Balsam Poplar Hardwood and Mixedwood
- V2 Black Ash Hardwood and Mixedwood
- V3 Other Hardwoods and Mixedwoods
- V4 White Birch Hardwood and Mixedwood
- V5 Aspen Hardwood
- V6 Trembling Aspen (White Birch) - Balsam Fir / Mountain Maple
- V7 Trembling Aspen - Balsam Fir / Balsam Fir Shrub
- V8 Trembling Aspen (White Birch) / Mountain Maple
- V9 Trembling Aspen Mixedwood
- V10 Trembling Aspen - Black Spruce - Jack Pine / Low Shrub
- V11 Trembling Aspen - Conifer / Blueberry / Feathermoss

#### Conifer Mixedwood Vegetation Types

- V12 White Pine Mixedwood
- V13 Red Pine Mixedwood
- V14 Balsam Fir Mixedwood
- V15 White Spruce Mixedwood
- V16 Balsam Fir - White Spruce Mixedwood / Feathermoss
- V17 Jack Pine Mixedwood / Shrub Rich
- V18 Jack Pine Mixedwood / Feathermoss
- V19 Black Spruce Mixedwood / Herb Rich
- V20 Black Spruce Mixedwood / Feathermoss

#### Pure Conifer Vegetation Types

- V21 Cedar (incl. Mixedwood) / Mountain Maple
- V22 Cedar (incl. Mixedwood) / Speckled Alder / *Sphagnum*
- V23 Tamarack (Black Spruce) / Speckled Alder / Labrador Tea
- V24 White Spruce - Balsam Fir / Shrub Rich
- V25 White Spruce - Balsam Fir / Feathermoss
- V26 White Pine Conifer
- V27 Red Pine Conifer
- V28 Jack Pine / Low Shrub
- V29 Jack Pine / Ericaceous Shrub / Feathermoss
- V30 Jack Pine - Black Spruce / Blueberry / Lichen
- V31 Black Spruce - Jack Pine / Tall Shrub / Feathermoss
- V32 Jack Pine - Black Spruce / Ericaceous Shrub / Feathermoss
- V33 Black Spruce / Feathermoss
- V34 Black Spruce / Labrador Tea / Feathermoss (*Sphagnum*)
- V35 Black Spruce / Speckled Alder / *Sphagnum*
- V36 Black Spruce / Bunchberry / *Sphagnum* (Feathermoss)
- V37 Black Spruce / Ericaceous Shrub / *Sphagnum*
- V38 Black Spruce / Leatherleaf / *Sphagnum*



Classifying a forest stand to an NWO FEC V-type requires an assessment of the relative proportions of tree species in the main canopy, and the general understory/ground vegetation conditions. On the ground, this is readily accomplished by identifying species and visually estimating their percent cover on the plot. In aerial photo interpretation, some of the vegetation species, especially trees, may be identified directly from their appearance on the photo. Identifying less visible species (especially in the understory) requires some inference based on interpretation of visible features, such as overstory vegetation, shrub layer when visible, landform type, and topographic position.

#### 1.4.3.1 Aerial Photo Interpretation of Tree Species

With training and experience, identification of tree species on 1:15 840 black and white aerial photos is possible. Sayn-Wittgenstein (1960, 1961, 1978) and Zsilinszky (1966) provide detailed descriptions of the appearance of different tree species on black and white aerial photos. The aerial appearance characteristics of some boreal tree species are summarized in a table within the aerial photo interpretation key for V-types in the Roslyn Lake Study Area.

#### 1.4.3.2 Aerial Photo Interpretation of Understory/ Ground Vegetation

On 1:15 840 black and white aerial photos, understory vegetation may be visible in stands with an open canopy, or through canopy openings and along the edges of the stand. In such cases, some species may be distinguished based upon their tonal differences (e.g., mountain maple [*Acer spicatum* Lam.] is much brighter than is alder [*Alnus* spp.]) as well as the site location and the surrounding overstory species. More typically, however, the understory is obscured by tree cover. In these circumstances, general understory conditions may be inferred from the interpretation of more visible features.

Identifying vegetation conditions that may not be directly observable on aerial photos requires an understanding of the relationships among species (synecology), and between species and their physical environments (autecology).

Synecological information describes associations among overstory and understory species. Photo interpreters should acquire such information for the geographic area being interpreted. Once familiar with local species relationships, the interpreter may make inferences about the understory vegetation (especially species composition) based on the identification of tree canopy conditions as interpreted from aerial photos.

Species autecological information helps to describe the site conditions with which a particular species is typically

associated; therefore, it is also useful in estimating understory vegetation for a particular vegetation community. Many species have specific soil moisture and nutrient requirements. Thus, although they may not be directly visible on an aerial photo, conclusions may be made about the type and abundance of understory species based on aerial photo interpreted soil/site conditions.

#### 1.4.3.3 Vegetation Toposequence and Vegetation Sequence Models

Many soil/site conditions (e.g., soil moisture, organic matter content, available soil nutrients) vary predictably along topographical gradients (e.g., drier to wetter, from upper to lower slope) (Brady 1984, van Groenewoud 1986). Vegetation, in turn, responds to the range of physical (soil/site) and biological conditions along the slope.

Overstory conditions can be described as pure conifer, conifer-dominated mixedwood, hardwood-dominated mixedwood, or pure hardwood. Within each of these broad overstory groups, *tree canopy types* can be defined based on component tree species. Within tree canopy types, a range of understory vegetation conditions can be expected to occur, typically in response to slope gradients and corresponding soil/site conditions. The combination of overstory and understory conditions associated with different tree canopy types is a basis for determining NWO FEC V-types. Table 5 lists 14 tree canopy types and indicates which NWO FEC V-types would be included in each canopy type. Using tree canopy types in combination with topographic gradients and soil/site conditions, numerous *vegetation toposequence models* can be developed.

Vegetation toposequence models illustrate the relative slope positions of various vegetation conditions along a topographic gradient on a hypothetical landscape (Baldwin et al. 1990). For similar combinations of tree canopy type, soil/site, and slope conditions, the pattern of vegetation development will be repeated. Vegetation toposequence models can be created to illustrate the typical vegetation patterns for a range of different canopy type, soil/site, and slope combinations. Once developed, vegetation toposequence models can be used as API tools to extrapolate local understory vegetation characteristics.

Some soil/site conditions are not associated with slope position, but rather vary in response to proximity to other site factors (Brady 1984). The degree of variation is related to the proximity to the influential factor. Vegetation conditions vary in response to these gradients of soil/site conditions. Examples of slope independent vegetation responses are seen in areas of colonization that exhibit seral progression (i.e., encroachment of lichen, moss, herbs, and shrubs over bedrock), and the edge effect found



**Table 5.** NWO FEC V-type groupings within "Tree Canopy Types".

Tree canopy type	Component V-types
Hardwood / Hardwood-dominated Mixedwoods:	
Balsam Poplar, Black Ash	V1 - V2
White Birch	V4
Trembling Aspen	V5
Trembling Aspen, Balsam Fir	V6 - V7
Trembling Aspen, Black Spruce, Jack Pine	V8 - V9 - V10 - V11
Conifer-dominated Mixedwoods:	
White Cedar	V21 - V22
White Spruce - Balsam Fir	V14 - V15 - V16
Jack Pine	V17 - V18
Black Spruce	V19 - V20
Pure Conifers:	
White Cedar - Larch	V21 - V22 - V23
White Spruce - Balsam Fir	V24 - V25
Jack Pine	V30 - V29 - V28 - V31 - V32
Black Spruce (upland)	V30 - V31 - V32 - V33 - V34
Black Spruce (lowland)	V35 - V36 - V37 - V38

at the margins of forest stands (increased abundance of shrubs due to increased light availability). Unique combinations of tree canopy type and soil/site conditions will develop predictable vegetation sequences. *Vegetation sequence models* illustrate the relative position of slope independent vegetation conditions within various combinations of tree canopy type and soil/site condition.

V-type toposequence models and V-type sequence models may be created by expressing the vegetation conditions represented in vegetation toposequence and vegetation sequence models, respectively, as NWO FEC V-types.

## 1.5 The Roslyn Lake Case Study

### 1.5.1 Background

A pilot project was initiated in the summer of 1987 to address the operational mapping and aerial photo interpretation aspects of the NWO FEC V-types and S-types. For this trial mapping initiative, the Roslyn Lake Study Area (hereafter referred to as "the RLSA") provided a relatively undisturbed, mature boreal forest condition; an adequate road network to facilitate easy access to most parts of the area; and a combination of vegetation, soil, and climate conditions that was representative of boreal forest conditions in the immediate area east of Lake Nipigon.

This report describes the methodology used to develop API keys for identifying S-types and V-types in the RLSA on 1:15 840 scale, vertical format, black and white aerial photos. The keys' structures are outlined in the report, but

the complete keys are presented in full as appendices to the report. Tips for using the keys are provided in Appendix A; the API key to S-types appears in Appendix B; the API key to V-types forms Appendix C; and a glossary of select terms is provided in Appendix D.

### 1.5.2 Study Area

The RLSA (Fig. 1) is located to the east of Lake Nipigon, about 60 km northeast of Nipigon, Ontario. The approximately 100-km<sup>2</sup> (10 km x 10 km) study area (center: 87° 34' W, 49° 14' N) is bordered on the northeast by Upper Roslyn Lake and on the northwest by Kabamichigama Lake. It is found on the National Topographic Series (NTS) 1:50 000 scale map-sheet "Gurney Lake, 42E/4". The RLSA lies within the Lake Nipigon Forest Management Agreement Area, under license to Domtar Forest Products Ltd. of Red Rock, Ontario.

The general terrain is rugged to rolling; Precambrian bedrock strongly controls the local relief and soil drainage. Most soils in the study area are of glacial origin; coarse-textured stony and bouldery tills of varying depths are widespread. Shallow soils are especially common throughout the general area and outcrops of bare bedrock are abundant. Throughout the study area, concavities in the bedrock and lower landscape positions support local organic deposits. Outwash, lacustrine, colluvial, and other deposits are also found, but only as minor occurrences in localized areas (Gartner 1979).

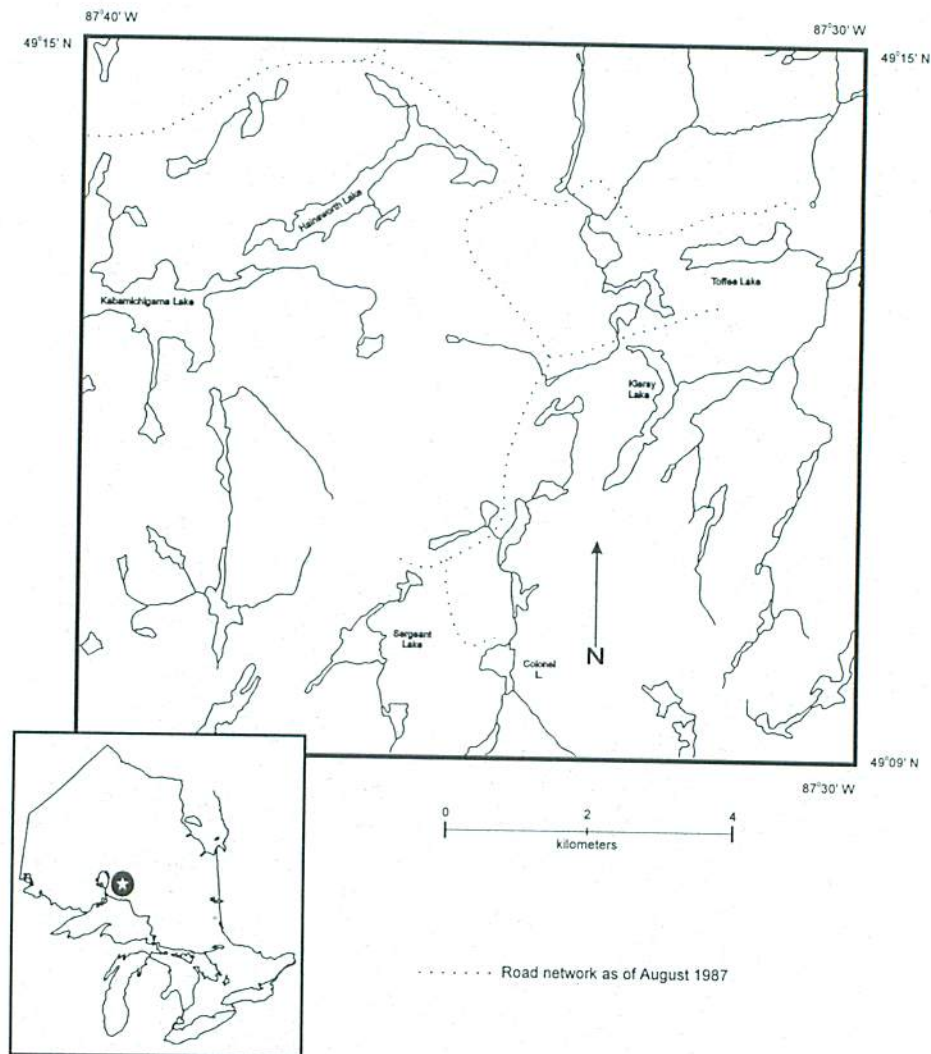


Figure 1. Roslyn Lake Study Area, showing major water bodies and the road network as it existed in August 1987. Inset map shows the study area in a provincial context.

The study area is in Rowe's (1972) Boreal Forest Region (B.9, Central Plateau). At the time of study, pure conifer stands were predominant, and black spruce (*Picea mariana* [Mill.] B.S.P.) was the most abundant tree species in the area. The forest was generally mature to overmature black spruce, which occurred in pure and mixed stands on upland and lowland sites. The pure stands were most often associated with wet, organic, lowland sites. In the upland condition, black spruce commonly occurred with jack pine and/or balsam fir (*Abies balsamea* [L.] Mill.). Jack pine and balsam fir were also dominant species in many mixed stands throughout the area. White birch (*Betula papyrifera* Marsh.) and trembling aspen (*Populus tremuloides* Michx.) occurred as minor components in some mixed stands with black spruce, jack pine, and balsam fir. They also occurred as small isolated stands of

pure hardwood. White spruce (*Picea glauca* [Moench] A. Voss), eastern white cedar (*Thuja occidentalis* L.), and larch (*Larix laricina* [Du Roi] K. Koch) occurred occasionally throughout the study area.

At the time of the field survey program (summer 1987), none of the RLSA had been recently harvested. Domtar began harvesting within the area's boundaries early in 1988. Harvesting operations were scheduled to continue in the general area until at least 1997 (R. Booth, pers. comm.). A variety of harvesting methods were employed within the RLSA, ranging from clear-cuts to small alternate strip and patch cuts.

A basic network of forest access roads existed in the study area at the time of the field surveys, thereby providing access to most of the locations sampled. Remote sampling locations were accessed by canoe and by aircraft.



## 2.0 METHODS

There were three main areas of work associated with this project. The first involved gathering ground truth data. The second area was the development of the NWO FEC API keys. Finally, illustrative and example materials were created to support the application of the API keys.

Ground truth data was collected in the summer of 1987 as part of a pilot FEC mapping project carried out by the Canadian Forest Service (Sault Ste. Marie) and the Ontario Ministry of Natural Resources, Northwestern Science and Technology Unit (Thunder Bay). The data gathered as part of that project were used in the development of the API keys presented in this report.

Development of the API keys for the RLSA involved five steps: (1) design of the key structures, (2) selection, development, and refinement of API tools, (3) incorporation of API tools into the keys' structures, (4) optimization of the keys' structures, and (5) final validation of the keys.

Supportive materials were created to illustrate the aerial photo appearance of criteria used in many of the main decision points found within the API keys. These materials included S-type and V-type toposquence diagrams, annotated aerial photo stereo pairs, and an example of aerial photo interpretation of NWO FEC V-types and S-types.

### 2.1 Ground Truth Exercise

Ground truth data collection is an integral part of the development of API keys. As part of a demonstration project to map NWO FEC S-types and V-types, ground truth data were collected in the RLSA in the summer of 1987. The development of API keys for the RLSA, as described in this report, was supported by these ground truth data. Following is an overview of the sampling approach used in the ground truth data collection phase. Both the sampling approach and the type of data collected are important factors in the development of API keys.

#### 2.1.1 Stratified Sampling Approach

A stratified sampling approach was adopted in order to sample the full range of vegetation and soil conditions in the RLSA with a minimum of sampling effort. Soil and vegetation conditions were used to stratify the RLSA.

##### 2.1.1.1 Soil Strata

The NOEGTS map sheet for Roslyn Lake (Mapsheet 5079) described gross surficial deposit types at a scale of 1:100 000. However, at that scale, the entire RLSA was described simply as a bedrock knob with minor portions of ground morainal till. Clearly the scale of the NOEGTS map was unworkable due to the large degree of mapping

generalization; more detail about the local variations in soil conditions had to be reflected in the soil strata.

Soil strata were developed by preliminary aerial photo interpretation of the RLSA, and through consultation with Ontario Geological Survey (OGS) staff. Three factors were found to be dominant controlling influences on the distribution and characteristics of soils found in RLSA: (1) thickness of soil overburden, (2) topographic shape or expression of the underlying bedrock, and (3) geomorphic mode of deposition of the soil parent material. All three factors were criteria in defining the soil strata. Preliminary strata were tested, calibrated, and finalized during a reconnaissance road tour of the RLSA in which landform features, dissected by the road network, were observed firsthand. Areas that were inaccessible by road were observed during a low level, helicopter reconnaissance flight over the RLSA.

The soil strata were defined as:

1. >75 percent exposed bedrock;
2.  $15 \leq 75$  percent exposed bedrock;
3. ablation till moraine;
4. glacio-fluvial and ice contact deposits; and
5. organic accumulations.

These strata were delineated as homogeneous polygons directly on the aerial photos of the RLSA.

##### 2.1.1.2 Vegetation Strata

The vegetation strata were based on a combination of broad groupings of NWO FEC V-types, and the FRI working group concept of dominant tree species in the stand. Four broad vegetation groups were recognized: pure hardwoods, hardwood-dominated mixedwoods, conifer-dominated mixedwoods, and pure conifers. Individual (or groups of) species further subdivided the broad groups to define 14 vegetation strata.

The vegetation strata were defined as:

1. pure hardwood dominated by trembling aspen and/or white birch;
2. pure hardwood dominated by other hardwood species;
3. hardwood-dominated mixedwoods with balsam fir and/or white spruce as the main conifer component;
4. hardwood-dominated mixedwoods with jack pine as the main conifer component;
5. hardwood-dominated mixedwoods with black spruce as the main conifer component;
6. conifer-dominated mixedwoods with balsam fir and/or white spruce as the main conifer component;



7. conifer-dominated mixedwoods with jack pine as the main conifer component;
8. conifer-dominated mixedwoods with black spruce as the main conifer component;
9. conifer-dominated mixedwoods with red pine (*Pinus resinosa* Ait.) and/or white pine (*Pinus strobus* L.) as the main conifer component;
10. conifer-dominated mixedwoods with other conifers as the main conifer component;
11. pure conifer dominated by balsam fir and/or white spruce;
12. pure conifer dominated by jack pine;
13. pure conifer dominated by black spruce (upland); and
14. pure conifer dominated by black spruce (lowland).

Vegetation strata were initially identified on a 1:15 840 scale FRI map by assessing each FRI stand description and allocating it to one of the strata. FRI polygon boundaries were dissolved wherever adjacent stands were classified into the same stratum. Since the FRI map was produced as a 1:15 840 scale aerial photo mosaic base map, the vegetation strata polygons (delineated on the FRI map) could be traced onto acetates and overlaid onto the RLSA 1:15 840 scale aerial photos for use in subsequent aerial photo interpretation.

#### 2.1.1.3 Stratified Map

A stratified map of the RLSA was created by manually overlaying the soil and vegetation strata polygons onto a base map. From this map, all existing soil and vegetation strata combinations could be located; not all of the combinations occurred (e.g., hardwood and hardwood dominated mixedwood stands did not occur on organic soils). Road networks were also overlaid onto the base map, thus enabling the identification of strata combinations that could be accessed by road.

#### 2.1.2 Sample Point Selection

The main criteria for selecting sampling areas was the need to sample the range of soil/vegetation strata combinations within the RLSA. A matrix of soil and vegetation strata was created and used to monitor sampling progress. Areas that represented targeted combinations of soil and vegetation, and which could be reasonably accessed by vehicle or motorized canoe, were identified on the base map. Additional areas that had to be accessed by aircraft were also identified, but only to ensure adequate sampling of all soil/vegetation combinations and to maximize geographic coverage.

Sampling areas were then located and observed on the aerial photos. Sampling areas appeared homogeneous with respect to soil conditions because the soil strata were

originally photo interpreted as homogeneous units. Vegetation conditions within sampling areas were more heterogeneous because vegetation strata were often derived from a combination of more than one FRI polygon, and therefore comprised more than one stand condition.

Transects were drawn through vegetationally homogeneous portions of the sampling areas, and sampling points were located along the transect lines so that typical conditions would be described by the field crews. Where possible, transects and plot locations were positioned along slope gradients. Transect length, the number of sampling points along the transect, and the interval between sampling points varied depending on the features, topography, and range of conditions within the vegetationally homogeneous portions of the sampling area.

Anomalous features on the landscape were intentionally avoided. However, if a transect crossed through a feature that seemed atypical, field crews were directed to ground truth it and annotate the aerial photos accordingly.

#### 2.1.3 Ground Truth Data Collection

In the field, two-person crews completed descriptions of temporary 10-m x 10-m plots that were established at predetermined sample locations along select transects. At each plot, NWO FEC V-type and S-type (Sims et al. 1989), texture of the soil parent material, soil moisture regime (Bates et al. 1982), landform type, percent exposed bedrock and/or surface stoniness on the plot, topographic position, and percent slope across the plot were determined and recorded. Additionally, the proportions of each tree species in the canopy (e.g., black spruce, 80 percent; jack pine, 20 percent) were determined by ocular estimation, within the plot boundary and for the surrounding stand. General comments were noted regarding the overall stand condition and the plot's representativeness of the surrounding area.

Plot locations were pinpointed on 1:15 840 scale black and white aerial photos. The aerial photos were annotated with additional field observations of the stand and site conditions encountered along each transect.

#### 2.2 Development of NWO FEC Aerial Photo Interpretation Keys

The process of API key development described in this report required the following steps:

- design key structure;
- select, develop, and refine API tools;
- incorporate API tools into the key structure;
- optimize key structure; and
- validate API key.



Both S-type and V-type API keys were developed by this process. Following is a description of each step as it was applied for each key. Where the steps are specific to either soil or vegetation characteristics, they are described separately; where possible, steps are described in generic terms that can be applied to the development of either API key.

### **2.2.1 Design of the S-type Aerial Photo Interpretation Key Structure**

The NWO FEC S-type key and factsheets (Sims et al. 1989) were examined to identify basic soil factors that make up the critical pathways required to classify an S-type. Four soil factors (mode of deposition, parent material texture, soil depth, and soil moisture regime) were found to be diagnostic of all NWO FEC S-types. Two additional soil factors (depth of organic accumulation and the relative proportions of ground cover by *Sphagnum* and feathermoss) were identified as diagnostic characteristics in the determination of NWO FEC organic S-types.

The basic soil factors were assessed for their aerial photo interpretability. Only one factor, the relative ground cover by *Sphagnum* and feathermoss, was determined to be directly observable on the aerial photos, but this was possible only under ideal viewing conditions. However, based on the experience and knowledge of the photo interpreter, the basic soil factors could all be inferred from aerial photo interpretation of observable features and with the aid of various API tools. Because the factors could be indirectly assessed by aerial photo interpretation, they were used in the framework for the API key for S-types.

The soil factors were ranked from most general to most specific in their ability to resolve individual S-types. Using this ranking, the soil factors were arranged to form the basic structure or decision model that would resolve all S-types. All six factors may or may not be required for determining an individual S-type. The key structure, therefore, outlines all the decisions that must be made in determining an S-type, and reflects the requisite soil factors and the sequence of their assessment for each of the NWO FEC S-types.

### **2.2.2 Design of the V-type Aerial Photo Interpretation Key Structure**

The NWO FEC V-type key and factsheets (Sims et al. 1989) were examined to identify the basic vegetation factors that make up the critical pathways used to classify a V-type. Two vegetation factors (relative proportions of tree species in the main canopy and assessment of the understory/ground cover conditions) were diagnostic of the V-types.

The vegetation factors were assessed for their aerial photo interpretability. Only the relative proportions of tree species in the main canopy could be consistently and directly observable on aerial photos. Understory shrub and ground cover conditions were directly observable on aerial photos only under ideal viewing conditions. Based on the experience and knowledge of the photo interpreter, the basic vegetation factors could be observed directly or inferred through aerial photo interpretation of observable features and with the aid of various API tools. These two vegetation factors formed the framework of the API key for V-types because both could be determined by aerial photo interpretation.

The vegetation factors were ranked from most general to most specific in their ability to resolve individual V-types. Using this ranking, the vegetation factors were arranged to form the basic structure or decision model that would resolve all V-types. Not all of the V-types required assessments of both factors in their identification. The key structure outlines the decisions that must be made in determining a V-type and reflects the requisite factors and the iterative process of determining dominance in the tree canopy.

### **2.2.3 Selection, Development, and Refinement of Aerial Photo Interpretation Tools**

API tools that could be used to resolve the decision criteria at each point through the two API keys were acquired, modified, or developed as necessary. Tools that would aid the identification on aerial photos of forest tree and shrub species, and of landforms already existed in numerous publications (e.g., Zsilinsky 1966, Sims and Baldwin 1991). The pertinent information was extracted from these sources and is summarized in tables that are located throughout this report (e.g., Table 2) and in the body of the API keys (see Appendices B and C). Another tool was developed to assess soil depth (see Soil Depth Decision Support Tables; Appendix B), and RLSA-specific tools were developed, including soil/landform and vegetation/landform relationships and toposequence models. The development of these models is briefly outlined below.

#### **2.2.3.1 Ecological Models/Relationships**

All sources of information about the RLSA (maps, photos, ground observations) contributed to a knowledge of the area's vegetation and soil characteristics, and of the interactions of these biological and physical components of the landscape. The interactions defined ecological relationships, some of which were common and recognized beyond the limits of the RLSA, and others which were more obscure or specific to the RLSA. Understanding ecological relationships was critical in photo interpreting vegetation and soil conditions, specifically V-types and S-types.



Ecological relationships were tools upon which inferences were made about soil and vegetation conditions that were otherwise not directly observable on aerial photos.

Based on previous experiences, the photo interpreter expected to find certain common relationships between vegetation, soil, and landform in the RLSA. These preconceived, mental constructs were tested against ground truth data, aerial observations, interpretation of aerial photos, examination of maps and reports, and consultations with persons who were familiar with the RLSA. Some of the relationships were validated; others had to be revised or calibrated. Some new relationships were formulated by the photo interpreter.

Some of the ecological relationships that were investigated for the RLSA are listed below:

- *overall vegetation conditions* (i.e., What range of species actually existed in the RLSA and what characteristics distinguished different conditions?);
- *overall soil conditions* (i.e., What range of soil conditions actually occurred in the RLSA and what characteristics distinguished different conditions?);
- *vegetation-vegetation relationships* (i.e., What species were commonly found in association with, and in proximity to, each other?);
- *slope-landform relationships* (i.e., What range of slope and topographic expression was expected for particular landform types?);
- *slope-moisture relationships* (i.e., How did soil moisture vary along slope gradients within a particular soil texture class?);
- *vegetation-slope relationships* (i.e., What species tended to be associated with crest and upper slope positions relative to those that tended to be associated with lower, toe, depressional positions?);
- *landform-texture relationships* (i.e., What soil texture class[es] tended to be associated with particular landform types?); and
- *texture-slope relationships* (i.e., Did soil texture change along slope gradients, and, if so, how did it vary for a particular slope gradient/landform type?).

#### 2.2.3.2 Toposequence Models

Observations made at ground truth plots and while interpreting the aerial photos indicated that many soil and vegetation conditions were linked directly to slope gradients; that is, certain soil or vegetation conditions were found consistently at particular slope positions. Toposequence models were created to illustrate the relative placement of soil and vegetation conditions along

slope gradients. Separate toposequence models were created for each distinct landform type and each distinct tree canopy type in the RLSA.

Other soil and vegetation conditions were not related to slope position. Instead they were observed to have consistent patterns related to their positions relative to other soil/site/vegetation conditions. In the RLSA, these relationships were most apparent for vegetation conditions. A number of vegetation sequences were created to illustrate these nonslope related relationships.

The relative placement of soil and vegetation conditions was influenced by the patterns experienced in the ground truth data collection, the ecological relationships that were observed in the RLSA, or by the photo interpreter's "tool kit" of past experience and knowledge.

##### 2.2.3.2.1 S-type Toposequence Development

Basic soil characteristics (soil parent material textures, soil depth, and soil moisture) were assessed for each common landform type found in the RLSA. These soil conditions were then related to slope and topographic position.

The resulting relationships were then used to create soil catenae for each of the landform types. This was accomplished by developing modal soil profiles depicting the soil/site conditions likely to be found in each of the slope positions along a topographic gradient.

The component slope positions of each catena were then expressed as NWO FEC S-types, thus transforming the soil catenae to S-type toposequences.

The field descriptions of sample locations were used as necessary to correct or adjust the hypothesized models.

##### 2.2.3.2.2 V-type Toposequence Development

The ground truth vegetation/site conditions (e.g., abundance and species composition of low and tall shrub layers) were assessed for each combination of landform type and tree canopy type found in the RLSA.

Where possible, vegetation/site conditions were related to topographic position. These relationships were then used to create vegetation toposequences by creating modal vegetation descriptions depicting the vegetation/site conditions likely to be found at various locations along a slope. Preliminary V-type toposequence models were developed by expressing the slope associated vegetation conditions as NWO FEC V-types.

Where the vegetation/site relationship to topographic position was not obvious, attempts were made to relate



vegetation/site conditions to nontopographic site characteristics, such as marginal proximity or degree of soil aeration. These relationships were used to create vegetation sequences by creating modal vegetation descriptions depicting the vegetation/site conditions as they would likely occur along a proximal gradient. Preliminary V-type sequences were developed by expressing the proximally associated vegetation conditions as NWO FEC V-types. The field descriptions of sample locations were used as necessary to correct or adjust the hypothesized models.

#### **2.2.4 Incorporation of Aerial Photo Interpretation Tools in the Key Structure**

The structure of each API key laid out the decisions that had to be made in determining S-types or V-types. The API tools were adapted for many of the decision points in the API keys. For example, a soil depth estimation tool and S-type toposequence models were incorporated into the API key for S-types at numerous decision points. Descriptions of tree crown and shrub species appearances, and V-type toposequence and sequence models were incorporated into the API key for V-types.

The preliminary keys were tested by comparing photo interpreted S-types and V-types with ground truth assessments of S-type and V-type. The API key structures and API tools were adjusted as necessary to improve their accuracy. S-types and V-types that were not recorded in the ground truth exercise were culled from the preliminary key. Also, groups of similar S-types and V-types that could not be reliably distinguished through API, were left as groups in the API keys.

#### **2.2.5 Optimization of the Structure of the Keys**

Once the keys performed accurately, they were organized to maximize the efficiency of photo interpreting S-types and V-types. All efforts were made to keep the keys short while maintaining their accuracy. The keys were designed so that the decision points leading to the most common S-types and V-types would be considered first. The complexity of aerial photo interpretation increases as one progresses through the keys, thus less skilled interpreters may be able to classify groups of S-types and V-types, if not the individual types. The order of some decisions was altered primarily to eliminate the repetition of lengthy descriptions.

#### **2.2.6 Final Validation of the Keys**

The final versions of the API keys were evaluated to confirm their completeness, accuracy, and efficiency by comparing the resultant S-type and V-type API interpretations with the S-type and V-type values observed at the ground truth sample points.

### **2.3 Stereoscopic Photo Pairs**

A series of aerial photo stereo pairs that illustrate the aerial appearance of many of the keys' main decision criteria were selected, annotated, and mounted for stereoscopic viewing in this report (see Sections 3.7 and 3.8). Supplementary tables that describe the photo annotations were also prepared. These accompany the stereoscopic photo pairs. In some of the examples, contrasting conditions were annotated adjacent to each other on the same photo pair so as to allow comparative observations.

### **2.4 Mapping Example**

Mapping V-types and S-types is demonstrated on a stereoscopic photo pair from the RLSA that contains a wide range of vegetation conditions and landforms. The spatial extents of S-types and V-types have been delineated as polygons using the techniques found in the "Tips for Success" (see Appendix A) and each polygon has been classified to S-type and V-type using the API keys. The annotated photo pair is mounted for stereoscopic viewing in this report (see Section 3.8). A legend on the photo pair lists the S-type and V-type for each polygon delineated in the example mapped area. Soil, site, and vegetation conditions of two contrasting polygons are described in an accompanying table.

## **3.0 RESULTS**

Similar processes were involved in the development of the API key to S-types and the API key to V-types. The results of critical stages in the development process are presented here for each of the API keys. General soil and vegetation characteristics of the RLSA are described first. Toposequence models that illustrate some of the S-type/landscape relationships and some of the V-type/landscape relationships are presented. In the interest of conserving space in the body of this report, each API key is introduced with an overview of its structure and how to use it. The full API keys are presented in a "stand-alone" format, in the appendices of this report.

Field observations along 96 transects throughout the RLSA provided detailed ecological descriptions at some 680 plot locations. These field descriptions, along with other existing sources of information, provided a descriptive knowledge of the RLSA that was required for developing API keys for S-types and V-types in the RLSA.

### **3.1 Soil Characteristics of the Roslyn Lake Study Area**

The RLSA was characterized by a few dominant soil conditions, most notably, extremely to moderately shallow soils developed in a thin mantle of coarse loamy ablation till over strongly undulating bedrock.



Bedrock in the area was impermeable to surface moisture and runoff. The depth to bedrock was, therefore, an important determining factor in the assessment of soil moisture.

Local relief was strongly undulating and frequently ridged. Variations in soil depth and mode of deposition were strongly associated with relative landscape position in the RLSA.

Shallow ablation tills occupied the majority of the RLSA. Soil particle size of the till was very uniform and ground truth sampling characterized it as silt loam. There was also a significant coarse fragment content that varied greatly across the RLSA.

The following S-types were found:

- 9 shallow soil types ( $SS1 \leq SS9$ );
- 8 deep mineral types ( $S1 \leq S4$ ,  $S7 \leq S9$ ,  $S11$ ); and
- 2 deep organics ( $S12F$ ,  $S12S$ ).

Some of these S-types were much more common than others throughout the study area (e.g.,  $SS1$ ,  $SS6$ ). Other S-types were less common; they characterized less common surficial deposits (e.g.,  $S1$ ,  $S2$  on glacio-fluvial deposits). The only S-types that were not encountered in the RLSA were the fine loamy and clayey types:  $S5$ ,  $S6$ , and  $S10$ .

### 3.2 Vegetation Characteristics of the Roslyn Lake Study Area

Species composition of forest stands throughout the RLSA was extremely homogeneous. Overall, the RLSA was characterized mainly by pure conifer and conifer dominated mixedwood stands. In general there was a predominance of black spruce and, to a lesser extent, balsam fir in the main canopy of many stands. Occasionally jack pine was the dominant canopy species.

Hardwood-dominated mixedwoods tended to be rare and of very limited areal extent. The hardwood component of stands in the area was usually white birch and/or trembling aspen, although white birch tended to be more predominant than aspen.

In many parts of the RLSA the white birch component of the stands was dead or dying. This condition was more advanced at the time of sampling (1987) than was evident on the aerial photos taken some 12 years previously (1975). This discrepancy between ground conditions and aerial photo appearance was an important consideration when interpreting the photos and in developing the interpretation keys; the estimation of mature white birch cover from the aerial photos was reduced accordingly.

Forest stands in the RLSA tended to have thick and extensive feathermoss mats as the most common ground cover condition.

The following V-types were found in the RLSA:

- 15 pure conifer types ( $V21$ ,  $V22$ ,  $V24$ ,  $V25$ ,  $V28 \leq V38$ );
- 7 conifer dominated mixedwood types ( $V14 \leq V20$ ); and
- 8 hardwood dominated mixedwood types ( $V4 \leq V11$ ).

### 3.3 Example S-type Toposequence Models

Following are schematic diagrams of two toposequence models that comprise common S-types in the RLSA. These toposequences illustrate how different S-types might be expected to occur on the landscape in relation to one another. Note that each model represents a soil catena (and a particular landform), a group of S-types with similar soil parent material but covering a range of soil moisture conditions. The S-types are shown in the order they would likely occur along a theoretical topographic gradient. No absolute scales can be placed on the horizontal distances nor the vertical soil depths represented in these diagrams. The spatial relationships represented in the diagrams may vary from location to location, but the general patterns of placement along a slope should remain the same.

The first example (Fig. 2) illustrates an extremely shallow to moderately deep, coarse loamy textured soil catena. This bedrock-controlled sequence is typical of a majority of the RLSA landscape. Bedrock is at or near the surface throughout the sequence. This first toposequence model was applied to the aerial photo interpretation of bedrock controlled slope sequences that exhibited the characteristics of a shallow, coarse loamy deposit in the RLSA.

At slope crests, bedrock is normally bare/exposed and is therefore classified as  $SS1$ . In shallow depressions/dishes of the exposed bedrock, thin layers of mineral and organic material accumulate and are classified as  $SS2$  or  $SS3$ .  $SS1$ ,  $SS2$ , and  $SS3$  should be expected to occur in close proximity to one another at crest and upper slope positions in bedrock-controlled landscapes.

Down the slope, away from the crest, mineral and organic materials tend to be developed in thicker deposits. Mineral soil thickness can vary from upper to lower slope in these bedrock-controlled sequences, but typically it is less than 1 m. Such shallow, coarse loamy soils are classified as  $SS6$ .

At the bottom of the bedrock slope, deeper depressions/dishes in the bedrock and restricted drainage result in moderately deep ( $50 \leq 100$  cm) accumulations of peaty organic material. Such deposits are classified as shallow to moderately deep organics,  $SS9$ .

The second toposequence model (Fig. 3) illustrates the deep, coarse loamy textured soil catena associated with ablation tills in the RLSA. Ablation tills are common



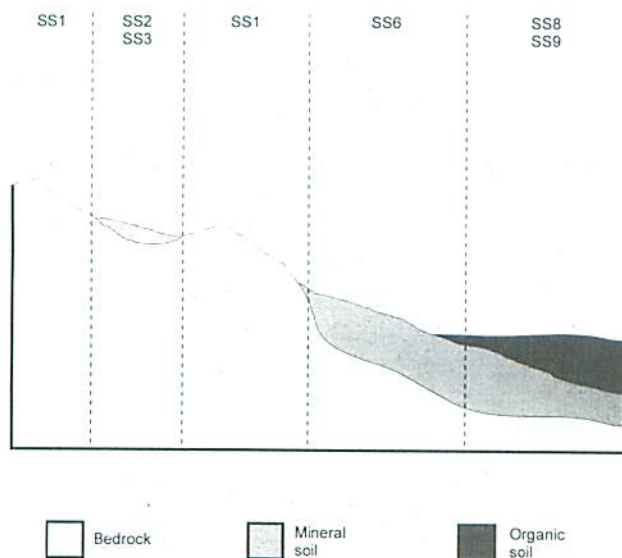


Figure 2. Extremely shallow to moderately deep, coarse loamy soil catena.

glacial deposit features in the RLSA. This sequence comprises coarse loamy parent materials like the first model, but bedrock is absent from the soil profile and does not significantly influence the surface expression of the landscape. All of the associated S-types in this sequence are therefore deep (>1 m). This toposequence model was applied to features on the aerial photos identified as deep ablation tills.

Deep coarse loamy soils are classified as S3 or S8 depending on the soil moisture regime. It is accepted that soil moisture tends to vary from drier to wetter down a slope gradient. Along a slope in ablation tills, S3, the drier phase of this soil catena, is normally found on upper slope positions. S8, the moister phase, tends to occur on lower slope positions.

As in the previous model, organic material tends to have deeper accumulations at lower slope positions. Moderately thick peat (20–39 cm) over mineral soil is expected in the transition between deep mineral and deep organic soils; in the NWO FEC these are classified as S11, peaty phase soils. As the peaty organic material accumulates to >40 cm, the soil is considered a deep organic that is classified as S12F or S12S, depending on the relative abundance of feathermoss and *Sphagnum*. Therefore, S11 should be expected at the toe of slopes in transition from upslope mineral soils to deep organic soils; S12F and S12S should normally occur in depressions at the bottom of slopes.

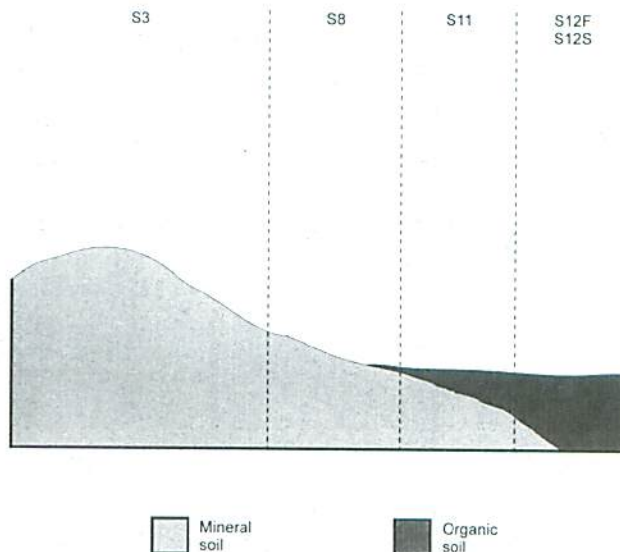


Figure 3. Deep coarse loamy soil catena.

### 3.4 Example V-type Toposequence Models

Following are schematic diagrams of two toposequence models that comprise common V-types in the RLSA. These toposequence models illustrate how the V-types within a vegetation sequence might be expected to occur on the landscape in relation to one another. Each model represents a vegetation sequence that is defined overall by dominant overstory conditions; the component units of each sequence (V-types) are defined by a range of understory conditions that typically reflect soil moisture and soil nutrients along a landscape gradient.

The first example (Fig. 4) illustrates an upland black spruce sequence that comprises several pure conifer V-types, and which is developed on shallow soils along a slope gradient. In the RLSA, the predominance of black spruce dominated pure conifer stands on bedrock-controlled topography make this a very common vegetation sequence. In terms of vegetation classification, these sequences are mosaics of spruce-dominated V-types.

In the RLSA, the V-types of this sequence were each associated with particular slope positions. Slope gradients usually define soil moisture gradients, drier to wetter down the slope. In addition to the characteristics of their tree canopies (overstories), the different V-types were influenced by soil moisture conditions and could therefore be described in terms of slope position.

At the crest of bedrock slopes, where bedrock was at or very near the surface, forest stands were sparsely treed



with black spruce and jack pine. Ground cover was dominated by patches of lichen and feathermoss. Stands in these conditions were classified as V30.

At upper slope positions, and closely associated with exposed bedrock, soil moisture was fresh and the tree canopy was mainly black spruce with minor components of jack pine. Shrub and herb cover was moderately dense, and feathermoss persisted as a continuous forest floor cover. These stands were classified as V31. Stands that had a greater proportion of jack pine in the canopy, with scattered clumps of shrubs, few herbs, and continuous feathermoss mats, were classified as V32. These stands tended to occur on mid-slope positions where site conditions were dry to fresh.

At low and toe slope positions, soil depth and soil moisture increased and jack pine became an infrequent occurrence in the canopies. Stands at these slope positions were classified as V33. They were comprised of black spruce in the canopy; ericaceous species, especially Labrador tea (*Ledum groenlandicum* Oeder), in the shrub layer; and small patches of *Sphagnum* moss interrupting otherwise continuous feathermoss mats. Commonly at the toe of slopes, stands were characterized by black spruce canopies and ericaceous shrub layers, but *Sphagnum* moss was more abundant, usually covering a minimum of 10 percent of the ground area. These stands, classified as V34, represented a transition between upland and lowland conditions.

The components of this vegetation sequence did not always occur on the ground in the exact configuration

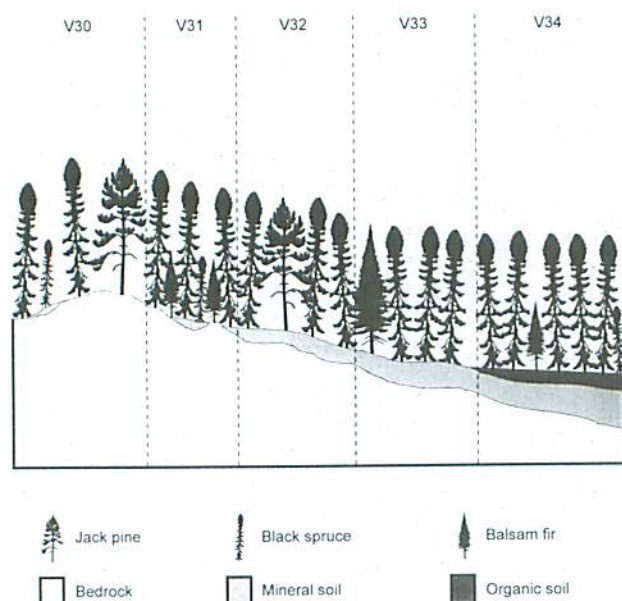


Figure 4. Upland black spruce vegetation toposequence.

represented in the model. Sometimes, an actual (real) version of this sequence lacked one or more of the modeled V-types. However, the relationships represented in this model were successfully applied to black spruce (and jack pine) dominated conifer stands that developed on slopes to interpret (identify) the existing sequence of V-types.

The second vegetation toposequence model (Fig. 5) depicts a V-type sequence that is not associated with a topographic gradient but is typical of wet, lowland/depressional sites in the RLSA. The relative (landscape) position of V-types comprising this sequence is a response partly due to the proximity to oxygenated, nutrient-rich telluric water. Other factors influencing the relative position of V-types include depth of peaty organic material, ground water pH, and degree of decomposition of organic matter.

In the RLSA, the margins of lowland landscapes reflect a transition zone between upland, mineral conditions and low-lying (depressional), deep organic conditions. Soils at margins of lowlands tended to be peaty organics with mineral soil usually encountered within 1 m of the organic surface. Oxygen and nutrient rich seepage water from adjacent upland mineral sites entered the organic complexes in these marginal areas. Vegetation on these sites therefore exhibited considerable species variety and abundance. In the transition zone, black spruce was the main tree species and an abundance of shrubs, including speckled alder (*Alnus rugosa* [Du Roi] Spreng.) and Labrador tea, was common. Ground cover was dominated by *Sphagnum* and feathermoss. These conditions were classified

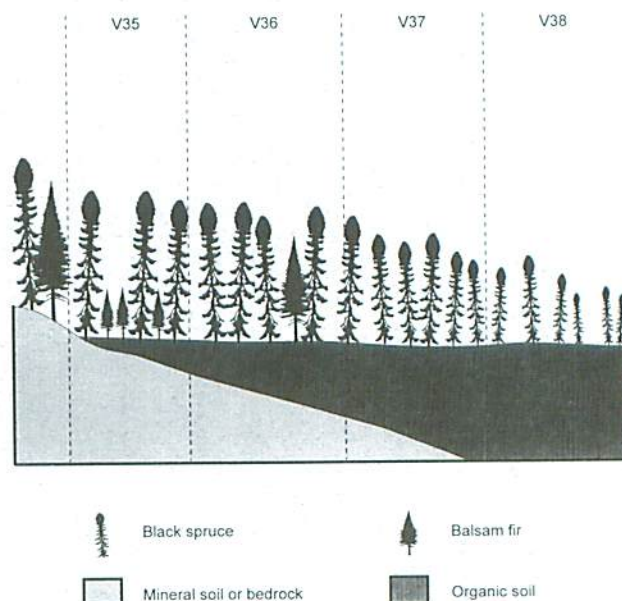


Figure 5. Lowland black spruce vegetation toposequence.



as V35 where there was a significant amount (>10 percent) of speckled alder; or alternatively, V36 where herb and shrub species were abundant but there was <10 percent cover by speckled alder. Vegetation classification at the margin of lowland, organic deposits usually varied from V35 to V36; stands of these two V-types often overlapped with one another.

Moving from the margin toward the middle (core) of the lowland organic deposit, there was a trend toward nutrient poorer, more acidic and anaerobic site conditions that resulted from restricted water flow through the deep (>1 m) peat deposits. Vegetation conditions reflected these poorer site conditions: trees were more stunted and occurred in scattered clumps, shrub and herb species diversity was limited to species that could tolerate the wetter and poorer conditions, and *Sphagnum* was the main ground cover. In the poorest conditions, black spruce rarely attained a height of 10 m and occurred only in widely spaced clumps. These very open, patchy stands were classified as V38. In poor site conditions, stands that had taller, less widely spaced trees were classified as V37.

Usually not all the V-types presented in this vegetation sequence occur in actual lowland organic landscapes (sequences). However, the landscape positions of these V-types in relation to one another and in relation to the surrounding upland landscape are accurately portrayed here. These relationships were applied to the interpretation of lowland black spruce sequences in the RLSA to identify lowland black spruce V-types.

### 3.5 Overview of the S-type Aerial Photo Interpretation Key

The main organizational units in the aerial photo interpretation key to the S-types are the soil catenae that encompass the S-types identified in the RLSA. The key first distinguishes organic and mineral soil conditions. Within the mineral soils, the key then identifies three soil depth classes: very shallow, moderately shallow, and deep mineral. The very shallow and moderately shallow groups constitute two soil catenae. Within the deep mineral soil group, four additional catenae are described.

The API key guides the decision making process required to identify S-types on aerial photos. The user navigates through the key by answering "yes" or "no" to the decision criteria provided. The basic structure of the API key, outlining the main decision points, is provided here; the complete API key to the S-types and related API tools are presented in Appendix B.

#### 3.5.1 Basic Structure of the API Key to S-types

1. Deep peat/organic landform to PART I
2. Not a deep peat/organic landform to PART II

##### PART I (Deep Organic Landforms)

1. Polygon at toe slope S11
2. Polygon at margin of peatlands S12F
3. Polygon is level/depressional organic accumulation, not at margin S12S

##### PART II (Shallow Mineral, Shallow Organic, Deep Mineral Landforms)

1. Landform is boulder pavement, boulder wash, talus, scree slope SS4
2. Very shallow soils and exposed bedrock sites Group A
3. Moderately deep mineral soils Group B
4. Deep mineral soils Group C
5. None of the above go back to Start

##### GROUP A (Very Shallow Soils and Exposed Bedrock)

1. Bare rock, discontinuous moss/lichen over bedrock SS1
2. Extremely shallow mineral and/or organic over bedrock SS2
3. Very shallow mineral and/or organic over bedrock SS3
4. Pockets of forested peatland; open (non-treed) peat over bedrock SS9

##### GROUP B (Moderately Deep Mineral Soils)

1. Sandy landforms SS5
2. Coarse loamy landforms SS6
3. Silty, fine loamy and clayey landforms SS7
4. Moist and peaty phase sites SS8
5. Forested peatlands; small open (non-treed) peatlands and fens SS9

##### GROUP C (Deep Mineral Soils)

1. Small areas of peat, minor peaty depressions S11
2. Coarse sandy soil catena to C-1
3. Fine sandy soil catena to C-2
4. Coarse loamy soil catena to C-3

##### Group C-1

1. Coarse sandy, dry to moderately fresh S1
2. Coarse sandy, moist S7

##### Group C-2

1. Fine sandy, dry to fresh S2
2. Fine sandy, moist S7

##### Group C-3

1. Coarse loamy, dry to fresh S3
2. Coarse loamy, moist S8



The API key for S-types will help the photo interpreter to organize his/her observations of features on aerial photos in order to make the best determination of S-type for a given location on the photo. The key was designed to be used when interpreting 1:15 840 black and white aerial photos. It was created based on the range of soil conditions sampled in the RLSA and does not, therefore, provide descriptions of the aerial appearance of all S-types in the NWO FEC. The key is intended for use in the immediate vicinity of RLSA; it cannot be reliably applied outside this area. The key describes conditions as they appear on 1:15 840 scale summer photography during the period of full vegetation development and cover (i.e., between June and late August).

The API key employs similar divisions as the NWO FEC soil key, working from identification of gross-scale features to identification of finer-scale features. The interpreter should consider the following process for classifying a location on an aerial photo to an S-type:

- Determine if the site is mineral or organic.

Organic and mineral soils are distinguished mainly by assessing surface shape, tone, vegetation cover, texture and pattern, and slope position (i.e., organic soils in low-lying areas, mineral soils in upland areas).

- Determine the relative soil depth by evaluating the surface and subsurface bedrock expression.

Shallow and deep soils are distinguished mainly by assessing the relative amount of bedrock exposure and by observing the degree to which the soil surface mimics the underlying bedrock surface shape and pattern.

- Determine the landform type and its associated parent material textural class.

It is understood that broad soil textural classes can be identified by the associated landform feature. The textural class will define the soil catena within which only a limited number of similar S-types can be identified.

- Assess the slope (landscape) position of the location in question.

Within a particular soil texture group (soil catena), relative soil moisture condition is estimated for each position along a slope gradient.

Where necessary, and as possible, assess vegetation conditions indicative of soil moisture and soil nutrient status.

- Assign S-type classification to the location.

Based on an understanding of the relationships among S-types within a soil catena and the landscape relationships of the S-types, evaluate all of the interpreted information to determine the best S-type classification.

The API key was designed to result in an individual S-type classification, but the interpreter should progress through the key only as far as he/she is confident of his/her skills in performing the required observations and interpretations.

### 3.6 Overview of the V-type Aerial Photo Interpretation Key

The main decision criteria in the API key for V-types are the composition of the tree canopy and the composition of the shrub layer. Initially, the key outlines three main divisions: pure conifer conditions, conifer dominated mixedwood conditions, and hardwood dominated mixedwood conditions. Within each of these groups, subsequent divisions (vegetation sequences) are achieved by determining the dominant (main) species (or group of species) in the tree canopy. The component V-types of each sequence are then distinguished by assessing the understory shrub conditions (species composition and relative abundance) and, when necessary, the slope position, landform type, and associated soil moisture conditions.

The API key guides the decision making process required to identify V-types on aerial photos. The user navigates through the key by answering "yes" or "no" to the decision criteria provided. The basic structure of the API key is provided here, outlining the main decision points; the complete API key to the V-types and related API tools are presented in Appendix C.

#### 3.6.1 Basic Structure of the API Key to V-types

The interpretation key for V-types will help the interpreter to organize his/her observations of features on aerial photos in order to make the best determination of V-type for a given location on the photo. The key was designed to be used when interpreting 1:15 840 black and white aerial photos. It was created based on the range of vegetation conditions sampled in the RLSA and does not, therefore, provide descriptions of the aerial appearance of all V-types in the NWO FEC. The key is intended for use in the immediate vicinity of the RLSA; it cannot be reliably applied outside this area. The key describes conditions as they appear on 1:15 840 scale summer photography during the period of full vegetation development and cover (i.e., between June and late August).



- |   |          |
|---|----------|
| 1. Tree canopy only conifer species<br>(may contain <5 percent hardwood)          | Part I   |
| 2. Tree canopy mainly conifer (40 percent<br>or greater cover by conifer species) | Part II  |
| 3. Tree canopy mainly hardwood<br>(may contain <40 percent conifer)               | Part III |

#### PART I (Pure Conifer Sites)

- |  |          |
|--|----------|
| 1. Mainly larch or cedar                 | V22      |
| 2. Mainly white spruce and/or balsam fir | V24, V25 |
| 3. Mainly jack pine                      | V28–V32  |
| 4. Mainly black spruce - upland          | V30–V34  |
| - lowland                                | V35–V38  |

#### PART II (Conifer Dominated Mixedwood Sites)

- |   |                 |
|---|-----------------|
| 1. Conifer component mainly cedar                             | V21, V22        |
| 2. Conifer component mainly<br>white spruce and/or balsam fir | (V14), V15, V16 |
| 3. Conifer component mainly<br>jack pine                      | V17, V18        |
| 4. Conifer component mainly<br>black spruce                   | (V19), V20      |

#### PART III (Hardwood Dominated Mixedwood Sites)

- |   |          |
|---|----------|
| 1. Hardwood species only white birch or<br>cover by white birch >80 percent | V4       |
| 2. Hardwood species (usually trembling<br>aspen) only, no conifer           | V5       |
| 3. Conifer component mainly balsam fir                                      | V6, V7   |
| 4. Conifer component mainly black<br>spruce and/or jack pine - yes          | V10, V11 |
| - no  | V8, V9   |

The API key was designed to employ similar divisions as exist in the NWO FEC vegetation key; it outlines a progression from the most obvious and easy to identify features through to less obvious features. Broad groupings of similar vegetation condition are recognized early in the key (e.g., hardwood-dominated mixedwoods vs. conifer-dominated mixedwoods vs. pure conifer stands). Beyond these major groups, the key progresses toward identifying pairs of similar V-types by recognizing individual tree species or species complexes, and then, where possible, the understory vegetation conditions that distinguish individual V-types are described.

In working through the key, the photo interpreter will be required to assess the vegetation and soil/site conditions on the aerial photos, and to make decisions based on the interpreted information. The interpreter should consider the following process for classifying a location on an aerial photo to a V-type:

- Determine whether the upper canopy is pure conifer, conifer-dominated mixedwood, or hardwood-dominated mixedwood.
- Determine the dominant overstory species and further classify the upper canopy on the basis of species composition.
- Identify the shrub layer species composition and shrub layer abundance from direct observations at the location.
- Where direct observation of understory conditions is not possible, assess the shrub layer by indirect means. Conditions may be inferred from observations of slope position, landform type, and the determination of soil moisture and nutrient conditions based on visible vegetation.
- Assign a V-type classification to the location by evaluating all directly observed information and any inferred information about the location.

It may sometimes be difficult to confidently distinguish individual V-types, particularly when the understory vegetation is obscured and it is hard to infer from the surrounding landscape. The API key for V-types will always lead the interpreter to a single V-type, but to ensure accurate classification the photo interpreter should progress through the key only as far as he/she is confident of his/her ability to perform accurate observation and interpretation.

### 3.7 Example Annotated Aerial Photo Pairs

The following photo stereo pairs (Figs. 6, 7, and 8) illustrate the aerial appearance of many of the keys' main decision criteria. Supplementary tables that describe the photo annotations accompany the photos. In some of the examples, contrasting conditions are annotated adjacent to each other on the same photo pair to allow for comparative observations.

### 3.8 Example of Aerial Photo Interpretation

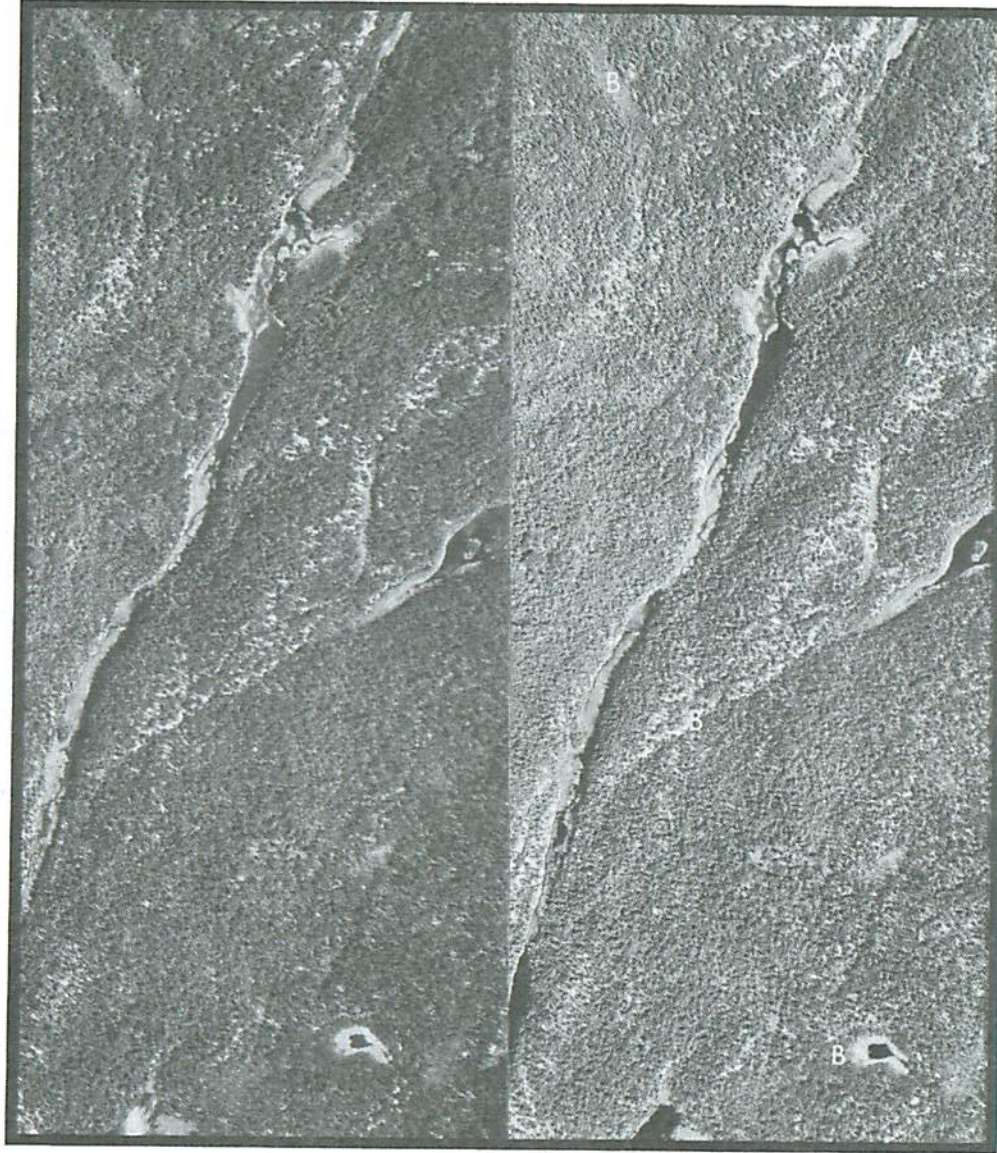
Figure 9 is presented as an example of the application of the API keys to delineate and identify the spatial extents of S-types and V-types. It demonstrates the "art" of dividing a landscape into identifiable, homogeneous NWO FEC units. Stereoscopic viewing of this example can also be useful in helping one decide "where to draw the line" in a seemingly gradual transition between S-types or V-types.



***Bedrock Knob with Very Thin, Discontinuous Mantle of Ablation Till***

Landform	Ablation till moraine on bedrock knob
Macrotopography	Entirely bedrock controlled
Microtopography	Very visible, entirely bedrock controlled
Fine geological surface features	Easily visible ( <i>see "A" on accompanying aerial photo pair</i> )
Proportion of area that is exposed bedrock and bedrock with lichen	Very high ( <i>see "A" on accompanying aerial photo pair</i> )
Surface drainage	Deranged pattern, completely controlled by bedrock shape and fine bedrock surface features such as folia, fracture, and fold ( <i>see "B" on accompanying aerial photo pair</i> )
Internal drainage	Very poor, bedrock controlled
Canopy closure	Very open, scattered, sporadic individuals and sporadic patches
Canopy species makeup	Black spruce, balsam fir, trembling aspen, white birch
Visibility of shrub layer	Not obscured
Shrub abundance	Scattered, sporadic patches or discontinuous, shrub poor to shrub rich
Shrub content	Conifer, mainly balsam fir and black spruce
NWO FEC S-types	SS1, SS2, SS3
NWO FEC V-types	V31, V33





*Figure 6. Bedrock knob with very thin, discontinuous mantle of ablation till, Roslyn Lake Study Area (photo # 75 4907 / 7 144-145). (Scale 1:15 840)*



<i>Comparison of Very Shallow Till Over Bedrock (Location A) and Moderately Deep Till Over Bedrock (Location B)</i>		
<b>Feature</b>	<b>Location A</b>	<b>Location B</b>
Landform	Very shallow till / bedrock	Moderately deep till / bedrock
Macrotopography	Entirely bedrock controlled	Entirely bedrock controlled
Microtopography	Visible	Somewhat obscure
Fine geological surface features	Visible	Somewhat obscure to fully obscure
Proportion of area that is exposed bedrock and bedrock with lichen	Moderately high	Moderately low to low
Surface drainage	Deranged, entirely bedrock controlled	Deranged, mostly bedrock controlled
Internal drainage	Very poor, bedrock controlled	Poor, bedrock controlled
Canopy closure	Open, scattered, sporadic individuals and continuous patches	Continuous well spaced individuals with sporadic patches to moderately closed, continuous cover with gaps rare
Canopy species makeup	Conifer; black spruce and balsam fir	Conifer and conifer dominated mixedwood; black spruce and balsam fir with white birch and trembling aspen
Visibility of shrub layer	Not obscured	Mostly visible
Shrub abundance	Mostly shrub poor but with several sporadic patches or dense shrub cover	Continuous patches to continuous cover with gaps common
Shrub content	Conifer shrubs, mainly balsam fir and black spruce	Conifer and broadleaved shrub species; balsam fir and black spruce, sometimes with white birch and trembling aspen
NWO FEC S-types	SS1, SS2, SS3	SS6, SS3
NWO FEC V-types	V31	V31, V20



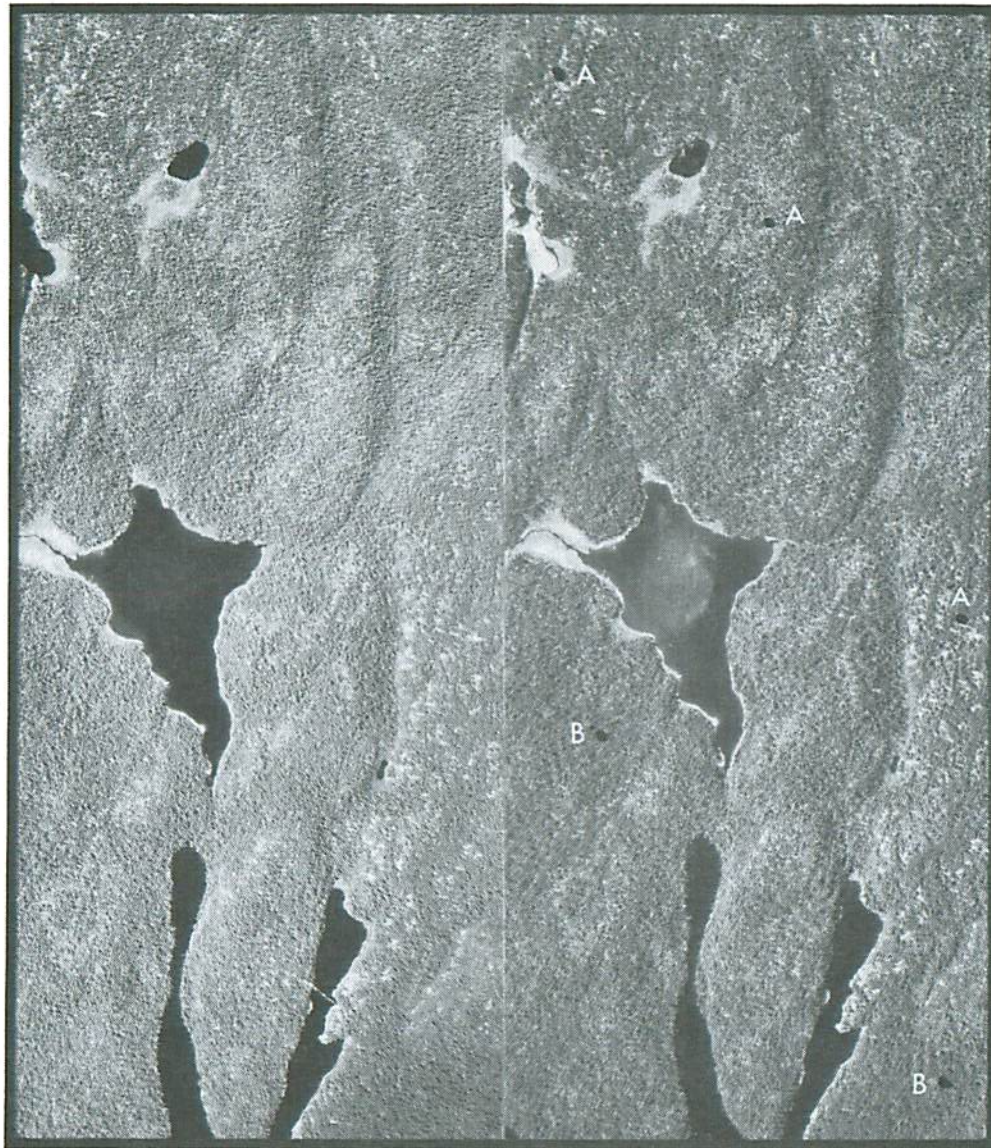


Figure 7. Comparison of very shallow till over bedrock and moderately deep till over bedrock, Roslyn Lake Study Area (photo # 75 4908 / 7 215-216). (Scale 1:15 840)



***Comparison of Deep, Sandy Outwash with Conifer Cover (Location A)  
and Very Shallow Till over Bedrock (Location B)***

<b>Feature</b>	<b>Location A</b>	<b>Location B</b>
Landform	Kame terrace	Ablation till or recessional moraine
Macrotopography	Level, not bedrock controlled	Entirely bedrock controlled
Microtopography	Slightly undulating, not bedrock controlled	Visible, entirely bedrock controlled.
Fine geological surface features	Not present	Visible
Proportion of area that is exposed bedrock and bedrock with lichen	Not present	Extremely high
Surface drainage	Not visible	Deranged pattern, completely controlled by bedrock shape and fine bedrock surface features such as folia, fracture, and fold
Internal drainage	Very good, no evidence of surface drainage or seepage	Very poor, entirely bedrock controlled
Canopy closure	Moderately closed to closed; continuous and smooth	Very open, continuous patches; irregular tree height
Canopy species makeup	Pure conifer; jack pine with minor black spruce component	Pure conifer; balsam fir, black spruce
Visibility of shrub layer	Moderately obscured	Not obscured
Shrub abundance	Shrub poor to moderately shrub rich	Sporadic clumps that appear not dense and shrub poor
Shrub content	Conifer	Balsam fir, black spruce
NWO FEC S-types	S1, S2, S7	SS2, SS3
NWO FEC V-types	V32	V20, V31



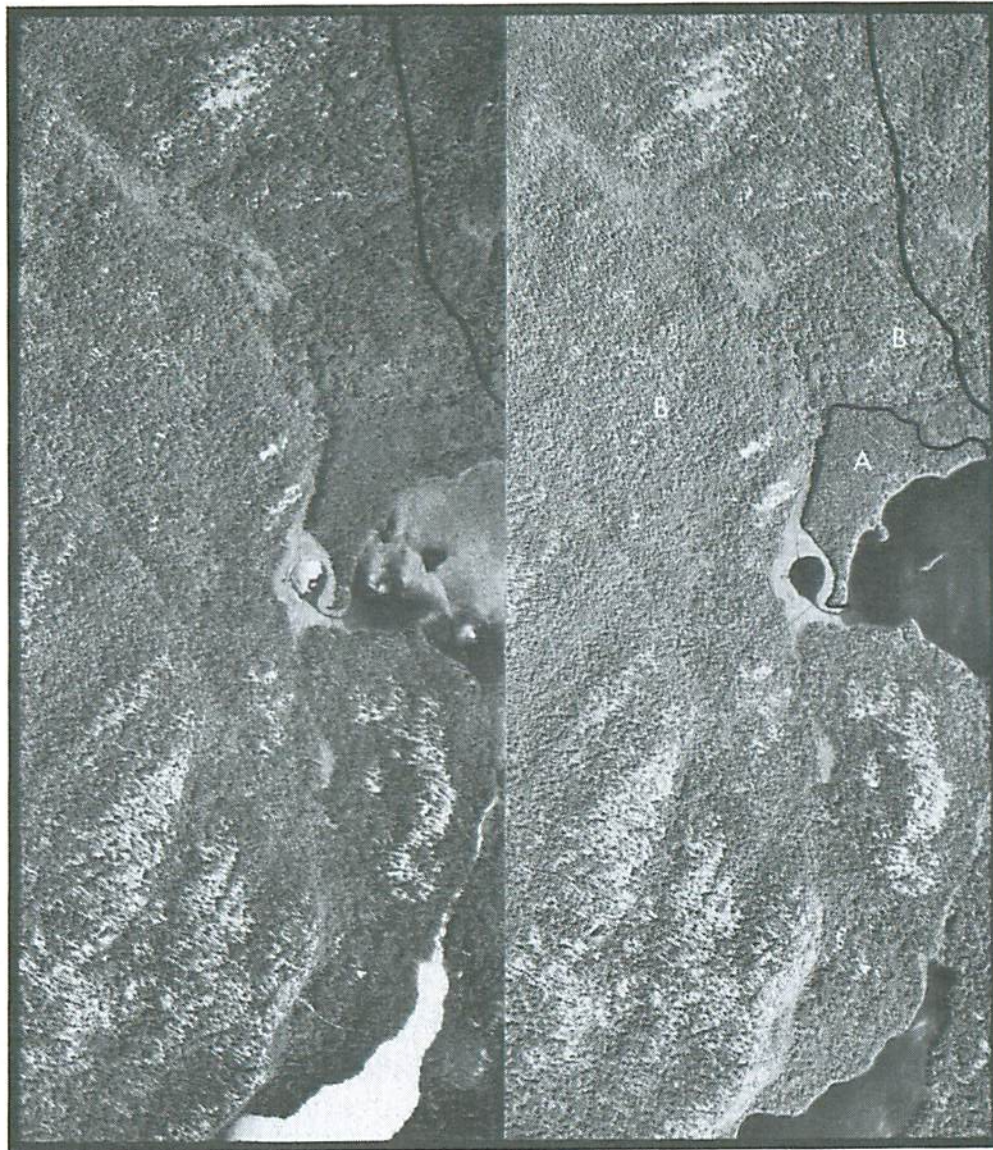


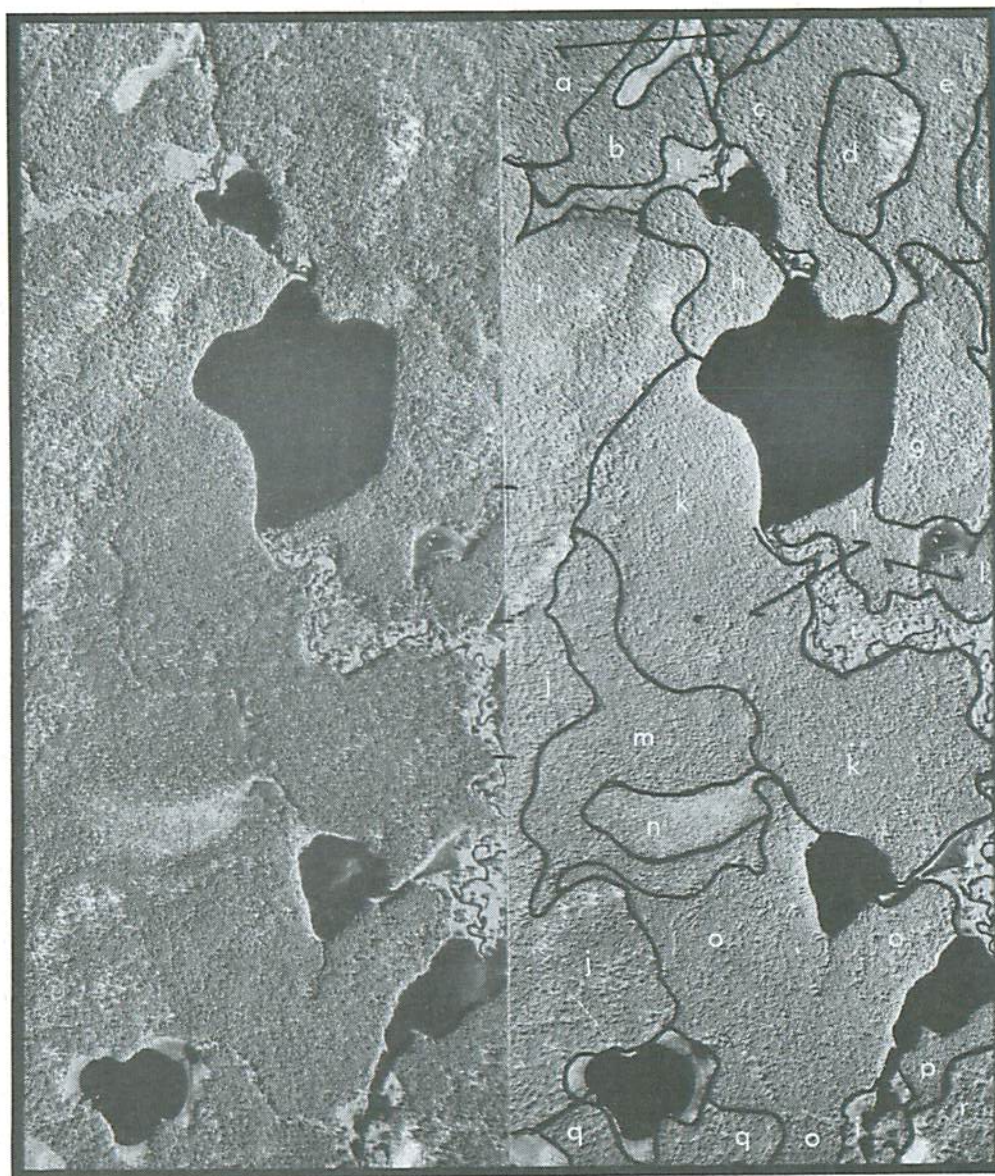
Figure 8. Comparison of deep sandy soil with conifer cover and very shallow till over bedrock with conifer cover, Roslyn Lake Study Area (photo # 75 4907 / 7 139-140). (Scale 1:15 840)



***Comparison of Moderately Deep to Deep Organic (Polygon n)  
and Sandy Outwash (Polygon k)***

<b>Feature</b>	<b>Polygon n</b>	<b>Polygon k</b>
Landform	Forested peatland	Sandy outwash
Macrotopography	Level to depressional, not bedrock controlled	Level, not bedrock controlled
Microtopography	Not present	Level, not bedrock controlled
Fine geological surface features	Not present	Not present
Proportion of area that is exposed bedrock and bedrock with lichen	Not present	Not present
Surface drainage	Very poor, restricted, local ponding	Few scattered moist depressions, no evident pattern
Internal drainage	Very poor, restricted by high water table	Very good, not restricted
Canopy closure	Several sporadic individuals and sporadic patches to continuous well spaced individuals with gaps common	Moderately closed, continuous evenly spaced individuals but includes a few patches that are somewhat open with moderately irregular tree height
Canopy species makeup	Pure conifer; black spruce	Pure conifer; jack pine with black spruce
Visibility of shrub layer	Visible	Moderately obscure
Shrub abundance	Poor to moderately shrub rich	Shrub poor to moderately shrub rich, occasional shrub rich patches
Shrub content	Black spruce, balsam fir, Labrador tea	Conifer, mostly jack pine, black spruce, and balsam fir
NWO FEC S-types	S11, S12F	S1, S2, S7
NWO FEC V-types	V34, V36, V37, V38	V28 V29, V32





Legend		
Polygon	S-type	V-type
a	SS3 / SS6	V31 - V20
b	S2	V31 - V20
c	S2	V31 / V20
d	SS2 / SS1	V31 / V30
e	S11 / S7	V34 / V35
f	SS3	V31 / V20
g	SS3 / SS6	V30 / V20
h	S2	V20 / V33
i	S11	V38 / V22
j	SS2 / SS1	V30 / V20
k	S2	V28:V29 / V32
l	S2	V28:V29 / V31
m	S7 / S11	V32
n	S11 / S12F	V38 / V37
o	S2 / S7	V28:V29 / V32
p	S2	V31
q	SS3	V31
r	SS6	V31
Conventions used:		
	V31 - V20	50% - 50%
	V31 / V20	primary / secondary
	V28:V29	indiscernible V-type grouping

Figure 9. Example aerial photo stereogram delineated with polygons defined by NWO FEC V-types and S-types, Roslyn Lake Study Area (photo # 75 4910 / 8 209-210). (Scale 1:15 840)



## 4.0 DISCUSSION

### 4.1 Current Status of Aerial Photo Interpretation Keys

The accuracy of aerial photo interpretation should be regularly confirmed with ground truth data. Similarly, aerial photo interpretation keys, the tools employed for a variety of mapping applications, should be tested to confirm their accuracy in general and their suitability for particular mapping purposes. The aerial photo interpretation keys presented here should be field tested in the RLSA to further confirm the photo interpretability of current NWO FEC V-types and S-types. The keys must also be tested to confirm their validity for any mapping applications.

### 4.2 Photo Interpretability of NWO FEC V-types and S-types

In general, the V-types and S-types that are found in the RLSA can be interpreted on 1:15 840 black and white aerial photos. This interpretability is enhanced by the availability of the API keys presented in this report.

Determining NWO FEC V-types on intermediate scale aerial photos is quite straightforward because the V-types are defined primarily by overstory conditions, and these are usually the most visible features on aerial photos of forested landscapes. The identification of tree species on aerial photos is a skill that can be learned. It will provide the basis for assessing canopy conditions that define individual V-types or groups of similar V-types. The recognition of understory vegetation, which is critical in distinguishing V-types with similar overstory conditions, can also be learned but this may require more interpretive effort. It is necessary to understand and be able to interpret the ecological relationships among soil, site, and vegetation conditions. These relationships form part of the framework and some of the decision criteria in the API key for V-types that is presented in this report.

By comparison, the NWO FEC S-types are more difficult to determine on intermediate scale aerial photos because the soil properties used to define them (soil depth, moisture regime, and texture) are not directly visible. In the aerial photo interpretation process, these properties are determined primarily by inference and deduction. To do this successfully, the interpreter should have a thorough understanding of the geomorphology and glacial landforms of the RLSA, as well as a knowledge of soil genesis, soil physics, and soil chemistry. Such knowledge is normally obtained through formal education and training in soil science, and through experience and training in soil survey. Many of these details are incorporated into the framework and decision criteria in the API key for S-types that is presented in this report.

The API keys may be used to identify individual types or groups of similar types. The level of classification achieved (i.e., groups or individual types) will depend on the skill level of the photo interpreter as well as on the intended use of the interpreted information. The ultimate use of the aerial photo interpretation product (i.e., land classifications, silvicultural prescriptions, moose habitat assessment) may also determine whether identification of groups of similar types is preferable to identification of individual types. For some purposes, keying out to groups of similar types may provide a sufficient level of detail. Regardless, photo interpreters should work through the keys only to the point where they are comfortable with the interpretation result.

### 4.3 Problems/Limitations of the Keys

The API keys for the RLSA are generally easy to use, and require simple interpretations and decisions. Inevitably, the keys will have some limitations for particular purposes.

Perhaps the most obvious limitation of the aerial photo interpretation keys is that, in their current format, they are applicable only for interpreting mature forest and site conditions in the immediate vicinity of the RLSA. They are not intended to be used to identify immature vegetation conditions or to differentiate wetland types or non-forested areas.

These API keys are specific to the RLSA and should not be applied "as is" outside the study area. The appearance (or expression) of FEC types is variable across northwestern Ontario (Wickware 1990). However, the style and organization of these keys may provide a suitable framework for developing similar keys for mature forest conditions in other geographic locations. The descriptions of features for the keys' decision criteria would have to be modified to reflect the local appearance (or expression) of V-types and S-types in other geographic areas. The liability of API keys developed for any geographic area should be confirmed before they are finalized.

The API keys in this report guide the interpretation process for identifying individual V-types and S-types as they exist in the RLSA. The API keys do not include all the types of the NWO FEC; only the S-types and V-types found during field sampling in the RLSA were included in these keys.

Some problems have been identified related to the determination of vegetation conditions in keying to a V-type. It has already been stated that understory vegetation is often obscured by overstory vegetation on intermediate scale aerial photos. Likewise, trees that form a secondary canopy may also be obscured on the photos by the main canopy.



This overlapping of layers may cause inaccurate V-type determinations, because in the NWO FEC system secondary trees are considered along with main canopy trees in the assessment of overstory dominance for V-type groups. Similar inaccuracies may also occur in photo interpreting mixedwood stands because there may be a tendency to underestimate the areal coverage of small crowned tree species, particularly the conifers, compared to large crowned, hardwood species. Ground observations must be compared with photo interpreted canopy assessments so that such inaccuracies are compensated for and minimized.

The level of photo interpreter confidence and success can vary greatly and is dependent on many factors, such as quality of imagery, visibility of the decision point criteria on aerial photos, and interpreter skill. Any of these factors may limit the aerial photo interpretation outcome to a group of similar S-types or V-types rather than to a single one.

API keys tend to reflect the skills and biases of the individual who created them. Therefore, subsequent users/photo interpreters may choose to modify these API keys to accommodate their own preferences, perceptions, and aerial photo interpretation abilities. The keys cannot compensate for deficiencies in aerial photo interpretation skill or inappropriate photography.

#### **4.4 Application of the Aerial Photo Interpretation Keys**

The primary application of these aerial photo interpretation keys is for identifying and mapping the spatial extent of NWO FEC types in the RLSA.

To map an area using aerial photo interpretation, the interpreter must first know the intended use of the final mapped product and its requisite level of accuracy and detail. These factors will dictate the resolution of aerial photo interpretation, the scale of photography, the extent of ground truthing, and the overall time and financial commitment required to achieve the goals of the mapping project.

Map production by aerial photo interpretation involves the delineation of homogeneous landscape units as they appear on the aerial photos. A "minimum polygon size" (MPS), the smallest sized landscape unit that may be delineated in an aerial photo interpretation exercise, must be determined to suit the scale and the intended use of the final mapped product. For example, mapping forest management units may require an MPS of several hectares. In this case study, the MPS suited to forest management activities was determined to be approximately 1 cm<sup>2</sup> on 1:15 840 scale aerial photos. This is equivalent to about

2.5 hectares on the ground. When interpreting aerial photos for the purposes of map production, only those features that are at least the size of the MPS would be delineated. Smaller features would not normally be delineated as independent polygons, but rather would be considered as "inclusions" in the surrounding, larger, otherwise homogeneous polygon.

The easiest landscape units to identify and delineate as polygons on aerial photos are large areas that have uniform aerial appearance. Delineating polygons can be complicated by areas of unique appearance that are smaller than the MPS. Typically, however, if a small patch is surrounded by a large and otherwise uniform polygon, the small patch(es) will be considered as an inclusion(s) in the larger polygon. Using the aerial photo interpretation keys, S-types and V-Types should be determined for each unique condition identified within the polygon. The proportion of the polygon occupied by each condition is estimated. This determines the dominant (most representative) condition (S-type or V-type) for the polygon. The inclusions typically represent subdominant conditions.

##### **4.4.1 Separation of the S-type and V-type Aerial Photo Interpretation Keys**

Interpretation and mapping of the S-types and V-types in isolation from one another is readily possible in the RLSA because separate aerial photo interpretation keys were developed for S-types and V-types, and these keys are not codependent. To determine a V-type, the interpreter does not have to know the S-type of the location, and vice versa.

Since the combination of skills and knowledge required to interpret either soil or vegetation is relatively unique, it may be unusual to find an interpreter who is competent in both areas. However, having separate aerial photo interpretation keys allows individual interpreters to work through the key that is suited to their skills and experience in order to create a corresponding map layer.

Maps showing the spatial extent of V-types and S-types may be produced in several different manners. Some of the different mapping approaches are described below.

##### **4.4.2 Layered Mapping Approach**

In a layered mapping approach the spatial extent of V-types and S-types would be shown on separate map layers. Some advantages and disadvantages of such a "two-part" or layered mapping approach include:

- A single vegetation condition may occur over a range of soil conditions (and vice versa). On a map that combines vegetation and soil, a vegetation polygon might, for example, artificially dissect an otherwise homogeneous soil polygon. Creating separate maps for vegetation and



soil prevents possible interference of one data layer by the other.

- By mapping the S-types separately from the V-types, the soil map remains valid even if the vegetation layer is altered by harvesting, fire, insect and disease infestations, or natural stand dynamics.
- If desired, the separate layers (or maps) can be combined or analyzed simultaneously. Using Geographic Information Systems (GIS) technology, thematic maps could be created based on various combinations of soil and vegetation attributes. The flexibility of this mapping system allows the selection of attributes for overlay that best suit the particular management activity.
- Without access to GIS technology, manually combining (i.e., overlaying) single-attribute maps may be difficult and time-consuming.
- The production of separate maps for the S-type and V-type classifications may prove to be time-consuming and costly.
- Some management activities may be best served by focusing on a single-attribute map during the decision making process. A layered mapping approach is well suited for such situations.
- Several attributes may need to be considered simultaneously in the decision making process. Some attributes may only become important when they are considered in combination with others. A layered mapping approach is well suited to these circumstances since it allows the selection of attributes on which to apply overlay, intersect, proximity, and buffering analysis techniques.

Clearly, a layered mapping approach, especially when coupled with GIS technologies, provides the resource manager with the greatest degree of flexibility, power, and precision.

#### **4.4.3 Site Type Mapping Approach**

Site type maps combine V-type and S-type classifications in each polygon on a single map. Polygons would be delineated after considering all the attributes of interest (e.g., V-type, S-type, timber volume, stand age, habitat potential) for a particular landscape location. Although the aerial photo interpretation keys provided here are separate for the S-types and V-types, they facilitate the identification of both on aerial photos. Once identified, the types can then be considered along with any other site attributes in determining appropriate polygon boundaries. The advantages and disadvantages of this approach are summarized as follows:

- Several ecological attributes may be considered at once for a particular landscape location without having to rely on GIS technology to facilitate overlaying individual attribute maps. However, there is no flexibility for changing the boundaries for individual attributes on a multiple-attribute map without having to consider all of the other attributes at the same time. This may be especially limiting for the vegetation features of a landscape that are subject to radical change due to harvesting, insect/disease infestation, fire, etc.
- A single vegetation condition may occur over a range of soil conditions (and vice versa). It might, therefore, be difficult to delineate polygon boundaries in complex landscapes.
- The scale of site type units may be more conducive to some planning uses.
- Since polygon boundaries are defined by a combination of site attributes, the true boundary for any one attribute may not be accurately portrayed. This makes it difficult to extract reliable maps of individual attributes without having to reinterpret the aerial photos.
- In order to map the V-types and S-types as combinations in each polygon, the interpreter will require the aerial photo interpretation skills to utilize both keys (i.e., be able to photo interpret both vegetation and soil/site features). A person with general skills in each area may only be able to reliably identify groups of types rather than individual types.
- The production of a single site type map that combines the S-type and V-type classifications (as well as any other attributes of interest) may be somewhat less expensive than the production of separate maps for each attribute.

#### **4.4.4 Annotated Forest Resource Inventory Maps**

An alternative to producing a new map that combines many site attributes is to annotate an existing map base, such as FRI base maps, with additional site information. Again, the aerial photo interpretation keys for the RLISA readily facilitate the addition of V-type and S-type classifications to FRI polygons—the FRI aerial photos can simply be reinterpreted using the keys to determine the V-type or S-type for each polygon. This is a relatively simple and inexpensive way to enhance the ecological information associated with standard FRI polygons. However, since FRI polygons represent forest stands that are defined by overstory tree species composition and wood volumes, the maps may not accurately portray the spatial extents of different vegetation and soil conditions. Another problem associated with the reliance on FRI maps is



that the forest resource is continually changing as a result of harvesting activities, fire, and insect and disease damage. This necessitates constant updating and redefinition of FRI polygon boundaries.

#### **4.4.5 Geographic Information Systems**

Each of the interpretation keys uses the fundamental relationships among soil, site, landform, and vegetation to interpret V-types and S-types on aerial photos. Some of these relationships may be built into GIS algorithms or models designed to automate FEC mapping. The organizational structure as well as the decision points in the keys should, therefore, prove to be useful in designing and testing GIS algorithms.

#### **4.4.6 Digital Thematic Mapping**

The S-type and V-type aerial photo interpretation keys should be valuable aids for the training and development of thematic mapping systems for remotely sensed data (e.g., Landsat Thematic Mapper satellite images). Interpretation of V-types and S-types on 1:15 840 black and white aerial photos could be used as an intermediate level or form of ground truth information; the photos could provide information about the spatial extents and the ranges of conditions that are associated with each V-type and S-type. Such information could then be used for classifying and analyzing aggregates of digital data points.

#### **4.5 Implications for Forest Management**

Ontario's Crown Forest Sustainability Act mandates resource managers to manage the forest in an ecologically sustainable manner. It is therefore imperative that these individuals have access to a full complement of information about forest ecosystems. NWO FEC V-types and S-types are important tools for describing forest ecosystems in northwestern Ontario, yet the classification has historically required ground surveys to determine their spatial extents. The capability to photo interpret V-types and S-types on intermediate scale black and white aerial photos, as demonstrated in this case study, may reduce the intensity of such ground surveys by providing a more efficient method of delineating the spatial extent of V-types and S-types over a survey area.

The potential benefits of this capability for forest management programs cannot be ignored. Although a certain amount of field survey work will still be required to verify aerial photo interpretations, the accurate identification of FEC V-types and S-types should be achievable with considerably less field work. In turn, this should translate into more efficient use of manpower, and temporal and financial budgets.

Considerable ecological information is associated with each S-type and V-type. Thus, if a unit of the forest

landscape is classified to one of the types, a range of information about the site can be inferred from the classification. Ideally, S-types, V-types, and standard FRI attributes should all be mapped as separate layers. Failing this, in the FRI mapping process, polygons should be delineated with consideration given to component S-types and V-types. This may result in the division of standard FRI polygons to reflect unique, homogeneous S-type and V-type conditions. Another option, although less desirable, is to annotate existing FRI polygons with the proportions of component V-types and S-types. Although more information about the stand is indicated, the information is not spatially referenced as accurately nor is it as homogeneous as if it were delineated as unique polygons.

One of the main sources of mapped soil information in Ontario is the OGS Northern Ontario Engineering Terrain Study (NOEGTS) series of 1:100 000 scale maps (e.g., Gartner 1979). These maps delineate the boundaries of major surficial deposit types, but the map scale is too small to portray the soil conditions that may be critical from a silvicultural or operational perspective. Being able to map S-types at the same scale as FRI maps (1:15 840 or 1:20 000) would facilitate the consideration of important physical site conditions that might influence forest management operations. The aerial photo interpretation key for the S-types is an example of an approach that is useful for identifying and mapping soil conditions at such scales.

#### **5.0 CONCLUSION/RECOMMENDATIONS**

One method for the creation of API keys has been successfully demonstrated in the development of aerial photo interpretation keys for the NWO FEC S-types and V-types in the Roslyn Lake Study Area. Supporting materials, tools, and techniques for these API keys have either been identified or developed, and then presented as part of this report. An example aerial photo interpretation exercise was provided so as to illustrate the application of the NWO FEC API keys in a spatial context.

The API keys presented in this report are useful for accurately identifying NWO FEC V-types and S-types on vertical format, 1:15 840 scale, black and white aerial photos of the RLSA. The majority of S-types and V-types can be reliably identified and delineated through aerial photo interpretation. Some S-types and V-types are less reliably identifiable as individuals, but can be identified in groups of related types.

The demonstrated photo interpretability of the V-types and S-types has distinct implications for forest management. Current forest management programs rely primarily on aerial photo interpretation to inventory the forest resource. This has been an efficient and relatively accurate method for identifying tree species and mapping forest



stands for management purposes. Today, new approaches for ecologically sensitive forest management are required, in spite of limited financial resources. The V-types and S-types of the NWO FEC provide an ecological framework on which to base management decisions, and they can be identified and their spatial extents delineated on intermediate scale aerial photos. Forest managers infer a wealth of ecological information from each V-type or S-type, especially when the spatial extents and distributions are known.

Based on this case study of the aerial photo interpretation of NWO FEC V-types and S-types, the following recommendations are suggested:

- Test the keys in a mapping application of the mature forest and associated soil conditions in the RLSA.
- Recognize the skill sets required to reliably photo interpret vegetation and soil conditions and to develop training regimes that will address the mechanics of photo interpreting NWO FEC V-types and S-types on intermediate scale, black and white aerial photos.
- Ensure that photo interpreters have access to good quality photos or imagery of appropriate scales in order to properly assess V-types and S-types.
- Much of the methodology and development of the keys presented in this report was universal in nature (i.e., identification of tree canopy species, estimations of soil depth over bedrock). The keys, therefore, should be suitable as a "starting point" for the development of additional API keys that are specific to other biophysical/geographical areas. Thus it would be desirable to test the accuracy of the aerial photo interpretation keys in areas beyond the RLSA, and to determine the modifications that may be required to adapt them for other geographic areas.
- Evaluate methods of enhancing current forest resource information bases with V-type and S-type classifications.
- Develop GIS and nonspatial techniques for modeling or integrating interpreted NWO FEC units with other forest resource information.
- Integrate immature vegetation cover, wetland classification units, and other non-forest cover types into the NWO FEC aerial photo interpretation scheme.

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## **APPENDIX A. TIPS, EQUIPMENT, AND SKILLS FOR USING THE KEYS**

### **Tips for Applying the Keys**

- Start with the “known” and work toward the “unknown”. Clues about the identification of an unknown feature are often present in surrounding identifiable features. Once easily identified polygons have been delineated and identified, radiate outward by delineating and interpreting adjacent polygons. The concepts of toposequences, landform patterns, and position relative to other known objects or areas should assist in the process of interpreting the more difficult polygons.
- Delineate the largest, most obvious features first (e.g., exposed bedrock, large areas of organic accumulation).
- Progressively delineate smaller or more detailed polygons based on less obvious features (e.g., jack pine vs. black spruce pure conifer).
- Delineate polygons that are as homogeneous or uniform in appearance as possible without compromising the targeted minimum polygon size (MPS).
- Whenever possible, limit the number of S-types or V-types in a polygon to one, except where S-types or V-types are too finely mixed to separate or where the proposed product does not warrant this detail.
- Do not exceed the level of detail or resolution defined by the MPS and the planned map use.
- Refer to the annotated stereograms, toposequence illustrations, and landform descriptions provided in this report.

### **Equipment and Skills Required to Work Through the Keys**

- Appropriate imagery.
- Stereoscope suitable for 23-cm x 23-cm imagery. Mirror stereoscopes are most suitable as they generally show the entire area of overlap in 3-dimensional view. Two times (2x) magnification is preferred for general overviews, and the capability to view at 4x to 6x magnification for more detailed tasks is desirable.
- The ability to perceive three dimensions on aerial photos when using appropriate stereoscopic equipment and imagery.
- A predefined MPS that is suitable for the intended interpretation exercise.
- Familiarity and experience with identification of glacial landforms common to northern Ontario, both on aerial photos and at local ground truth locations.
- Familiarity and experience with the identification of tree species, both on aerial photos and at local ground truth locations.
- Base map of the study area showing the aerial photo flight lines and aerial photo principle point locations.



## **APPENDIX B. AERIAL PHOTO INTERPRETATION KEY TO S-TYPES**

### **Guide to the S-type Key**

The following key is intended for use in the interpretation of NWO FEC S-types on vertical, 1:15 840 scale, standard black and white stereo imagery. The recommended imagery format for this purpose is contact print positives from 23-cm x 23-cm (9-in. x 9-in.) negatives, exposed on flat or low-gloss surfaced, high contrast paper. The imagery should be flown during a window when vegetation is in full leaf (late June to late August).

The main decision criteria of this aerial photo interpretation key are soil depth, soil textural groups, and soil moisture, similar to the NWO FEC S-type key. Initially, the key has two main divisions, organic soils and mineral soils. The mineral soils are further divided into three groups according to soil depth criteria. Within each of these groups, the interpreter can distinguish individual S-types by the identification of landform features and their associated textural relationships as well as by consideration of the slope position and associated soil moisture conditions (i.e., soil catenae). Decisions are made throughout this key simply by answering "yes" or "no" to the description provided about the features being observed at a location on the photo.

The aerial photo interpretation key incorporates the S-types that were commonly found during field sampling of the Roslyn Lake Study Area; it is not a comprehensive key to all NWO FEC S-types. The key should only be used in the immediate vicinity of the RLSA. If it is to be used in other geographic locations, it should be applied with caution, and only after ground truth observations and calibration of the key for the new location have been completed.

### **How to Identify S-types on Aerial Photos Using the API Key**

1. On appropriate aerial photos delineate polygons of similar appearance and soil/site conditions (e.g., areas that have the same tone, texture, forest cover, species composition, elevation, originating landform, soil depth, or amount of exposed bedrock).
2. Cull all polygons including those representing open water and industrial sites (e.g., mine tailings, pits, or quarries).
3. Within each polygon select an interpretable unit (IU); that is, a homogeneous area that is representative of the vegetation and soil/site conditions found within the polygon. Ignore vegetation and soil/site conditions that represent less than 10 percent of the total polygon area; consider these only as inclusions.
4. Use the API key to identify the NWO FEC S-types associated with each IU.
5. Identify all S-types represented within the polygon and estimate the proportional area for each type.
6. Repeat Steps 3, 4, and 5 for each polygon.



# S-Type Aerial Photo Interpretation Key for the Roslyn Lake Study Area

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## START

Choose one of the following:

1. Polygon is on a deep peat or organic landform ..... go to **Part I**  
(see description below)
2. Polygon is NOT on a deep peat or organic landform. .... go to **Part II**  
Therefore polygon is on bedrock, mineral soil, or a shallow organic.

## Deep Peat or Organic Landforms

Level or low-lying areas with smooth surface. May be slightly sloping or domed. Drainage is restricted. Local ponding may be present. Flowing patterns or channel-like features are commonly seen in the tone, texture, and color of the vegetation. Open water may be present toward the polygon center and/or as a water ring at the polygon margin. Ground cover has characteristic smooth, fuzzy, or often a velvety appearance. Smooth transitions between areas of light tone and areas of darker tone are diagnostic. Small hummocks of peat may be evident.

Organic deposits are usually found in extensive lowland areas between major bedrock knobs and in extensive depressions on the surface of smooth, level, bedrock landscapes. They are often found in close association with gently arching lake shorelines where bright to white, even toned sand boundaries are not present at the water's edge.

Tree cover is generally dominated by black spruce, balsam fir, cedar, and larch. Canopy conditions vary from closed, in evenly and well stocked stands, to open, sometimes with scattered clumps of stunted trees. Tree height and vigor vary widely from noncommercial "stag spruce" to harvestable, even-aged, tall, and mature trees. The canopy often becomes more open or sparse toward the central portion of the organic area. Tall shrub species include black spruce, balsam fir, willow (*Salix* spp.), and speckled alder. Small clumps of dark toned ericaceous shrubs and/or light-toned grasses and sedges are often present.

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## Part I

## Deep Organic Landforms

Choose one of the following:

1. Polygon usually occupies the lower to toe slope positions immediately adjacent to (or transitional to) upland mineral areas. Polygon rarely extends into large, level, wet organic areas. Tree canopy generally contains black spruce, balsam fir, cedar, and/or larch. Hardwoods may also be present in the tree canopy. Shrub layer is commonly thick and may contain black spruce, balsam fir, alder, and/or willow. .... **S11**
2. Polygon usually located at margin of level peatlands. Sometimes found on the top of domed peatlands. Most commonly found adjacent to large, sloping mineral soil and bedrock. May be on toe slope position if adjacent to gently sloping deep soil landforms. Tree canopy is generally closed and contains black spruce, cedar, and/or larch. Water seepage, drainageways, and small creeks may be evident. .... **S12F**
3. Polygon is a level organic or a depressional organic basin that is not near the margin of the wetland nor adjacent to upland mineral sites. Tree canopy is mainly black spruce. Canopy may appear even, smooth, and closed, or very sparse and open, patchy, and discontinuous. Shrubs are usually conifer and are generally sparse. Evidence of water seepage, drainageways, and small creeks are usually not present. Open, standing water may be present within the polygon. .... **S12S**



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## Part II

## Bedrock, Mineral Soil, and Shallow Organic

Choose one of the following:

*Note: The decision process for Choices 2, 3, and 4 below, should be based on the accompanying Soil Depth Class Decision Support Tables. The mandatory conditions listed below each depth class should ALL be satisfied by the IU in order for that depth class to be chosen. Some auxiliary conditions for each depth class are listed, but note that these are only optional considerations.*

1. **Boulder Pavement, Boulder Wash, Talus, and Scree Slopes.** ..... **SS4**  
Fan-shaped, steep-sloping areas found at the base of sheer or steep rock faces. Colluvial rock rubble or fragmental rock talus is often visible. Boulders and stones may occur in conical piles (kames) or in linear arrangements as terraces along well established drainageways (boulder lag).
2. **Very Shallow Soils and Exposed Bedrock Sites.** ..... go to **Group A**  
(see Soil Depth Class Decision Tables)
3. **Moderately Deep Mineral Soil Group.** ..... go to **Group B**  
(see Soil Depth Class Decision Tables)
4. **Deep Mineral Soil Group.** ..... go to **Group C**  
(see Soil Depth Class Decision Tables)
5. **None of the above.** ..... **Ground Truth**



Soil Depth Class Decision Support Table (Mandatory Conditions)			
Mandatory conditions	Very shallow soils and exposed bedrock (Group A)	Moderately deep mineral soil (Group B)	Deep mineral soil (Group C)
Location and appearance	Polygons with numerous and/or large areas of exposed bedrock. Usually located on bedrock knobs and bedrock-controlled topography, mainly associated with crests and upper slope positions. Patches of exposed and lichen-covered bedrock are usually clearly visible as irregularly shaped, bright white to light grey areas. On average, > 30% of the polygon is exposed bedrock and/or bedrock with lichen cover.	Polygons associated with bedrock knobs. They are commonly located on the upper and mid-slope positions, on gently sloping to moderately steep sloping sides of bedrock knobs. Irregular shaped, discontinuous patches of exposed and lichen-covered bedrock may occur but are generally small in size and infrequent. On average, ≤ 30% of the polygon is exposed bedrock and/or bedrock with lichen cover.	When associated with bedrock knobs, polygons are usually found in lower and toe slope positions. Otherwise, they may be at any slope position on other mineral landforms. Patches of exposed and lichen-covered bedrock are infrequent, generally small in size, and are very localized. On average, < 10% of these polygons have exposed bedrock and/or bedrock with lichen cover.
Macrotopography	Macrotopography is determined entirely by the shape of the underlying rock. Gross bedrock surface features are clearly visible and strongly mimicked by ground surface and vegetation.	Macrotopography is determined entirely by the shape of the underlying bedrock. Gross surface features of the bedrock are clearly visible and strongly mimicked by the ground surface and vegetation.	Macrotopography is not determined by the shape of the underlying bedrock. It may, however, be weakly influenced by the shape of the underlying bedrock. Depositional patterns and features of the parent material are more apparent.
Microtopography	Microtopography is clearly determined by the shape of the underlying bedrock.	Microtopography is weakly determined or not determined by the shape of the underlying bedrock.	Microtopography is not determined by the shape of the underlying bedrock.
Fine bedrock surface features (cracks, striations, fractures, and rock folia)	Fine bedrock surface features are usually clearly visible.	Fine bedrock surface features are not visible or are only weakly expressed by vegetation surface cover.	Fine bedrock surface features usually are not visible.

Soil Depth Class Decision Support Table (Auxiliary Conditions)			
Auxiliary conditions	Very shallow soils and exposed bedrock (Group A)	Moderately deep mineral soil (Group B)	Deep mineral soil (Group C)
Drainage	Surface drainage is entirely bedrock controlled and follows the cracks, folds, and depressions in the rock surface.  Internal drainage is very poor due to bedrock impediment.	Surface drainage is almost entirely bedrock controlled and follows the fractures and folds of the underlying bedrock surface.  Internal drainage is poor or discontinuous.	Surface drainage is not bedrock controlled or is very weakly bedrock controlled.  Internal drainage is usually good due to the lack of bedrock control and the sandy to coarse loamy texture of most parent materials in the RLSA.
Forest cover	The tree canopy is usually patchy, although less commonly it may be continuous and open.	The canopy is closed to moderately open. The canopy may be patchy but the patches are moderate in size (>4cm <sup>2</sup> ) and the edges of the patches are smooth and rounded in general shape.	The tree canopy is normally closed with few openings.



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## Part II - Group A

## Very Shallow Soils and Exposed Bedrock Sites

*Note: These polygons are usually made up of many small and irregular patches described by Conditions 1, 2, and 3 below. Common practice is to delineate a complex area and then to assign a relative percentage for the conditions that are present. If any one condition meets the MPS criteria then it should be delineated as a separate polygon.*

*Condition 4 is often in close association with Conditions 1, 2, and 3 but is sufficiently distinct to warrant being delineated as a separate polygon if it meets the MPS criteria for the interpretation exercise.*

Choose one of the following:

1. **Bare Rock or Discontinuous Moss/Lichen over Bedrock.** ..... SS1<sup>1</sup>

Bright white to light grey patches with fractured appearance. Open and scattered tree canopy with sparse ground vegetation. Fine bedrock surface features and bedrock microtopography are usually clearly visible.

2. **Extremely Shallow Mineral and/or Organic Soil over Bedrock.** ..... SS2<sup>1</sup>

Bright patches, somewhat patchy or grainy. Tree canopy may be open to moderately closed. Surface vegetation is present though not usually abundant. Fine bedrock surface features are not visible. Bedrock microtopography is usually clearly visible.

3. **Very Shallow Mineral and/or Organic Soil over Bedrock.** ..... SS3<sup>1, 2</sup>

Grey areas, somewhat patchy or grainy. Overstory may be open to moderately closed. Surface vegetation may be moderately continuous to continuous. Fine bedrock surface features are not visible.

4. **Pockets of Forested Peatland, Non-forested Peat over Bedrock.** ..... SS9

Small, poorly drained, organic deposits usually with numerous islands of bedrock outcrops scattered throughout the polygon. Tree cover on these soils may be abundant; low shrub cover may also be dense.

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<sup>1</sup> SS1, SS2, and SS3 are usually found in close association with each other and complex polygons frequently occur.

<sup>2</sup> SS3 is often found as a transitional stage to the moderately deep soil grouping in Group B.



Choose one of the following:

1. **Sandy Landforms.** ..... SS5  
Polygon is on these landform types: esker, kame, kame terrace, outwash plain, outwash channel, valley train, sandy lacustrine plain or basin, beach ridge.  
(See Table 2 for description of landforms.)
2. **Coarse Loamy Landforms.** ..... SS6  
Site is on one of these landform types: recessional moraine, ablation moraine/till.  
(See Table 2 for description of landforms.)
3. **Silty, Fine Loamy, and Clayey Landforms.** ..... SS7  
Site is on one of these landform types: ground moraine, drumlin, lacustrine plain, delta, glacio-lacustrine plain or basin.  
(See Table 2 for description of landforms.)
4. **Moist and Peaty Phase Sites.** ..... SS8  
Small, poorly drained, organic deposits and/or kettles that have continuous tree cover and/or dense shrub growth.
5. **Forested Peatlands, Small Open Peatlands, and Fens.** ..... SS9  
Small organic deposits that are interspersed with numerous islands of bedrock outcrops.



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## Part II - Group C

## Deep Mineral Soil Group

Choose one of the following:

1. **Small areas of peat, small peaty depressions S11**

Small depressions and/or areas immediately adjacent to large forested peatland, ponded water, drainage channels, streams, or lakes. Tall shrubs are usually abundant and may include speckled alder and/or willow. Ground cover frequently contains dark-toned, clumpy, and fuzzy looking ericaceous shrubs such as Labrador tea and leatherleaf.

2. **Coarse Sandy Soils go to Group C-1**

Polygon is on one of these landform types: esker, kame, kame terrace, outwash plain, outwash channel, or valley train. (See Table 2 for description of landforms.)

3. **Fine Sandy Soils go to Group C-2**

Polygon is on one of these landform types: sandy lacustrine plain or basin, or beach ridge. (See Table 2 for description of landforms.)

4. **Coarse Loamy Soils go to Group C-3**

Polygon is on one of these landform types: end moraine, recessional moraine, ablation till, kame moraine. (See Table 2 for description of landforms.)

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## Part II - Group C-1

## Coarse Sandy Soils

Choose one of the following:

1. **Coarse Sandy, Dry to Moderately Fresh. .... S1**

Crest to lower slope positions. Good internal drainage. Absence of water ponding. Shrub poor to moderately shrub rich.

2. **Coarse Sandy, Moist. .... S7**

Lower and toe slope positions. Good internal drainage. Absence of water ponding. Shrub moderate to shrub rich.

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## Part II - Group C-2

## Fine Sandy Soils

Choose one of the following:

1. **Fine Sandy, Dry to Fresh. .... S2**

Crest to lower slope position. Good internal drainage. Absence of water ponding. Shrub poor to moderately shrub rich.

2. **Fine Sandy, Moist. .... S7**

Lower and toe slope positions. Good internal drainage. Absence of water ponding. Shrub moderate to shrub rich.

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## Part II - Group C-3

## Coarse Loamy Soils

Choose one of the following:

1. **Coarse Loamy, Dry to Fresh. .... S3**

Crest to lower slope position. Good internal drainage. Absence of water ponding. Shrub poor to moderately shrub rich.

2. **Coarse Loamy, Moist. .... S8**

Lower and toe slope positions. Good internal drainage. Absence of water ponding. Shrub moderate to shrub rich.

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## APPENDIX C. AERIAL PHOTO INTERPRETATION KEY TO V-TYPES

### Guide to the V-type Key

The following key is intended for use in the interpretation of NWO FEC V-types on vertical, 1:15 840 scale, standard black and white stereo imagery. The recommended imagery format for this purpose is contact print positives from 23-cm x 23-cm (9-in. x 9-in.) negatives, exposed on flat or low-gloss surfaced, high contrast paper. The imagery should be flown during a window when vegetation is in full leaf (late June to late August).

The main decision criteria of this aerial photo interpretation key, as with the NWO FEC V-type key, are composition of the tree canopy and composition of the shrub layer. Initially, this key has three main divisions based on overstory conditions: pure conifer, conifer-dominated mixedwood, and hardwood-dominated mixedwood. Each of these groups is further divided based on the dominant species (or group of species) in the tree canopy. Individual V-types may then be distinguished by assessing the understory shrub conditions (species composition and relative abundance) and, when necessary, the slope position, landform type, and associated soil moisture conditions. The user navigates through the key by answering "yes" or "no" to the description provided about the location being interpreted on the photos.

The aerial photo interpretation key incorporates the V-types that were commonly found during field sampling of the Roslyn Lake Study Area (RLSA); it is not a comprehensive key to all NWO FEC V-types. The key should only be used in the immediate vicinity of the RLSA. If it is to be used in other geographic locations, it should be applied with caution, and only after ground truth observations and calibration of the key for the new location have been completed.

### How to Identify V-types on Aerial Photos Using the API Key

1. On appropriate aerial photos, delineate polygons of similar appearance and stand conditions (e.g., areas that have the same tone, texture, forest cover, species composition, elevation, originating landform, soil depth, or amount of exposed bedrock).
2. Cull polygons representing open water and industrial sites (e.g., mine tailings, pits, or quarries).
3. Within each polygon select an interpretable unit (IU). An IU is a homogeneous area that is representative of the vegetation and soil/site conditions found within the polygon. Ignore vegetation and soil/site conditions that represent less than 10 percent of the total polygon area; consider these only as inclusions.
4. Use the API key to identify the NWO FEC V-types associated with each IU.
5. Identify all V-types represented within the polygon and estimate the proportional area for each type.
6. Repeat Steps 3, 4, and 5 for each polygon.



## V-Type Aerial Photo Interpretation Key for the Roslyn Lake Study Area

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### START

1. Tree canopy cover is composed of conifer species only  
(may contain < 5 percent cover by hardwood species). ..... go to **PART I**  
Tree canopy cover is composed of conifer and hardwood species, or hardwood species alone. .... go to 2
2. Tree canopy cover is mainly conifer (40 percent or greater cover by conifer species<sup>1</sup>). ..... go to **PART II**  
Tree canopy cover is mainly hardwood but may contain significant conifer  
(up to 40 percent of canopy cover by conifer<sup>1</sup>). ..... go to **PART III**

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<sup>1</sup> Although 50 percent seems a more natural number, 40 percent is used because of the tendency to underestimate the cover of conifer species due to overtopping of the conifer crowns by the hardwood canopy. Estimations of 41 percent – 50 percent cover by conifer are therefore directed toward the conifer-dominated section of the key.



## PART I

## Pure Conifer Sites

1. Tree canopy is mainly larch and/or cedar. IU usually occupies a depression or a lowland or toe slope position.  
*cedar* (broad and conical crown; tip usually rounded; branches not prominent)  
*larch* (conical crown; light tone; very light tone towards fall)  
YES. .... V22<sup>2</sup>  
NO. .... go to 2
2. Tree canopy is mainly white spruce and/or balsam fir.  
*white spruce* (conical crown; obtuse top; branches usually prominent)  
*balsam fir* (narrow, very pointed, conical crown; very symmetrical; branches not prominent)  
NO. .... go to 3  
YES. .... V24, V25  
(if understory is visible then choose a. or b. below)
  - a. Broadleaf shrubs are present ..... V24
  - b. Broadleaf shrubs are absent ..... V25
3. Tree canopy is mainly jack pine.  
*jack pine* (irregular crown; pointed top; smooth texture, even tone)  
YES. .... go to 3A  
NO. .... go to 4
- 3A >20 percent of IU is exposed bedrock and bedrock covered with lichen. Jack pine cover is sparse to patchy, with irregular tree height.  
YES. .... V30  
NO. .... go to 3B
- 3B Tree canopy cover is only jack pine.  
YES. .... V28, V29  
NO. .... V31, V32  
(if understory is visible then choose a. or b. below)
  - a. Shrub layer is moderate to dense and/or balsam fir is visible in shrub layer.  
Black spruce is commonly present in tree canopy ..... V31
  - b. Shrub layer is sparse. .... V32
4. Tree canopy is mainly black spruce.  
*black spruce-upland* (conical, slightly club shaped crown; prominent branches)  
*black spruce-lowland* (narrow, cylindrical or club shaped crown; usually on forested peatland)  
YES. .... go to 4A  
NO. .... Ground Truth
- 4A Polygon is on an upland position, not located on organic soils.  
YES. .... go to 4A1  
NO. .... go to 4B

<sup>2</sup> These conditions could also indicate V23. However, there were no V23 samples found in the Roslyn Lake Study Area ground truthing exercise so it was excluded from the key.



4A1 Exposed bedrock and bedrock covered with lichen >20 percent of IU.

YES. .... V30  
NO. .... go to 4A2

4A2 IU can be described by any of the following:

- is in a wet depression or "dish"
- is at toe of slope adjacent to forested peatland
- contains Labrador tea
- contains alder

YES. .... V34  
NO. .... V31, V32, V33  
*(if shrub layer is visible then choose a. or b. below)*

- a. IU has abundant tall shrubs or balsam fir is visible in the shrub layer ..... V31  
b. Shrub layer is sparse,  
and tree canopy contains jack pine ..... V32  
and tree canopy does not contain jack pine ..... V33

4B Polygon is located on an organic soil on wet, low lying or toe slope position.

YES ..... go to 4B1  
NO ..... Ground Truth

4B1 Tree canopy is open to moderately open. Stand may be very patchy or trees are evenly but sparsely distributed. Average tree heights are <10 meters and trees appear unmerchantable. Often found in the inner portion of large organic features and/or adjacent to open peatlands and/or water.

YES. .... V38  
NO. .... go to 4B2

4B2 Tree canopy is moderately open to closed. Trees may be in small clumps or evenly distributed. The average tree height is >10 meters.

NO. .... Ground Truth  
YES. .... V35, V36, 37  
*(if possible continue at a. below)*

a. IU can be described by any of the following:

- canopy is uneven, and there are visible drainage and seepage channels and/or patterns
- tree canopy contains larch or cedar
- shrub layer contains alder or willow

cedar (light tone, broad and conical crown; tip usually rounded; branches not prominent)

larch (conical crown; light tone; very light tone in fall; leafless in winter)

alder (very dark tone, clumpy or often found in linear or ringed distribution pattern, found in low landscape positions)

willow (light grey tone; very dense canopy; individual crowns not identifiable; evenly rounded and domed; fuzzy; smooth to fine granular; irregular stand pattern; even height profile)

YES. .... V35  
NO. .... V36, V37  
*(if possible choose a. or b. below)*



- a. Tree canopy is closed and has few open patches. Trees are tall and well formed. V36  
YES. ....  
NO. .... go to b.
- b. Tree canopy is moderately open and may have patchy or clumpy distribution. Tree heights are low or stunted, but trees still appear to be of merchantable size. Often found in the inner portion of large organic features and/or adjacent to open water. V37  
YES. ....



## PART II

## Conifer-dominated Mixedwood Sites

1. Conifer species is mainly cedar.

*cedar* (broad and conical crown; tip usually rounded; branches not prominent)

NO. .... go to 2  
YES. .... choose a. or b. below

a. Upland position ..... V21

b. Lowland, depressions or toe slope positions ..... V22

2. Conifer species is mainly white spruce and/or balsam fir.

*white spruce* (conical crown; obtuse top; branches usually prominent)

*balsam fir* (narrow, very pointed, conical crown; very symmetrical; branches not prominent)

NO. .... go to 3  
YES. .... (V14<sup>3</sup>), V15, V16

(if shrub layer is visible then choose a. or b. below)

a. Broadleaf shrubs are abundant ..... V15, (V14)

b. Broadleaf shrubs are not abundant ..... V16

3. Conifer species is mainly jack pine.

*jack pine* (irregular crown; pointed top; smooth texture, even tone)

NO. .... go to 4  
YES. .... V17, V18

(if shrub layer is visible then choose a. or b. below)

a. Shrubs are not abundant ..... V18

b. Shrubs are abundant ..... V17

4. Conifer species is mainly black spruce usually with white birch and sometimes with trembling aspen.

*black spruce-upland* (conical, slightly club shaped crown; prominent branches)

*white birch* (crown is small or crown is large, open or multiple; white trunk often forked; tends to grow in clumps)

*trembling aspen* (crown is small or crown is large, open or multiple; light trunk; trunk extends high into crown; trees grow singly, not in clumps)

NO. .... Ground Truth

YES. .... V20, (V19)<sup>4</sup>

<sup>3</sup> V14 was infrequently sampled in the ground truthing exercise suggesting that it is not common in the Roslyn Lake Study Area.

<sup>4</sup> The high occurrence of feathermoss ground cover in the Roslyn Lake Study Area resulted in most of the black spruce mixedwood sites being field keyed to V20. Even sites with significant trembling aspen in the canopy often keyed out as V20. Very few of these sites keyed out as V19. There was no reliable method to separate these two types based on aerial photo interpretation. By assigning V20 to all black spruce-dominated mixedwoods when applying the aerial photo interpretation key, the overall margin of error is reduced.



### PART III

### Hardwood Dominated Mixedwood Sites

- 1 Hardwood cover in tree canopy is only by white birch or cover of white birch >80 percent of IU.

*white birch* (crown is small or large, open or multiple; white trunk often forked; tends to grow in clumps)

YES. .... V4<sup>5</sup>

NO. .... go to 2

- 2 IU is entirely hardwood, usually trembling aspen.

*trembling aspen* (crown is small or crown is large, open or multiple; light trunk; trunk extends high into crown; trees grow singly, not in clumps)

NO. .... go to 3

YES. .... V5

- 3 Conifer component of tree canopy is mainly balsam fir.

*trembling aspen* (crown is small or crown is large, open or multiple; light trunk; trunk extends high into crown; trees grow singly, not in clumps)

*balsam fir* (narrow, very pointed, conical crown; very symmetrical; branches not prominent)

NO. .... go to 4

YES. .... V6, V7

(if shrub layer is visible then choose a. or b. below)

a. Shrub layer is mainly balsam fir and broadleaf shrubs are not abundant. .... V7

b. Broadleaf shrubs are abundant ..... V6

- 4 Conifer component is mainly black spruce and/or jack pine.

*trembling aspen* (crown is small or crown is large, open or multiple; light trunk; extends high into crown; trees grow singly, not in clumps)

*black spruce – upland* (conical, slightly club shaped crown; prominent branches)

*black spruce–lowland* (narrow, cylindrical or club shaped crown; usually on forested peatland)

*jack pine* (irregular crown; pointed top; smooth texture)

NO. .... V8, V9

YES. .... V10, V11

(if shrub layer is visible then choose a. or b. below)

a. Broadleaf shrubs are abundant ..... V10

b. Broadleaf shrubs are not abundant ..... V11

<sup>5</sup> A significant amount of "birch die back" has occurred over much of the Roslyn Lake Study Area; older imagery may not show this. Ground truthing is recommended for all imagery within the vicinity of the Roslyn Lake Study Area. Correlate field observations of white birch conditions with the conditions shown on the imagery. Adjust the aerial photo key if required.



Appearance of Tree Species on Black and White, Panchromatic Aerial Photos (Scale 1:15 840) <sup>6</sup>							
Feature	White spruce	Black spruce	Balsam fir	Jack pine	White cedar	Trembling aspen	White birch
Crown shape	Moderate to wide cone, pointed, dense, symmetrical	Slender, often cylindrical, sometimes club shaped	Needle-like top, very symmetrical, heavy base	Small to moderate, pointed top, irregular rounded	Wide conical with rounded top, smaller than other conifers	Open and rounded	Conical with rounded tip
Stand pattern	Not diagnostic	Regular	Irregular	Regular	Not diagnostic	Regular	Regular
Tone / contrast	Dark / usually low	Dark / moderately high	Moderate / high	Dark / low	Light / moderate to moderately high	Medium to dark / high	Moderately dark / usually low
Crown texture	Coarse	Fairly smooth	Smooth	Smooth	Smooth	Smooth, fine	Smooth, solid
Shape of canopy surface	Erratic changes in height	Even, gradual changes in height	Erratic changes in height	Even, gradual changes in height	Somewhat erratic changes in height	Even, gradual changes in height	Gradual changes in height
Canopy in pure stand	Somewhat closed	Closed	Somewhat closed	Closed	More open than other conifers	Closed, but looser than white birch	Closed, tightly

<sup>6</sup> After Zsilinszky (1966).



Appearance of Shrubs on Black and White, Panchromatic Aerial Photos (Scale 1:15 840)					
Shrub species	Location	Shape	Tone	Texture	Pattern
<b>Broadleaf shrubs (general)</b>	Crest to toe slope positions, margins of organic deposits	Rounded crowns, easy to vertically fix the crown surface, individual crowns are hard to see, groups of stems form clumps in crown surface	Extremely variable	Smooth to granular, may be fuzzy	Variable
<b>Mountain maple</b>	Upland areas	Canopy is very dense, individual crowns not clearly visible	Light to bright tone	Coarse granular to fine blotchy	Stand pattern is irregular, uneven height profile
<b>Speckled alder</b>	Low moist areas, along stream banks, margins of organics, rings around moist to wet depressions	Canopy is very dense, individual crowns not clearly visible, grouped or clustered, crown of groups or clusters are evenly rounded, domed	Dark even tone	Smooth to fine granular, fuzzy	Stand pattern is irregular, clumps often tightly grouped, even height profile
<b>Willow</b>	Low moist areas, along stream banks, margins of organics, rings around moist depressions	Canopy is very dense, individual crowns not clearly visible, crown of a clump is regularly spherical and smooth surfaced	Light tone	Fuzzy	Stand pattern is irregular, even height profile
<b>Conifer Shrubs (general)</b>	All slope positions, all organic deposits	Hard to vertically fix crown surface, very hard to identify individuals	Grey to very dark grey	Moderately coarse to coarse, irregular	Uneven height profile
<b>Black spruce</b>	All slope positions, all soil conditions	Slender crowns with pointed tops, crowns are difficult to vertically fix (but not as difficult as balsam fir), very hard to identify individuals	Variable from very dark to grey	Moderately coarse	Fairly even height profile
<b>Balsam fir</b>	Trend to increased stocking towards slope bottoms, moist to swampy conditions, uplands, shallow soils and areas of high bedrock exposure, commonly associated with conifer stands, especially black spruce	Crowns are very fine spires and thus are difficult to vertically fix, needle like, cannot identify individuals	Dark to very dark grey, evenly toned	Coarse and irregular	Uneven height profile



## **APPENDIX D. GLOSSARY OF SELECTED TERMS**

### **Canopy closure**

A relative estimation or measure of the proximity of tree crowns in a forest stand. A descriptive characterization of the quantity and dispersal of trees that comprise the upper canopy of the stand.

### **Closed canopy**

A stand of trees in which the limbs, boughs, and branches completely fill the space between the tree stems or boles. The ground surface, ground vegetation, or shrub layer are not visible through spaces in the canopy.

### **Even stand**

A stand in which the distribution of the individual trees is uniform and continuous. The height, crown shape, and crown size are uniform.

### **Fine geological surface features**

Fractures, crevices, glacial ice striations, lamellae, and folia in the surface of the bedrock that are often visible on 1:15 840 scale aerial photos.

### **Internal drainage**

Ability of precipitation to infiltrate and move laterally through a soil substrate as evidenced by the pattern and abundance of surface drainage.

### **Interpretable unit (IU)**

An area of any size on an aerial photo that is representative of a larger area or portion of a delineated polygon and upon which the aerial photo interpretation key is to be applied.

### **Macrotopography**

Landscape and landform items that have a photo size of >2 cm on 1:15 840 scale aerial photos. The gross shape or surface expression of landform features.

### **Microtopography**

Landscape and landform items that have a photo size of <2 cm on 1:15 840 scale aerial photos. The surface expression or shape of fine landform features. Very local in nature and varying in actual size from a few meters to approximately 100 meters in size.

### **Minimum polygon size (MPS)**

The minimum allowable size of a polygon or feature to be delineated on an aerial photo. The MPS can vary in size for different API exercises. Its size is dependent upon many factors including:

- scale of map to be produced;
- intended use of map;
- cartographic process limitations; and
- distinctiveness or significance of the mapped element.

### **Open canopy**

A stand of trees in which tree crowns are recognizable as individuals and are clearly separated from each other. The ground surface, ground vegetation, or shrub layer is usually visible through the intercrown spaces in the canopy.

### **Patchy stand**

A stand in which the trees are not evenly distributed, and tend to be grouped in clumps. There are spaces where no trees occur.



**Polygon**

An area of any size that has been delineated on an aerial photo. The area within a polygon should be homogeneous in content and uniform in appearance.

**Surface drainage pattern**

Pattern of lakes, rivers, intermittent creeks, rills, and organics. (e.g., Deranged drainage has no consistent pattern, shape, or direction. It is often the result of strong mitigating influences, such as underlying bedrock.)