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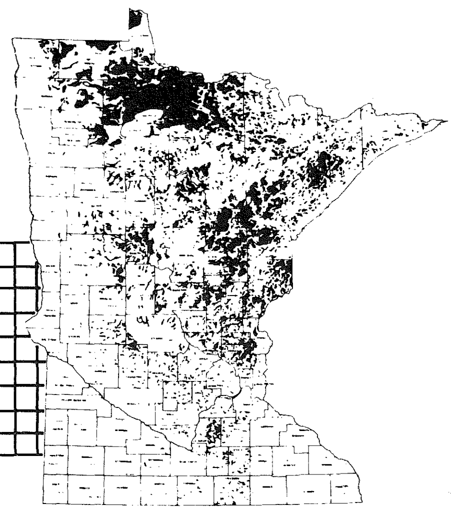
MINNESOTA PEAT PROGRAM

Vegetation Analysis of the Red Lake Peatlands by Remote Sensing Methods



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VEGETATION ANALYSIS OF THE RED LAKE PEATLANDS

BY REMOTE SENSING METHODS

Final Report

to

Peat Program, Minnesota Department of Natural Resources

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VEGETATION ANALYSIS OF THE RED LAKE PEATLANDS BY REMOTE SENSING METHODS [1/]

by

Roy T. Hagen and Merle P. Meyer[2/]

ABSTRACT

Summer, leaf-on 1:15,840 scale B&W infrared 23 x 23-cm (9 x 9-in) forest aerial photography supplemented by 35 mm color infrared (CIR) vertical aerial photography and 35 mm color oblique aerial photographs was used to perform a vegetation classification and analysis of 225 square miles of the central portion of the Red Lake Peatlands in northwestern Minnesota. The vegetation was classified to a 3-ha (7.5-ac) minimum using a scheme based on species, height, vigor, density, and pattern. Nine 35 mm CIR aerial photographic transects flown at two scales (1:80,000 continuous coverage and 1:11,000 photo plots) were located in key areas to demonstrate vegetation types, landscape features, environmental gradients, and types of disturbance -- i.e., natural or man-made.

INTRODUCTION

For most of this century, Minnesota's peatlands, over 2,800,000 ha (7,000,000 ac), have been considered of very low economic value. Their main use in northern Minnesota has been for the production of lowland conifers for pulpwood under low levels of management. Following the widespread, ill-conceived, and almost totally unsuccessful attempts at drainage for agricultural development (circa 1905-1920), interest in our peatlands declined for a long period of time, and they remain a large, little studied, poorly

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understood resource. This situation is changing rapidly, spurred by growing pressures for development of peatlands, particularly proposals for large-scale extractive use of peat as an energy source.

The Minnesota Department of Natural Resources (MDNR), by legislative mandate and by virtue of its dominant peatland ownership position, has primary control over peatland development in Minnesota. To partially meet the obvious need for basic information necessary for assessing impacts, weighing alternatives, and developing regulations, the MDNR has funded a number of research studies and inventories; the vegetation analysis of Red Lake Peatlands described in this report is one of them.

The Red Lake Peatlands were targeted for this study by the MDNR for several reasons. They contain the most highly developed patterned peatlands in Minnesota. A large sector has been designated as a National Landmark and is under study for registration as a National Landmark. Likewise, a portion has been recommended for designation as a Scientific and Natural Area under the MDNR Division of Parks and Recreation. Finally, the study area coincides at least in part with that of four other concurrent biological studies also funded by the MDNR: (1) ecological and floristic studies of peatland vegetation, (2) bird populations and habitat use, (3) relationships of amphibians and reptiles to peatland habitats, and (4) importance of peatland habitats to small mammals.

PROJECT AREA LOCATION, DESCRIPTION

A. Location

The study area lies in northwestern Minnesota in northeastern Beltrami County and a portion of west central Koochiching County (Figure 1). It is centered at Latitude 48°18'N. by Longitude 94°39'W., and covers 583.5 km^2 (225.3 mi^2) or 57,680 ha (144,200 ac). The precise limits of the study area were defined at the inception of the project by the MDNR. Portions of nine 7.5-minute USGS quadrangles are included, and they served as the basic working units for the study.

B. Physiography

The Red Lake Peatlands have developed on the portion of the lakebed of Glacial Lake Agassiz that was drained prior to 10,000 years B.P., but general peat accumulation did not begin until much later when the cooling climate produced conditions favorable for peatland development (Wright 1972).

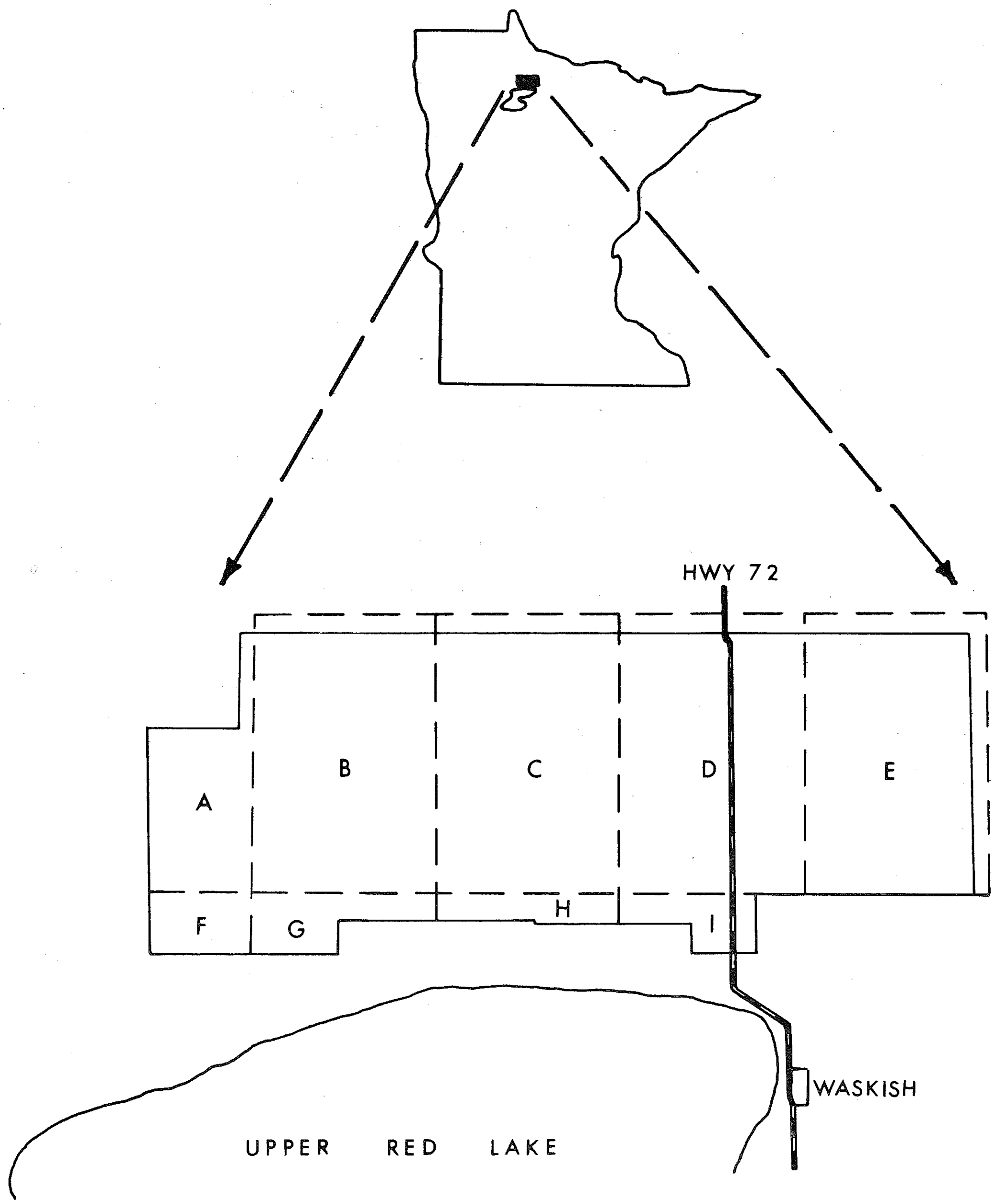


Figure 1. The general location of the Red Lake Peatlands Study Area is indicated on the map at the top. Shown at an increased scale below it are the boundaries of the study area (solid line) and of the 7.5-minute quadrangles involved (dashed lines): A- Oaks Corner, B- Hilman Lake, C- Chase Brook SW, D- Ludlow Lookout Tower, E- Wayland SW, F- Ponemah NW, G- Ponemah NE, H- Waskish NW, and I- Waskish NE.

Three radiocarbon dates are available for the Red Lake Peatlands: (1) the easternmost taken from a water track on the eastern edge of the Wayland SW Quadrangle is dated at 3,950 ± 80 yrs. B.P. (Wisc. 1037), (2) another taken in the large water track just west of Hilman Lake in the Hilman Lake Quadrangle is dated about 3,000 yrs. B.P. (Griffin 1975), and (3) one taken in the same water track near the western edge of the Oaks Corner Quadrangle was dated at 1,950 ± 65 yrs. B.P. (Wisc. 1035). These three dates, though sketchy, may indicate a gradual westward expansion of the peatlands from 4,000 to 2,000 B.P.

The lacustrine substrate does not form a basin but rather a broad, very gently sloping, saddlelike plain with its east-west trending crest only 1.5-2.1 m (5-7 ft) above Red Lake (Heinselman 1963). Peat now blankets all but 1.1% of the study area, the only exposed mineral soil being found in the Ludlow Island Complex (Ludlow Lookout Tower and Wayland SW quadrangles), in the southeast corner of the Wayland SW Quadrangle, and in the Waskish Quadrangle. Three-acre Hilman Lake is the only naturally occurring open water body in the study area; its cause is unknown.

Soper (1919) published peat depths for parts of Beltrami County from survey data collected in conjunction with the drainage program underway at that time. Three hundred thirty-three peat depths are reported within the present study area covering all but the western one-fifth of the area and the two tiers of sections in Koochiching County. The deepest peat deposits -- commonly exhibiting depths of 3.0-4.3 m (10-14 ft) to 4.9 m (16 ft) at a maximum -- occur along the crested bog divide near the southern edge of the Chase Brook SW and Hilman Lake quadrangles. The peat depths north of the bog divide in the ovoid island complex are only slightly less (2.4-4.3 m (8-14 ft)), as are those in the spruce-sphagnum bogs in the northern half of the Wayland SW Quadrangle. Peat depths in the large minerotrophic fens tend to be a little shallower than the adjacent bogs with average depths of about 1.8-2.4 m (6-8 ft) in the Ludlow Lookout Tower and Wayland SW quadrangles and 1.8-3.1 m (6-10 ft) in the Hilman Lake Quadrangle. Peat depths reported by Farnham and Grubich (1966) along the crested bog divide tend to run slightly greater than those reported by Soper.

C. History

Beltrami County was settled late in the history of the state and there was little activity in the peatlands north of Red Lake prior to 1900. However, during the period from about 1909 through 1917, Beltrami County undertook a massive ditching program with 1370 km (850 mi) of ditch constructed in present day Beltrami County (Lake of the Woods County split off from Beltrami County in 1922). The goal was to render the peatlands suitable for farming; the ditches were to be paid for over a 20-year period by a special ditch tax levied against the properties benefited. Any group of landowners could petition the district court to have their properties ditched. The petition for Ditch 25 was signed by nine landowners, only three of whom lived on the land affected; the ditch was built at a cost of $554,700. The ditching, which followed section lines with little apparent regard for natural drainage patterns, was unsuccessful, the lands were forfeited for taxes, and the county was left hopelessly in debt. The indebtedness was eventually paid by the State of Minnesota, which purchased the tax-forfeited lands from the county for the amount of the debt, ostensibly for the creation of a game preserve (Vandersluis 1963).

There are 357 km (222 mi) of these old ditches in the study area, of which all but 1.6 km (1 mi) are in Beltrami County. The ditches are spaced one every 1.6, 3.2, or 4.8 km (1, 2, or 3 mi). The only unditched sectors are the 41.4 km^2 (16 mi^2) of Koochiching County and about 90.6 km^2 (35 mi^2) of minerotrophic peatland in the southwestern corner of the study area. Less than one-half of one percent of the ditched peatlands in the study area were ever farmed, and most of the farms initiated lasted only a short while.

Since the early ditching spree, most of the study area has become a de facto wilderness area. Timber harvest has not been a major activity; most of it has been concentrated on the Ludlow Island Complex and, more recently, in the better stands of black spruce on the bog divide in the southern edge of the Chase Brook SW Quadrangle and in the Waskish NW Quadrangle. Some smaller stands of black spruce have also been cut west of Highway 72 in northern Ludlow Lookout Tower and northern Chase Brook SW quadrangles. Christmas tree harvest in black spruce stands has been a very widespread seasonal activity but apparently one of low impact. Close inspection of aerial photographs indicates nearly all black spruce stands have been gone over by Christmas tree cutters at one time or another.

The only all-weather road within the study area is State Highway 72, which started out as a frequently impassable "ditchbank" road but has since been improved to a two-lane paved asphalt highway.

D. Vegetation/Hydrology

The patterns so characteristic of the vegetation of the Red Lake Peatlands have intrigued all who have seen them since the first aerial photography was flown in 1940. Although many of these landscape features have been described in some detail and numerous hypotheses have been set forth, few of the causal mechanisms and dynamics of the system are known. Clearly, the vegetation is intimately related to the hydrology with respect to water source, water chemistry, and the volume and channelization of surface and near-surface flow. Nowhere is this more dramatically demonstrated than in the difference between the central raised bog complex centered in the Chase Brook SW Quadrangle and the huge patterned sedge fen, often referred to as the Western Water Track, immediately to the west. The bog complex is an ombrotrophic peatland; the only known input of water and nutrients is from the sky. The bog waters are very acid, low in dissolved salts, and highly colored with dissolved organic matter. Exposed surface water is not common. The area supports a nearly continuous cover of moss, predominantly sphagnum, and various densities of tree cover. The trees are predominantly black spruce, although tamarack is also common.

The Western Water Track is a minerotrophic peatland; in addition to precipitation, a major source of water is mineral-rich groundwater and surface runoff from the mineral uplands to the west. The waters are only slightly acidic, relatively rich in dissolved salts, and generally only slightly colored. Mosses are only a minor component of the fen vegetation; sedges predominate and the trees that occur on scattered islands are mostly tamarack. Shallow, standing surface water is common throughout most of the summer.

The demarcation between the central ombrotrophic bog complex and the minerotrophic Western Watertrack is obvious on any aerial photograph. However, there are numerous areas where the distinctions are not clear, the source of water is not obvious, and the peatlands cannot be readily classified as ombrotrophic or minerotrophic. Much of the peatlands east of the central raised bog complex are influenced, to different degrees, by nutrient enriched groundwater from the Ludlow Island Complex and other scattered mineral islands. The vegetation ranges from decidedly ombrotrophic spruce-sphagnum bog to minerotrophic sedge fen with many gradations and variations in between.

Even in the large ombrotrophic bogs on deep peats (over 2 m), the vegetation and the water chemistry change markedly as one progresses downslope.

Within the central raised bog complex, Gorham et al. (1978) reported decreasing acidity and vegetation increasingly characteristic of minerotrophic fens as one proceeds from the spruce-covered bog divide (Carex trisperma - Vaccinium vitis-idaea association defined by Gorham et al.) downslope north across the broad open sphagnum-covered community (Carex oligosperma association) and into the narrow patterned fen water tracks that separate the distinctive ovoid-shaped spruce-sphagnum islands. Why this should be is not known, but one sees the same vegetational change on the western slope of the large ombrotrophic bog in the northern half of the Wayland SW Quadrangle. Increasing volume of near-surface flow downslope and channelization of flow are probably important factors in the vegetational gradient, but the cause of change in water chemistry is not understood.

The raised ovoid-shaped spruce-sphagnum islands are the most distinctive feature of the central bog complex. They first appear one to two miles north of the bog divide. These islands are short and squat, their width nearly equalling their length. Their margins are very poorly defined on the upslope ends where they grade into the Carex oligosperma association described by Gorham et al. (1978). They are mostly covered with stunted black spruce of various densities.

A little farther downslope is another set of large, more streamlined, ovoid islands sharply delineated by narrow patterned fen water tracks. The length of these islands is generally at least twice their width. A very distinctive feature of these ovoid islands is their open centers; similar islands are not known to occur elsewhere in Minnesota. More will be said about these islands in the Discussion section of this paper.

Other ovoid spruce-sphagnum islands occur across most of the northern half of the study area -- all north of the watershed divide. Some are completely surrounded by the patterned fens of large water tracks and tend to be well defined with length two to three times greater than width. They tend to support a more productive, nearly continuous cover of black spruce (where undisturbed by fire or dwarf mistletoe). Some give the distinct impression of having been formed by the fusion of two or more smaller islands. A good example, located at the central right edge of the Chase Brook SW Quadrangle, is the island with the curious fire scar. This fusion would imply that the islands have increased in size through time. Two large features (top center of the Chase Brook SW Quadrangle and top right of the Ludlow Lookout Tower Quadrangle) resemble ovoid islands, but are totally fused upslope with large ombrotrophic peatlands.

Another landscape feature of the central bog complex is the pattern of small, nearly circular, spruce-sphagnum islands in a sedge fen that occurs immediately upslope (south) from the ovoid islands with the open centers. This pattern is believed to be unique, at least to Minnesota, and its cause is unknown.

All of the major fens in the study area and many of the smaller ones display the distinctive ridge and pool pattern described by Heinselman (1963), Hofstetter (1969), and others. Although highly variable in terms of size, spacing, degree of development, and vegetative cover, the ridges are invariably oriented more or less perpendicular to the direction of surface water movement. Furthermore, this pattern is only found (1) in open sedge fens with significant surface and near-surface flow, (2) in fens disturbed by ditching and subsequently invaded by shrubs and/or trees, (3) in margins of ombrotrophic bogs immediately adjacent to patterned fens, and (4) occassionally in very open, largely sphagnum-covered communities, downslope from decidedly ombrotrophic bogs where there are indications of channelization of near-surface flow; the ridge and pool pattern found in this bog-fen transition type is poorly developed compared to that characteristic of open sedge fens.

The larger patterned sedge fens display another feature commonly called tamarack islands. They are generally streamlined, teardrop-shaped islands invariably oriented parallel to the direction of water movement. They are variable in their size, shape, spacing, vegetative cover, and degree of development. The head or upslope ends of the islands, often have a dense clump of tamarack with scattered black spruce. The tails are dominated by ericaceous shrubs and/or bog birch. Others are almost devoid of trees; one island that was observed in the Western Water Track had a clump of tamarack on the tail end and only shrubs at the head. In some places, islands have apparently grown together into various shapes. All support a more or less continuous cover of various mosses. The Western Water Track is dotted with hundreds of tamarack islands. Others occur in the patterned fens that drain north from the central raised bog complex, and a few are found in the large patterned fen northwest of Ludlow Island.

The last major features within the study area are the vast stands of stunted tamarack, which border both sides of the Western Water Track west of the central raised bog complex and upslope from the westernmost ditches. The stand of tamarack north of the water track is especially stunted and uniform with a faint pattern reflecting the near-surface water movement. South of the Western Water Track, the tamarack are very stunted near the water track but become increasingly more vigorous to the south where portions have been commercially logged.

The presettlement vegetation patterns, though altered to different degrees by the ditches and to a lesser extent by fire, are still discernable over most of the study area. Logging and agriculture have been too localized to have much effect. Two areas have been altered substantially to the point where the original nature of the peatland is in doubt. The first is the ditched portion of the area northwest of the upper arm of the Western Water Track. This is mostly a broad, open area covered with dense ericaceous shrubs except near the ditches, where taller deciduous shrubs (bog birch and willow), grasses, and sedges predominate. Scattered tamarack are of moderate vigor. This area ends abruptly upslope at the southwesternmost ditch. Beyond lies the vast stunted stand of tamarack described earlier. This may well have been the nature of the disturbed area before ditching; if so, it has been greatly altered. The second heavily disturbed area lies south of the Ludlow Island Complex and east of Highway 72. It is not at all clear what this area was like before ditching and fires altered it.

Over the remainder of the area, ditching has tended to have relatively little effect on the ombrotrophic bogs and relatively large effects on the minerotrophic fens. Ditches tend to be disruptive in direct relation to the degree with which they happen to correspond with natural drainage patterns. Wherever a suitable food supply exists, beavers have colonized the ditches and have caused localized flooding and disruptions in water movements. These effects are continually changing as new dams are built and old dams abandoned. Most of the ditched minerotrophic peatlands support suitable food species for the beaver and, consequently, numerous beaver colonies are present in the ditches. The ditched ombrotrophic bogs generally do not support beaver colonies, although one is amazed at the locations where dams are sometimes found.

PROJECT OBJECTIVES

The main objective of the project was the preparation of 100% site-specific 1:24,000 scale vegetation classification maps of the Red Lake study area from aerial photography. A second smaller area in St. Louis County's Toivola

Bog was contemplated for study but it was not possible to accomplish this in the current study. The study area vegetation classification was to be accomplished through use of the most recent available medium-scale forest aerial photography, supported by special 35 mm aerial photography overflights at the time of the project.

A second objective of the study was the selection or design (if need be) of a peatlands vegetation classification scheme that was not only suited to the Red Lakes study area, but also subject to adaptation for use on differing conditions outside the study area. Upon reviewing the existing classification schemes, the MDNR found none to be satisfactory in their present form (the lack of concise, usable definitions of terms such as bog, fen, and swamp forest presented too many ambiguities in applying any particular scheme). Consequently, it was decided to develop a new classification scheme based upon species dominance and to make the detail of the scheme be a function of the quality of the aerial photography used.

The final study objective was to measure and summarize areas by cover type and by 7.5-minute quadrangles for the study area.

AERIAL PHOTOGRAPHY

The most recent 23 x 23-cm (9 x 9-in) aerial photography available for the basic vegetation classification was 1:15,840 scale summer infrared B&W coverage flown in 1976 (Beltrami County) and in 1972 (Koochiching County). Overall quality was, on the average, fair for forest stands but fair to very poor for shrub and important herbaceous plant communities. Consequently, it was determined that supplemental small-format aerial photography would be necessary.

Three different types of supplemental 35 mm were selected for use: (1) total coverage of the area with 35 mm 1:120,000 scale vertical color infrared photography, (2) dual camera (f = 28 mm and f = 200 mm, respectively) color infrared vertical photography flown so as to provide coverage of approximately 56.3 km (35 mi) of representative transects selected by the investigators, and (3) color obliques of selected ground areas to further assist in the interpretation of the B&W aerial photographs.

The transects flown with the dual 35 mm camera system were accomplished in such a manner and from an altitude sufficient to provide continuous coverage at a scale of 1:80,000 with the 28 mm focal length camera. Simultaneously, the 200 mm focal length camera (bore sighted to the center of the 1:80,000 line of photography) was triggered at a regular, preselected interval to provide

1:11,000 scale photo plots along the transect. This supplemental photography was intended to (and did) serve the following purposes: (1) assisted in the basic vegetation classification, (2) served as a working base for field checking for all investigators, and (3) increased the understanding of peatland characteristics and bog processes.

DATA COLLECTION, RESULTS

A. Phase I - Vegetation Classification

1. Study Design

Procurement of materials - location and purchase of 1:15,840 scale photos, purchase of the nine stable base 1:24,000 scale orthophoto 7.5-minute quadrangles for base maps, purchase of orthotopomaps, purchase of overlay, drafting film, and other working materials.

- Preliminary field reconnaissance.
- Photo overlay preparation.
- Gathering reference data.
- Preliminary photo interpretation and field checking.
- Photo interpretation.
- Transfer of photo interpreted detail to 1:24,000 scale base map overlays.
- Final drafting of 1:24,000 vegetation overlays, editing, and photographic duplication.
- Area measurement of cover types, tabulation, and summary by cover type by quadrangle.

2. Reference Data

Reference data for this study included diverse sources of information used to better understand, analyze, and classify the vegetation of the Red Lake Peatlands. Sources of reference data used included the following: (1) published literature, (2) various maps, (3) personal communication with other investigators and resource managers, (4) direct field observation on the ground or from the air, (5) color infrared photography from Phase II of this study, (6) other small-scale color infrared photography flown independently by the IAFHE Remote Sensing Laboratory, (7) true color, low altitude oblique aerial photographs taken throughout the study area, and (8) 1940 black and white aerial photographs and satellite (Landsat) imagery.

3. Classification Scheme

As stated earlier, the classification scheme used was developed specifically for the Red Lake Peatlands by the senior author under guidelines set down by the MDNR. Because it is based on species dominance, it should be readily adaptable to other peatlands.

The classification scheme was not formalized until after the completion of the summer's field work at the commencement of the photo interpretation process. The degree of detail is essentially a function of the quality and resolution of the 1:15,840 scale B&W photography. The classification scheme, in its final form, is shown in Table 1.

Peatlands and Mineral Uplands

The Peatlands and Mineral Uplands categories are distinguished by the presence or absence of peat -- a situation not always clearly discernable on the aerial photography, however. The two main interpretation clues are topographic relief and vegetative cover. Even on the uplands the relief is often very slight and is even more difficult to detect where obscured by tree cover. Vegetation generally provides the strongest indication of mineral uplands, but here, too, one must be careful. In the northeast corner of the Oaks Corner SW Quadrangle, the interpreter found quaking aspen (*Populus tremuloides*), a typical upland species, growing on 56 cm (22 in) of peat over sand. For these reasons, peatland-upland transition zones were delineated on the vegetation maps with a distinctive symbol to indicate to the user that these are areas of generally shallow, perhaps even discontinuous, peat. However, in classifying the vegetation and in measuring the acreages of these zones, they are considered Peatlands.

As the Mineral Uplands were only of secondary interest to this study, their vegetation was cover typed using a very general, physiognomic classification. All undeveloped and nonagricultural uplands supported a nearly continuous cover of woody vegetation. The woody vegetation was classified as needleleaf evergreen trees (N), broadleaf deciduous trees (d), deciduous shrub (Sd), or as mixtures of these three types (e.g., DN, DSd). Each class had to have at least 10% visible coverage to be included in a cover type designation. For example, shrub coverage pertains only to those shrubs that are not obscured by a tree canopy and are, therefore, visible to the photo interpreter.

The other two upland classes, Abandoned Agriculture (AAu) and Developed (Dv), are land use categories. State Highway 72, which is an

Table 1. Classification Scheme Developed For Red Lake Peatlands.

MINERAL UPLANDS

WOODY	-	≥ 10% canopy cover
N	-	Needleleaf evergreen forest
D	-	Broadleaf Deciduous forest
DN	-	Mixed; over 10% cover of both D and N
Sd	-	Deciduous Shrub
NONWOODY	-	< 10% cover of woody species
Au	-	Agriculture; field or pasture
AAu	-	Abandoned Agriculture (not used within the past year)
Dv	-	Developed; largely unvegetated

PEATLANDS - Includes Uplands - Peatlands transition zone

FOREST TYPES

Species		
Sp	-	Black Spruce
Ms	-	Dwarf Mistletoe infection in black spruce
T	-	Tamarack
Sc	-	Swamp conifer; black spruce and/or tamarack
C	-	Northern white Cedar
SpC	-	Black Spruce and/or Cedar
P	-	Aspen (Populus spp.)
F	-	Black Ash (Fraxinus)
Height		
a	-	< 8 meters average height
b	-	≥ 8 meters
Vigor	-	Applied only to undisturbed stands
-	-	Low vigor; trees stunted and height < 8m
Density		(Canopy cover)
'	-	10-40%
''	-	41-70%
'''	-	71-100%

PEATLANDS... CONT'D.

DECIDUOUS SHRUBS

Species		
W	-	Willow (Salix spp.)
WAl	-	Willow and/or Alder
B	-	Bog Birch
WB	-	Willow and/or Bog birch
Sh	-	Deciduous Shrub
Density	-	Same as for forest types

HERB, MOSS and ERICAD TYPES

M	-	Moss; continuous sphagnum with sparse sedges and ericads
Mh	-	Wet Moss; similar to M but on a wetter site, sedges and/or ericads more abundant
L	-	Leatherleaf; depicts a previously forested, burned over raised bog without tree reproduction, leatherleaf is commonly dominant
E	-	Ericads; continuous cover of ericaceous shrubs with or without a moss layer, graminoids sparse or absent
S	-	Sedge; little or no sphagnum
G	-	Graminoids; grasses and/or sedges
Ph	-	Phragmites; giant reed grass
Ut	-	Tamarack Understory; variable mixture of herbs, mosses, ericads and sometimes small dedicuous shrubs

SPECIAL FEATURES

R	-	Ribbed vegetation pattern
Ti	-	Tamarack islands; long narrow raised islands oriented parallel to water flow
Spi	-	Spruce island; circular spruce-sphagnum island in a sedge fen
Lg	-	Logged over
AA	-	Abandoned Agriculture

PEATLANDS...CONT'D.

CONVENTIONS

Minimum type unit: 7½ acres

General sequence of symbols for combined types:

1. R, AA or Lg
2. Forest type
3. Deciduous shrub
4. Herb, moss or ericad type
5. Ti or Spi

OTHER SYMBOLS

- Type line
- Mineral upland
- Peatland-upland transition (shallow peat)
- Direction of water flow in a ditch
- Project area boundary
- Quadrangle boundary
- Open water

artifically created upland, was classified Dv.

Peatlands Vegetation

Peatlands vegetation was broken into three main groups: Forest Types, Deciduous Shrub Types, and Herb, Moss and Ericad Types.

Forest Types

Forest Types were described by species, height, vigor, and density, in that order. Black spruce (sp) and tamarack (T) were clearly the two major tree species on peatlands; northern white cedar (C), Populus spp. (P), and black ash (F) also occurred as mappable units but were all very limited in aerial extent. Dwarf mistletoe infections in black spruce stands cover large acreages and were broken out as a separate forest type (Ms). Black spruce and tamarack were frequently indistinguishable in certain situations; this occurred primarily in low density, very stunted stands on the downslope margins of spruce-sphagnum bogs and in small sapling-size reproduction on old burns. In general, species identification of trees becomes more difficult as a direct function of decreasing size and height of the tree and of decreasing crown cover (density). Indistinguishable stands of spruce and/or tamarack were classified Sc (Swamp conifer). In a few instances black spruce could not be distinguished from white cedar; such stands were labelled SpC.

All forest stands were classified by height as follows:

a - less than 8 m average height.

b - greater than or equal to 8 m.

Height estimates were made while viewing the stands stereoscopically; they were not measured photogrammetrically and, therefore, are not precise estimates.

Undisturbed forest stands were further classified subjectively as to vigor. Stunted stands of low vigor are indicated with a short dash (-) following the symbol for height class. It was arbitrarily decided that stands over 8 m (26 ft) in average height (size class b) are, by definition, not stunted and of low vigor. A major difficulty arose, however, in attempting to assess the vigor of tree reproduction on disturbed sites, particularly on fire scars, in ditched fens and fen margins, and in dwarf mistletoe infections. This proved impossible to do in a meaningful way. In short, the low vigor class was only applied to stands of height class "a". A stand labelled with a short dash (-) quite clearly is of low vigor and probably will never get much over 8 m (26 ft) in height; most of these stands have not been significantly disturbed. All other stands of height class "a" that are not labelled with a dash (-) are on sites that have been disturbed in some way and may or may not be of low vigor. Tree reproduction of height class "a" on old burns was not classified as to vigor nor were dwarf mistletoe infections (Ms).

All forest stands were classified by density (canopy cover) as follows:

' - 10-40% crown coverage

'' - 41-70%

''' - 71-100%

A stand had to have a minimum of 10% tree cover to be classified as a forest stand. A stand of mixed species, height, or vigor classes was broken down by density classes as follows:

- mixed stands with 10-40% total crown coverage of all tree species were typed by the species having the greatest crown coverage and assigned the height and vigor class appropriate for that dominant species.
- mixed stands with over 40% total crown cover were broken into their components by density class (e.g., Spb"Tb', Spb'Spa').

However, there had to be at least 10% cover of a species of size class to be included in the cover type description. Furthermore, the total crown coverage of a stand must match the sum of the crown coverage classes in the cover type symbol. For example, a 10 m (33 ft) mixed stand with 45% cover of black spruce and 20% cover of tamarack should be correctly typed as Spb'Tb', not as Spb"Tb'.

Deciduous Shrubs

Deciduous Shrubs, the second major Peatland group, were classified by species and density; no height or vigor classes were attempted. Species identification of shrubs from medium scale B&W aerial photographs is generally quite difficult, but, as was true for forest types, the species diversity of deciduous shrubs over most of the Red Lake Peatlands is extremely low, thereby greatly simplifying the photo interpreter's task. Over most of the study area, bog birch (Betula pumila) -B and willow (Salix spp.) -W are the only two deciduous shrubs that occur in significant amounts. Alder (Al) occurs locally in proximity to mineral uplands. Bog birch and willow frequently could not be distinguished;

such stands were labelled WB. If no species determination could be made, the deciduous shrubs were labelled Sh.

The same three density classes used for forest types were applied to Deciduous Shrubs. However, shrub density estimates refer only to those shrubs not found directly beneath a tree canopy; such shrubs are generally not visible to the photo interpreter and no attempt was made to "guess" at the shrub coverage beneath the canopy. As for trees, 10% was the minimum density for deciduous shrub classification. No shrub (or other understory type) designations were made if the tree density exceeded 70%.

As one would expect, the Herb, Moss, and Ericad (ericaceous shrub) Types were more difficult to classify and identify than the Forest and Deciduous Shrub Types. With the exception of the Phragmites communis type (Ph), none of the others were classified, nor could they be identified, to the species level. This is due primarily to the short height and the greater species diversity of these types. As used in this report, herbs shall include both graminoids and forbs.

Herb, Moss, and Ericad Types were classified mainly on the basis of the presence or absence of a sphagnum moss layer. This was done because sphagnum is not only an indicator of site but also has the marked ability to alter the site where it occurs because of its wide C/N ratio, the strongly acid reaction of its remains,and its consequent resistance to decomposition (Heinselman 1963).

Three types (M, Mh, and L-) are characterized by a nearly continuous layer of sphagnum moss. The pure M (Moss) type occurs most commonly immediately downslope from decidedly ombrotrophic forested bogs but can occur also on bog divides, in the open centers of the ovoid-shaped spruce-sphagnum islands in the Chase Brook SW Quadrangle, and on the lateral fringes of forested bogs where they interface with sedge fens. It is characterized by nearly continuous sphagnum, sparse sedges, and short, sparse ericads. There is generally very little open surface water, but the water table is very close to the surface. The nonforested M type corresponds closely to the Carex oligosperma association of Gorham et al. (1978).

M was further used to describe the understory of the low and medium density stunted spruce and/or tamarack bog forests, which normally occur contiguous to and immediately upslope from the open M type (common examples are Spa-'M, Spa-"M, Sca-'M). As an understory, the M type is still characterized by nearly continuous sphagnum but is generally a little drier; the ericaceous shrubs are usually more vigorous and dense. The M understory seems to correspond with the Carex trisperma association of Gorham et al. (1978), but it is not distinguishable on the aerial photography except by the presence of a partial forest canopy. The understory of bog forests of over 70% density was, of course, not described, and nearly all undisturbed stands of height class b (over 8 m (26 ft)) also had over 70% canopy cover. The M type is virtually never associated with Deciduous Shrub types.

M was never used to describe bog forests that have been disturbed by fire, logging (Lg), or dwarf mistletoe (Ms). The understory of all bog forests that have been burned and that have less than 70% cover of tree reproduction is typed L. The symbol L denotes leatherleaf (Chamaedaphne calyculata), a common dominant on such sites. It is generally possible to tell quite accurately on the B&W photography whether or not a site was forested prior to fire; it is most difficult to tell where the prefire forest stand was very stunted and of very low density (10-20% cover).

The L type again has a nearly continuous cover of sphagnum. Ericads differ greatly in vigor and density; sedge cover is never dense. If discernable tree reproduction is less than 10%, the stand is simply classified as L. Tree seedlings and small saplings on a burn may be difficult for the interpreter to discern and actual tree density in such a case may be underestimated.

The third category characterized by a sphagnum layer is the Mh type (h for hydric). This type is similar to the M type but occurs on wetter sites that are generally transitional between bog and fen. The Mh type is found principally in two situations: (1) within surrounding areas of the M type where the near-surface runoff has been partially channelized producing wetter conditions, and (2) on the ridges of some patterned fens, particularly fens that receive a large part of their waters from ombrotrophic peatlands. In the first situation the sedge component is generally more important than in the M type, and in the second case the ericads clearly predominate over the sedges.

Two of the Herb, Moss, and Ericad Types have little or no moss cover; these are the S (Sedge) and G (Graminoid) categories. Both are characteristically fen types, but they can also result from localized flooding (normally caused by beaver dams) of more ombrotrophic peatlands. Graminoids is a general class dominated by grasses and/or sedges. The S type is clearly dominated by sedges.

Grasses and sedges could not be distinguished directly by their spectral response patterns, but areas where grasses may predominate can be inferred by site, degree of disturbance, and degree of wetness. Virtually all patterned fens that have not been severely "dried up" by ditches or road obstructions are dominated by sedges -- most commonly *Carex lasiocarpa*. Those fens that are much drier, such as occur immediately downslope from Highway 72, may be dominated by grasses such as *Agrostis* spp. This relative dryness is apparent on the infrared photography, and the graminoid component is then typed as G. Various mixtures of grasses, sedges, and deciduous shrubs commonly form bands of varying width along ditches in some minerotrophic peatlands. This is very common in the northwestern section of the Hilman Lake Quadrangle where *Calamagrostis canadensis* is a common dominant. This seems to be at least partly related to past fires. Other graminoid mixtures occur as a result of flooding by beaver dams constructed in the ditches.

Two types, E and Ut, may or may not have a moss layer. E (Ericads) is commonly leatherleaf. Because of the closed canopy of ericads, the presence or absence of a moss layer cannot be detected on aerial photographs; field observation revealed that both situations can occur. The E type normally occupies sites that are transitional between ombrotrophic and minerotrophic but tend towards the minerotrophic. This type is often devoid of trees, but when trees occur, they are most commonly tamarack. The E type often includes varying densities of bog birch and may grade into dense stands of bog birch, which have an understory of ericads. However, unless the bog birch is significantly taller than the ericads, it cannot be readily detected.

The other type, Ut (Tamarack Understory), is a variable mixture of herbs, mosses, and ericads that may sometimes include small deciduous shrubs such as bog birch. It most commonly occurs as an understory in low density stunted tamarack stands on minerotrophic or transitional sites but may also occur on nonforest sites (often with scattered, widely spaced tamarack). It generally includes a fairly rich mixture of herbs and ericads, which tend to obscure the extent of the moss layer. Most stands classified Ut probably have a moss layer, but one that is perhaps more variable than those found on ombrotrophic sites. The Ut is, to some extent, the "catch-all" category for herb, moss, and ericad stands that do not fit readily into any of the other types.

The final type, Ph (Phragmites communis), was identifiable to the species level because of its unusual height. Even so it was only identified in the Ponemah NE Quadrangle, where it occurs as distinctive circular clones with a dense understory of ericads (E).

Where two Herb, Moss, and Ericad Types occur together in the same type unit, the symbol for each is given with the symbol for the type having the greatest coverage coming first. A coverage of 10% was the minimum limit for inclusion in a cover type symbol.

Special Features

Special features, including three natural vegetation patterns and two types of human activities, were also noted on the vegetation maps. The first and most common vegetation pattern noted is the ridge and pool or ribbed pattern denoted by an R preceeding the cover type symbol. This feature is, of course, characteristic of patterned sedge fens, but it also often extends for a short distance into very different vegetation types immediately adjacent to the fens. This pattern is also present in fens that have been strongly invaded by shrubs following ditching even where the cover of ericads or bog birch approaches 100%. However, comparison of 1940 and 1976 black and white photography shows that in some portions of ditched patterned fens, notably their upslope margins, vegetational changes during this time period have obscured the ribbed pattern to the point where it is no longer discernible. Though not as well developed as in the patterned fen, a ribbed pattern can also sometimes be detected in the pure Mh type where water seems to be channelized within a larger area of M.

The presence of small tamarack islands in a patterned fen was denoted by the symbol Ti following the cover type symbol. This was done only for islands less than the minimum type unit (3 ha (7.5 ac)).

Islands larger than this were cover typed according to their vegetative cover. Likewise, the occurrence of the small, nearly circular spruce-sphagnum islands in a sedge fen in the Chase Brook SW Quadrangle was denoted by the symbol Spi following the cover type symbol.

Human Activity

The two types of human activity noted on the vegetation maps are Logging (Lg) and Abandoned Agriculture (AA). Recent clearcuts with little vegetative cover were simply typed as Lg. Where the site had been revegetated, Lg was followed by the appropriate cover type symbol. If a cut was only partial (more common on older cuts), the description of the remaining tree canopy precedes the symbol Lg, which is then followed by the description of the reproduction.

Abandoned Farms

Abandoned farms are denoted by the symbol AA; and AA precedes the usual cover type symbol(s). There are no active farms within the study area. Some of the oldest farms have probably been abandoned for 50 or 60 years, and evidence of them is becoming more indistinct with the passage of time. However, 1940 B&W aerial photography, which shows these old farms more clearly, became available after the interpretation had already been completed. Inspection of this photography indicated that most of the old farmland had been delineated quite accurately.

Minimum Mapping Units

All peatland types were mapped down to a 3-ha (7.5-ac) minimum type unit. Open water was delineated down to about 0.4 ha (1 ac) and is indicated with a shaded film overlay.

Other Designations

The direction of water flow in the ditches was indicated with small arrows wherever the flow could be determined from the presence and character of beaver dams and ponds. Most beaver dams are found in minerotrophic peatlands, where suitable food species occur.

4. Aerial Photo Interpretation

The vegetation classification was accomplished using the most recent 1:15,840 scale B&W infrared 23 x 23-cm (9 x 9-in) forest aerial photography. The dates of the photography are 1976 and 1972 for Beltrami and Koochiching counties, respectively. The photo interpretation was accomplished on the effective areas of alternate photographs -- the effective area being defined as that portion of alternate photographs in a flight strip delimited by half the endlap area within the flight line and half the sidelap area with adjacent flight lines. Photo preparation included the determination of effective areas on the B&W photographs and the subsequent transfer of the effective areas to specifically prepared 23 x 23-cm (9 x 9-in) clear stable base film overlays registered to the photographs using three fiducial marks per photograph. Interpretation was done on the overlay using ink drafting pens for delineating and labelling cover types. All interpretation was done while viewing the photographs stereoscopically using a reflecting mirror stereoscope with 3X magnification.

Extensive use of supplementary 35 mm color infrared and true color photography was used as an interpretation aid. The photo interpreter's work station was set up in conjunction with an EK Carousel slide projector and viewing screen in a way to permit the interpreter to switch from viewing the B&W photography stereoscopically to viewing the projected image of the 35 mm transparencies merely by turning in his chair.

The color infrared transect and photo plot photography, flown as part of Phase II, was used in this manner for those areas covered. In addition, complete physical coverage of the entire study area was flown on September 22, 1978 at the scale of 1:120,000. It was flown from 3,352 m (11,000 ft) above ground level with a 35 mm camera equipped with a 28 mm lens. EK Aerochrome Color Infrared Type 2443 film with a Wratten 15 filter was used. Six flight lines with a total of about 160 exposures were required to provide this coverage. In addition, approximately 200 true color large-scale 35 mm aerial oblique photographs were taken throughout the study area to further aid in interpretation.

The color infrared photography was especially valuable in emphasizing relative differences in the amount of surface water -- a feature often strongly correlated with the presence, or absence, of a moss cover. The color infrared photography also highlighted certain vegetational differences associated with water chemistry and various types of disturbance (e.g., fires, logging, etc.). The color oblique photographs were particularly valuable for identification of tree species and for differentiating between low shrubs and graminoids. Many of the obliques were flown in mid-October when the tamarack were at their peak of fall color and when the dark colored shrubs stood out against the straw-colored sedges and grasses.

The photo interpretation was done between November, 1978 and May, 1979 by the senior author. All interpreted overlays were carefully edited and edge-matched with adjacent overlays before detail transfer to the base maps was begun.

5. Map Compilation

Upon completion of the photo interpretation for a given quadrangle, transfer of the interpreted photo detail to the 1:24,000 scale orthophotoquad base map was done by an experienced technician with a Map-O-Graph Model 55 overhead projector. The Map-O-Graph projects the image of the interpreted overlay onto the base map, whereupon the technician adjusts for scale and orientation using features marked on the overlay that are identifiable on the photoquad. The main features used for this purpose were ditches (especially ditch intersections), fire scars in forested areas, dwarf mistletoe infection centers, tamarack islands, and other sharply defined features. Once "set-up" was completed, an overlay was laid down over the photoquad and the interpreted detail manually copied onto the new overlay.

After the detail transfer to this intermediate overlay was completed, the intermediate was carefully edited and edge-matched with adjoining quadrangles, and a final drafted copy, suitable for reproduction, was traced from the intermediate onto drafting film. The cover type symbols on this final draft were put on with dry transfer lettering. From each of the final drafted vegetation overlays, a single contact scale stable base photographic negative and a positive stable base film transparency was made -- the latter was registered to the orthophotoquads on the final display.

6. Acreage Measurements

Acreages were measured and summarized by cover type and by quadrangle. The total number of unique cover types (various combinations of Forest, Deciduous Shrub, Herb, Moss, and Ericad Types, and Upland Types) that occurred within the study area was in excess of 200. As it was not practical to measure and tabulate this large number of types, a system of grouping into more general classes was devised. This was done in cooperation with the MDNR and, at their request, the emphasis was put on the peatland forest types.

The acreage summary table is shown in Appendix A. Notice that the Peatland Types are hierarchically arranged into a number of subgroups and acreage totals. The first major division of Peatland Types is between those with a ridge and pool or ribbed pattern and those without. It was felt that this was ecologically the most meaningful grouping. Peatlands with a ridge and pool pattern were first broken down by sedge cover, then by tree cover. Peatlands without a ridge and pool pattern were first divided into Forest and Nonforest Types; Forest Types were further subdivided by species and the species by height, vigor, and density classes. Notice that the L cover type was included as a forest type even though it does not currently support over 10% tree cover. Recall that L depicts a bog that was forested prior to fire and has not yet, for whatever reason, been reforested.

Appendix B is a nearly complete listing of all the specific cover types occurring in the study area grouped by the acreage summary categories they were tallied under. The basic conventions used in making the groupings are as follows:

Forest Types

- Deciduous Shrub, Herb, Moss, and Ericad understories are ignored.
- If a cover type contained both a and b height classes, the a component is ignored and the cover type is categorized according to the species and density of the b components (e.g., Spb'Spa'L is found under Spb').
- If the b component is composed of an unequal mixture of species, the cover type is categorized by the dominant species in density class''' (e.g., Spb"Tb' is found under Spb''').
- If the b component is composed of a mixture of Sp or T and Sc, the cover type is categorized as Sp or T, accordingly, and the density class is the sum of the densities of Sp or T and Sc (e.g., Spb'Scb'M is found under Spb").
- If there is no b component, then conventions 3 and 4 still hold except that b should be replaced by a whenever it appears (e.g., Spa"Ta' is found under Spa''' and Spa'Sca'M is found under Spa").
- All cover types containing the symbol Lg are categorized as Lg.

Nonforest Types

- The Shrub category includes all cover types with a Deciduous Shrub component regardless of what Herb, Moss, and Ericad Types may be included.
- Cover types comprised of a mixture of Herb, Moss, and Ericad Types are categorized by the type having the greatest coverage (i.e., the

first symbol appearing in the cover type designation).

- All cover types beginning with AA fall into the AA category.

Types With a Ridge and Pool Pattern

- The S or G category includes only the RS, RG, and RSTi cover types.
- The 10-90% S or G categories include all the cover types that are composed of a mixture of S or G and some other type(s).
- The less than 10% S or G categories include all the cover types for which S or G do not appear in the symbol.

B. Phase II - Color Infrared Transects and Photo Plots

1. Study Design

- Development of criteria for selection of transect locations.
- Selection of transects, flight planning.
- Aerial photography.
- Indexing and preparation of photography for field checking.
- Field check of selected photo plots and description of key features.
- Final formatting, description, mounting, and display of transect and photo plot photography.

2. Selection of Transect Locations

Although the camera system, film type, and photographic scales to be used for the transects and photo plots were specified by the MDNR, the transect location choice was left mainly to the authors. It was desirable to obtain the photography by the end of July in order to coincide with vegetation "peak of green" and to make it available for field use, both as a base for gathering reference data for Phase I and for use by other interested investigators during the 1978 summer field season. Because this project did not begin until July 1, 1978, the question of transect location selection had to be faced immediately.

The following criteria were used in choosing the transects:

- The number of representative community types covered by the transects should be maximized.
- The number of distinctive or unique vegetation patterns covered should be maximized.
- Where possible, transects should cut across environmental gradients.
- The transects should illustrate the different types and degrees of both natural and man-made disturbance occurring within the study area.

As soon as the 1:15,840 scale B&W photography was received, it was laid out on large tables in a rough mosaic, which was used as a planning base for locating the transects. Fortunately, the Ecological and Floristics Study Group had already completed much of their field work within the study area by mid-July, and Dr. Paul Glaser provided invaluable advice based upon their field observations. Ultimately, nine transects of varying lengths were selected (Figure 2).

3. Overflight

By mid-July, the transect selections and flight planning had been accomplished and the wait for photographic weather began. The weather, of course, is beyond the control of the aerial photographer -- a problem that was compounded for the Red Lake overflight both by the lack of a reporting weather station in close proximity to the peatlands and by the flying time required to reach the area from the Twin Cities (circa two hours). Also, aircraft and pilot were not always available when needed. Several flights were cancelled either at the airport or en route to Red Lake as weather reports or conditions changed.

As a consequence, the transect overflight was not completed until August 30, 1978. Two Nikon 35 mm motordrive cameras mounted in the bottom camera bay of a Cessna 206 aircraft were used for the flight. One was fitted with a 28 mm side angle lens to provide complete physical coverage of the transects at the nominal scale of 1:80,000. The other camera was fitted with a 200 mm telephoto lens and was exposed simultaneously with the first camera to provide 1:11,000 scale photo plots covering a small area at the center of each of the 1:80,000 scale frames. Both cameras were loaded with EK Aerochrome Color Infrared Type 2443 film and were fitted with Wratten 15 filters. Flying height was 2,240 m (7,350 ft) above ground level.

After flying all nine transects, the photographer determined that the camera fitted with the 28 mm lens had malfunctioned. However, the problem was corrected, and he proceeded to refly all nine transects with both cameras, thus obtaining two complete sets of photo plots and one set of transect photography.

The photography is relatively cloud-free except for some minor clouds and cloud shadows in the last three transects flown. A more pervasive problem was severe vignetting on the photo plot exposures (i.e., the photo centers are bright and the margins are quite dark), apparently a function of the particular

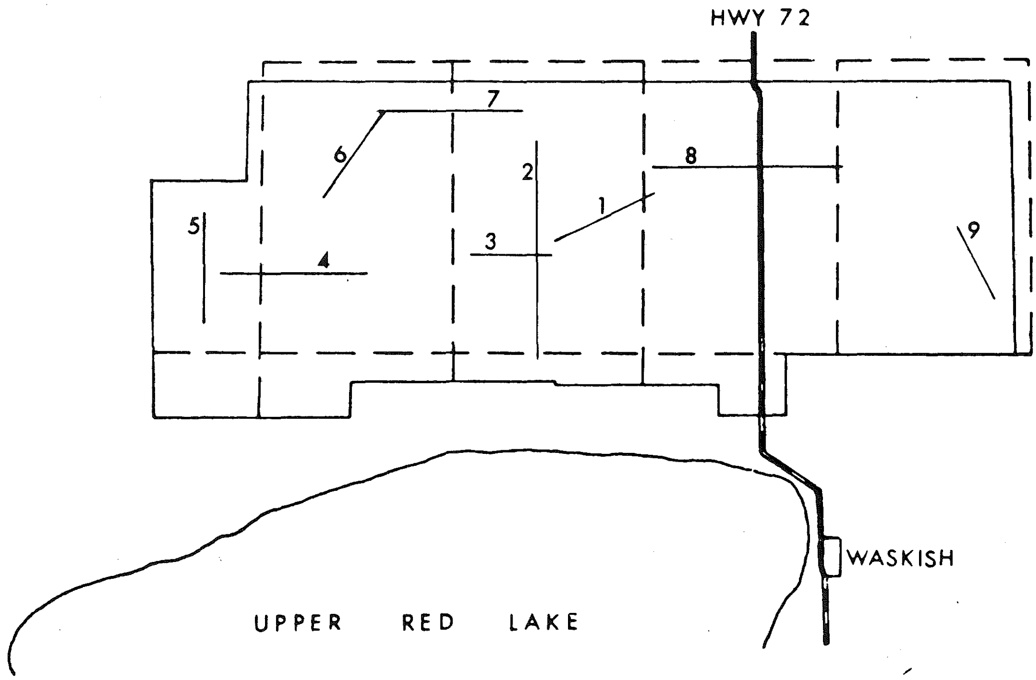


Figure 2. Transect locations.

lens used.

4. Field Verification, Data Collection

Following processing of the film, internegatives and 8.9 x 12.7-cm (3½x5-in) color prints were made of all the transects and photo plots. The original CIR transparencies, the internegatives, and the prints were all indexed as follows: (a) the transects were numbered Tr-1 through Tr-9, (b) exposures comprising a transect were numbered consecutively 1, 2, 3, ... from west to east or north to south, and (c) photo plots within each transect exposure were lettered a, b, ... (e.g., Photo Plot Tr 4-5b).

The color prints were next prepared for field use. The transect prints were "stripped up" in overlap position and taped to thin cardboard. Selected photo plots of particular interest were similarly mounted and all prints fitted with overlays for field notations.

The transects were visited in mid-October using a helicopter. Landings were made on many of the photo plots and observations made of vegetation types, species, height, density, condition, surface water, special features, etc. True color aerial obliques were also taken to further document certain features.

Unfortunately, the photography was flown too late to be available for other investigators to use during the 1978 field season. However, as most peatland types are very stable and change very slowly with time, the transect photography and photo plots will remain a valuable aid for field investigators for a considerable period in the future. Examples of both scales of photography are shown in the next section.

C. Final Products

In addition to this report, the final products of this project consist of a set of seven permanent, three-panel folding displays, each display covering one, or portions of two, 7.5-minute quadrangles. On the center panel of each display are mounted the 1:24,000 scale orthophotoquad and vegetation overlay with the overlay in place registered to the photoquad and adjoined by a copy of the classification scheme.

The right-hand panel displays the color infrared transect photography for the quadrangle and selected photo plots and may include aerial obliques, ground shots, or individual exposures from the 1:120,000 scale CIR overflight. Nearly all photographic materials on this panel are in the form of 8.9 x 12.7-cm (3½x5-in) color prints. The transect prints were carefully aligned and cut to permit consecutive prints to be edge-matched. Features of interest are indexed directly on the color prints with dry transfer lettering and each item displayed is accompanied by a brief narrative.

The main item on the left-hand panel is an orthotopographic map, which is accompanied by an overlay displaying a variety of information. Transect locations are indicated on this overlay, as are the approximate field of view, roll, and exposure number of all the 35 mm color oblique photographs within the quadrangle. Roll, exposure number, and location of ground shots are also indexed. The location of vegetation sample releves done by the Ecological and Floristics Study Group are marked as are the locations of peat core samples and water samples collected by that study group. The water chemistry (pH, specific conductivity, and absorbance) of the water samples is given in a table mounted adjacent to the orthotopomap. Peat depths as reported by Soper (1919) are also indicated on the overlay. In addition to the topomap and overlay, each left-hand panel also has a legend and a location sketch for the quadrangle(s) displayed.

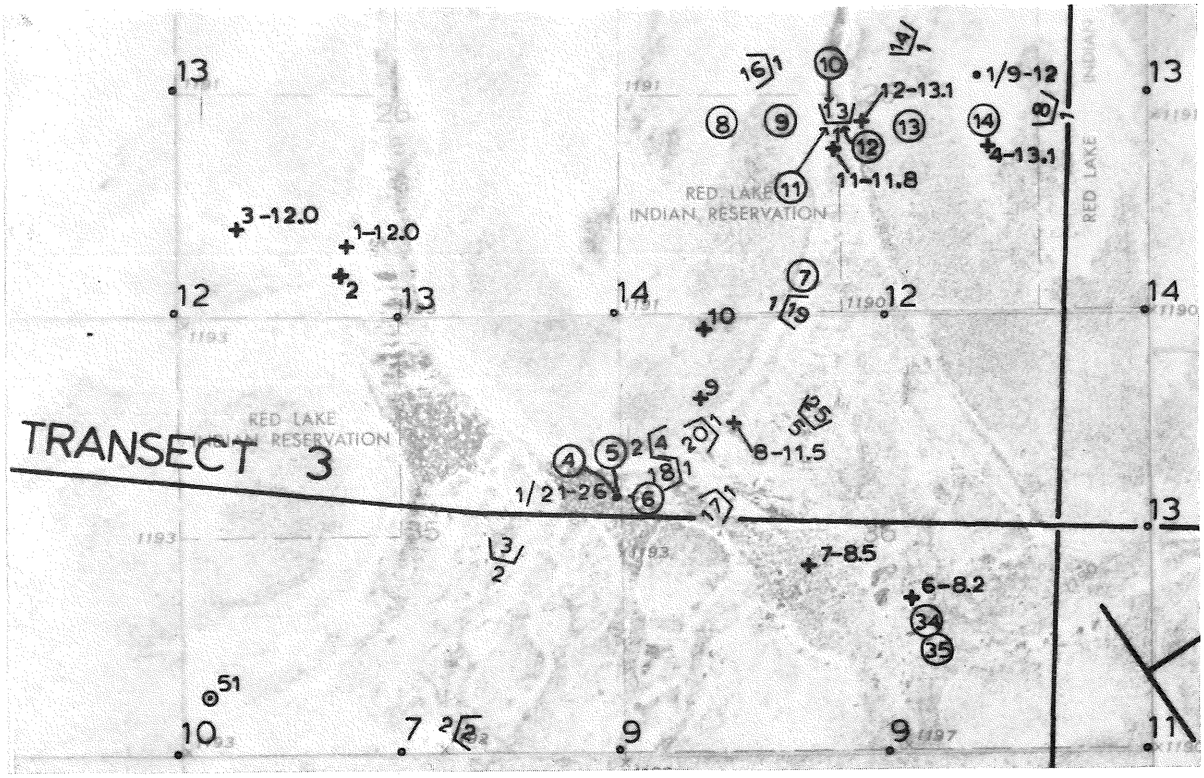
A sample of a portion of the Chase Brook SW Orthotopomap with overlay in place is shown in Figure 3. Because the topomap overlays have a semimatte surface, it will be easy to add further information to them as desired.

Figures 4, 5, 6, 7, and 8 each consist of an 8.9 x 12.7-cm (3.5x5-in) color print made from an individual transect exposure or photo plot accompanied by a near-contact scale copy of a portion of the corresponding orthophotoquad with its vegetation overlay. This should provide a feeling for the nature of the final display materials.

DISCUSSION

Manual interpretation of conventional black and white medium-scale aerial photography supplemented by small format color infrared vertical photography and true color aerial obliques is an effective combination for the detailed type of vegetation classification and analysis of peatlands described in this report. It is truly a labor-intensive process, but, at present, there are no proven automated or semiautomated classification techniques that can produce the same detail and accuracy.

Obtaining peak-of-green color infrared photography for field use during the same field season can be a difficult problem; this was certainly well demonstrated by this project. Relying upon obtaining such photography as an aid in planning and executing detailed floristics work (as was done by the



LEGEND

(symbol)	-	Location and approximate field of view of aerial oblique photograph taken in summer or fall 1978.
20 / 3 (symbol)	-	Roll 3, Exposure 20.
• 1/30-31	-	Location of ground photographs Roll 1, Exposures 30 and 31.
(8)	-	Location and sample number of vegetation relevé done by Ecological and Floristics Study Group in 1978.
+3-12.0	-	+ indicates location of peat core sample collected by Ecological and Floristics Study Group in 1978, 3 is the core sample number and 12.0 is the peat depth at sample point.
°13	-	Peat depth reported by Soper, E. K., 1919, The Peat Deposits of Minnesota, Minnesota Geological Survey Bulletin No. 16.
⊙30b	-	Water Sample #30b

Figure 3. Contact scale copy of a portion of the Chase Brook SW Quadrangle Orthotopomap with overlay registered.

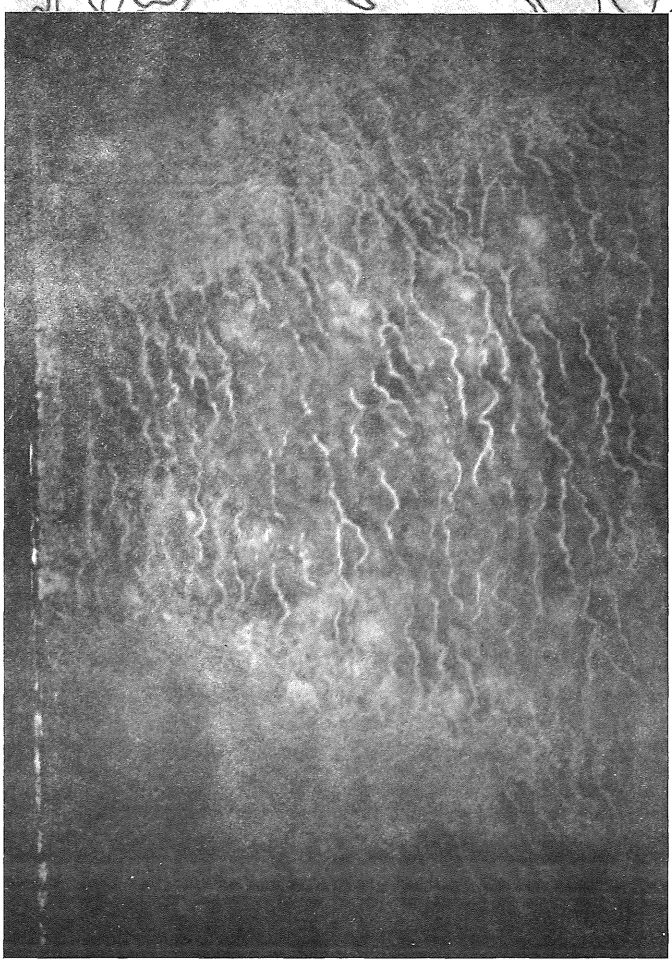


Figure 4. Above is a contact copy of a portion of the 1:24,000 scale Hilman Lake Quadrangle orthophoto with vegetation overlay in place. The Western Water Track (left 2/3) is split in two by the western tip of the central bog complex (right). Note the vegetation change across the ditch (top left, center).

To the left is a 3.5X enlargement of a 1:11,000 scale 35 mm CIR aerial photo plot showing the detail of the hatched area indicated above. This shows part of the pattern fen immediately downslope from the ditch. The ridges are partially invaded by bog birch.

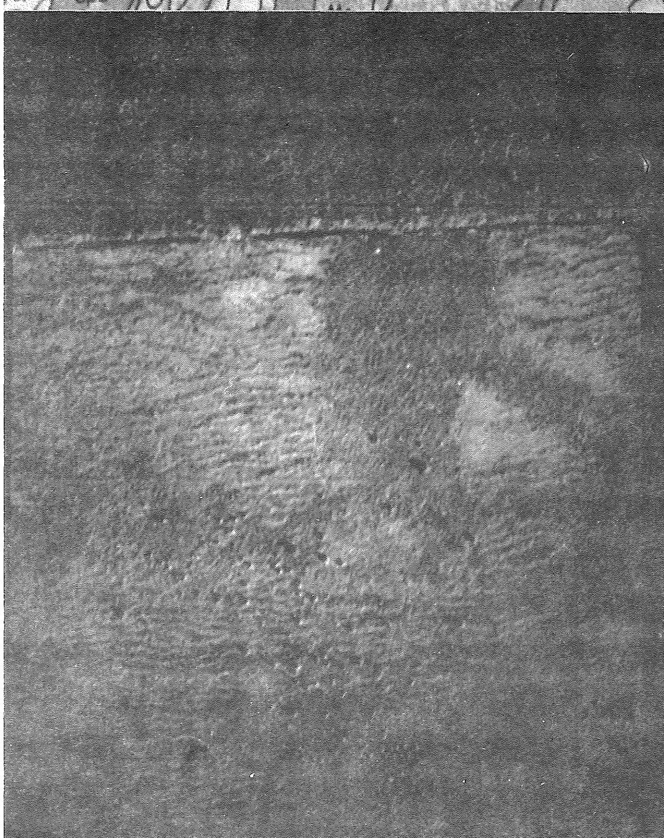


Figure 5. Above is a contact copy of a portion of the 1:24,000 scale Hilman Lake Quadrangle orthophoto with vegetative overlay in place. Pictured is the northwestern margin of the northern arm of the Western Water Track. The water track (right side) has been heavily disturbed by ditching.

To the left is a 3.5X enlargement of a 1:11,000 scale 35 mm CIR aerial photo plot showing the detail of the hatched area indicated above.

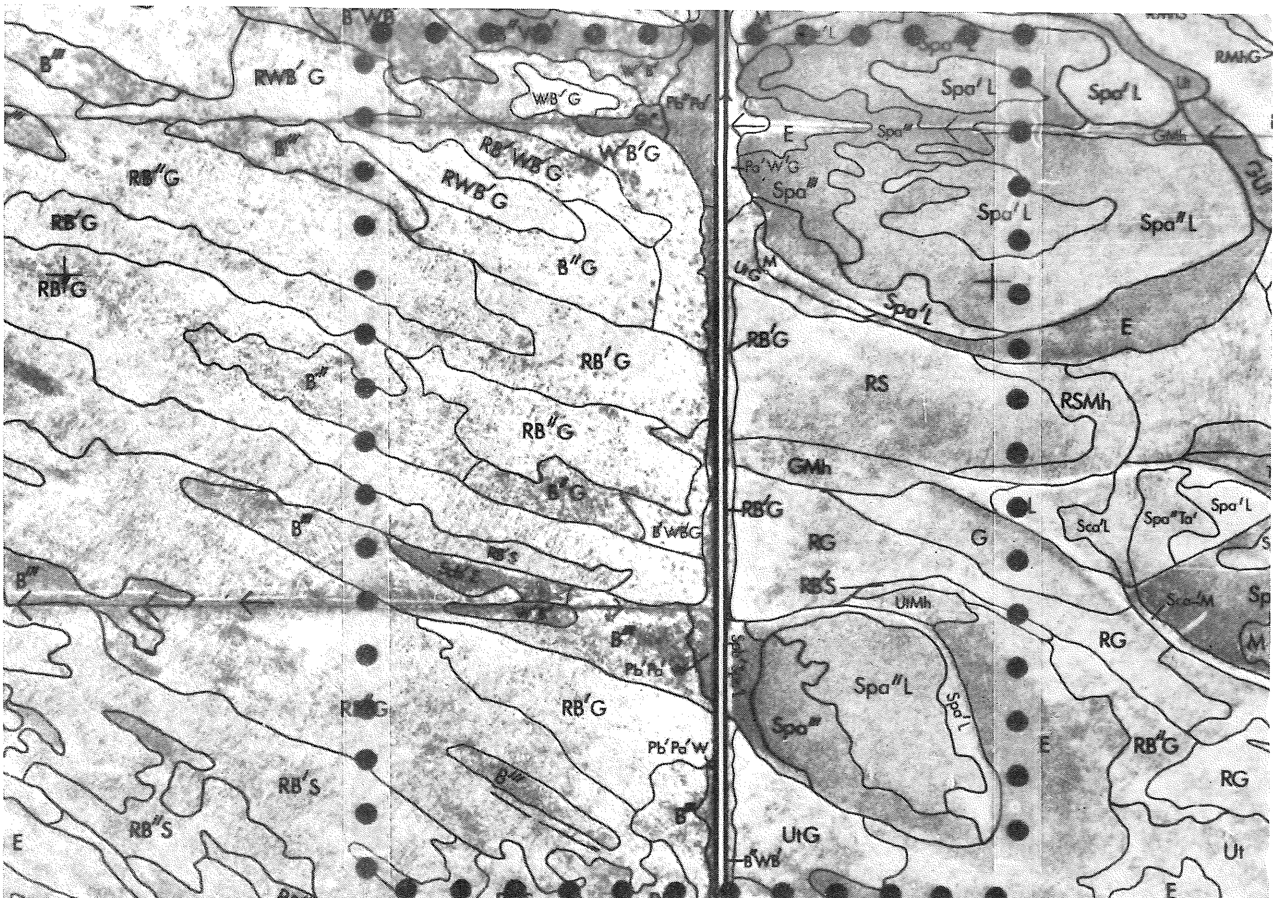


Figure 6. At the top is a contact copy of a portion of the 1:24,000 scale Ludlow Lookout Tower Quadrangle orthophoto with vegetative overlay in place. Patterned fen and ovoid-shaped spruce-sphagnum islands contiguous to State Highway 72 are pictured. As there are no culverts under this section of highway, virtually all runoff is diverted to the north by the road ditch - leaving the fen downslope (left side) partially "dried up" and invaded by bog birch.

Below it is a 3.5X enlargement of a 1:80,000 scale transect 35 mm CIR aerial photo of the area outlined with a dot boundary in the orthophoto map above.

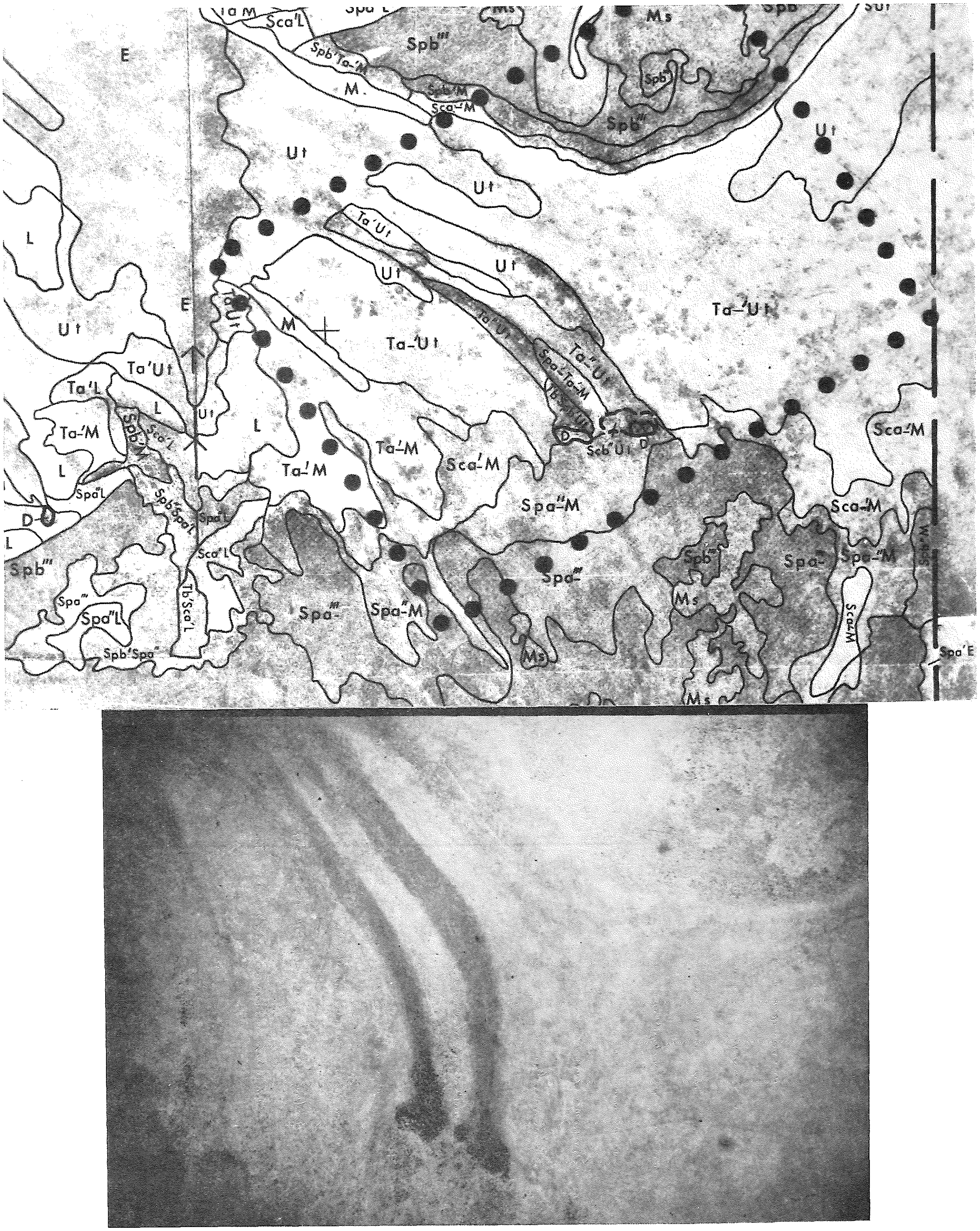


Figure 7. At the top is a contact copy of a portion of the 1:24,000 scale Wayland SW Quadrangle orthophoto with vegetative overlay in place. Featured are two small mineral islands surrounded by peatland. The area covered by the photo below it is identified by a dotted border.

Below is a 3.5X enlargement of a 1:80,000 scale transect 35 mm CIR aerial photo which dramatically highlights the curious "tails" extending downslope from the two islands. The tails probably result, at least in part, from nutrients leached from the mineral soils.

Figure 8. Above is a contact copy of a portion of the Chase Brook SW Quadrangle orthophoto with vegetative overlay in place. It features the unique pattern of nearly-circular spruce sphagnum islands in a sedge fen at the heart of the raised bog complex. Narrow water tracks drain to the north and east between the large, ovoid-shaped spruce-sphagnum islands with the open centers.

At the left is a 3.5X enlargement of a 1:11,000 scale 35 mm CIR aerial photo plot showing the detail of the hatched area indicated on the orthophoto map above. The dark tone depicts wet sedge fen surrounding the spruce-sphagnum islands. Note the faint ridge and pool pattern at the lower left.

Ecological and Floristics Study Group) is probably not feasible, as the major part of such field work must be done in late June and early July when most of the plants are in flower.

The color infrared photography, aerial obliques, and field observations revealed that most of the peatlands contiguous to Highway 72 have been quite severely impacted by fires, ditching, and the damming effect of the road itself. This is unfortunate, for access is a very major consideration in planning field studies in most peatlands. In general the more pristine areas in the Red Lake Peatlands are also the farthest removed from road access (perhaps a partial reason for their being pristine). Helicopter access may be feasible for studies that require a single or infrequent visit to remote sites, but it becomes economically impractical for most animal or hydrologic studies, which require frequent and repeated visits for observations or for monitoring traps or gaging stations.

As stated earlier, the causal mechanisms of most of the landscape features of the Red Lake Peatlands are poorly understood or unknown. We can add little to the basic understanding of these processes, but during the course of this project some possible correlations and hypotheses have been developed.

The first hypothesis concerns the ridge and pool pattern. In those peatlands that have not been ditched, the ridge and pool pattern seems to occur only where either the vegetative cover is nearly devoid of trees and shrubs, or on the margins of sites where the ridge and pool pattern may extend for a short distance into very different cover types such as a spruce-sphagnum bog. Although the pattern most commonly occurs in wet sedge fens with little or no moss cover, it does sometimes occur where sphagnum moss is nearly continuous (Mh type). When this happens, however, it is on the wettest moss sites, where there appears to be significant channelization of runoff, and again where trees and shrubs are nearly absent.

This correlation suggests that the mechanism responsible for initiating the ridge and pool pattern may be that observed by Drury (1956) in the Kuskokwim Lowlands in Alaska. Drury observed that organic debris transported by water flowing across a nearly level frozen surface was deposited in irregular ridges oriented more or less perpendicular to the direction of water flow. Although empirical evidence for this phenomenon in Red Lake Peatlands is lacking, we suggest this may be the causal mechanism for the ridge and pool pattern. Furthermore, water transport of organic debris would probably only produce this pattern in the absence of trees and shrubs, which would either prevent the movement of dead plant remains or would cause them to be deposited on the shrubs and trees themselves. Significant water transport of organic debris would probably only occur in the spring when runoff is normally at a maximum, when there is an abundant supply of dead leaves and other plant remains from the previous year, and before the new growth of sedges and other herbs have developed enough to impede such transport.

If this is the mechanism responsible for initiating the ridge and pool pattern, then the presence of this pattern on the margins of spruce-sphagnum communities bordering patterned fens would imply the recent expansion of the spruce-sphagnum community into the fen. That such expansion may occur is further indicated by the shape of some of the ovoid-shaped spruce-sphagnum islands that appear to have been formed by the fusion of one or more smaller islands. Indeed, one should expect that the long-term trend of the peatlands as a whole would be towards increasingly ombrotrophic conditions favoring the expansion of bog types as the blanket of peat increases in depth and as more of the mineral uplands within the watersheds are covered with peat thereby reducing the input of mineral nutrients into the waters of the peatland.

Another puzzling landscape feature is the large ovoid-shaped spruce-sphagnum islands with the open centers at the middle of the Chase Brook SW Quadrangle (Figure 3). Why are the centers nearly treeless while the margins are quite densely forested with black spruce? Fire has been suggested as a possible cause, but fires in black spruce are almost invariably crown fires, which leave very sharply defined margins easily discernible on aerial photography. The transition from the open centers to the denser black spruce follows a smooth gradient with gradually increasing height, vigor, and density of spruce. Also, the spruce is almost totally infected with dwarf mistletoe; there is a single, continuous 390-ha (976 ac) infected stand of black spruce on these islands. Dwarf mistletoe spreads slowly and is normally eliminated from a stand by fire. The large area of dwarf mistletoe infection in these spruce communities indicates that they have been free from fire for a long time.

It is suggested that the open centers of these islands may actually be drains occupying slight topographic depressions, and that part of the runoff from the crescent-shaped black spruce stands on the upslope heads of these islands may drain centripetally into the open centers. These crescent-shaped black spruce stands would then, in effect, occupy crested watershed divides at the heads of the islands. Supporting evidence for this theory is the observation that all of the open centers lead downslope into one of the narrow patterned fen water tracks that delineate the islands. Further, Gorham et al. (1978) reported these open centers are floristically very similar to the open sphagnum-covered bog drains that occur immediately downslope from the crested, spruce-covered bog divide at the southern edge of the Chase Brook SW Quadrangle.

A final bit of information was provided by a Landsat Return Beam Vidicon (RBV) image dated April 16, 1978. Snowmelt was largely completed by this date and runoff should have been near its maximum. The image clearly shows differences in the amount of surface water in the peatlands. The centers of the ovoid islands under discussion have a grey tone on the image indicating a moderate amount of surface water, whereas open areas known to be a result of fire on other ovoid-shaped spruce-sphagnum islands all appear white indicating almost no exposed surface water.

A final hypothesis concerns the dynamics of peatland expansion versus the downcutting of streams that drain the peatlands. No open streams occur within the study area. Runoff from the southern margin of the study area drains more or less directly into Upper Red Lake. A small part of the northeastern corner drains north and east into the East Fork Rapid River and the Black River. The remaining roughly two-thirds of the study area drains north into small tributaries of the Rapid River (Troy Creek, Chase Brook, and Miller Creek), or directly into the Rapid River itself. It is not known whether these streams are eroding headwardly and thereby slowly dissecting the peatlands or, conversely, whether the peatlands are encroaching on and burying the headwaters of these streams. There is some evidence that the latter may be occurring.

Normal postglacial erosion has been slowly dissecting the bed of Lake Agassiz. Such major streams as the Bigfork, Littlefork, and Rainy rivers have narrow valleys cut 6.1 - 18.3 m (20 - 60 ft) below the lake plain (Heinselman 1963). The Rapid River flows into the Rainy River east of Lake of the Woods, tumbling over falls and rapids near its mouth (Waters 1977). Have the effects of the downcutting reached the headwaters of the Rapid River and its tributaries?

At the same time as much of the surrounding peatlands were ditched (1909-1917), the ditch builders straightened and deepened several miles of the upper reaches of the Rapid River. It seems unlikely that this would have been necessary if the headwaters of the river had been undergoing downcutting.

Prior to the general accumulation of peat beginning 2-4,000 years ago, the roughly 1,165 km^2 (450 mi^2) area that became the Red Lake Peatlands must have supported a network of streams, perhaps intermittent, but with defined stream channels. Areas of similar size and relief but lacking a cover of peat near the Red River about 130 km (80 mi) to the west have such streams. If this were true, then the subsequent development and expansion of the peatlands must have buried the upper portions of these stream channels and there is no apparent reason to assume that this process is not continuing. At some point in time the downcutting of the Rapid River and its tributaries should balance and then reverse the process of peatland encroachment on the headwaters. Furthermore, one would expect this reversal to occur at different points in time on each of the streams. It appears that the reversal had not taken place on the headwaters of the Rapid River at the time of ditching. The situation regarding Troy Creek, Chase Brook, and Miller Creek is not clear, but seven peat depths reported by Soper (1919), all within 0.8 km (0.5 mi) east of the upper 6.4 km (4 mi) of Troy Creek and all only .6 to .9 m (2 or 3 ft), may indicate a relatively recent expansion of the peatland around the head of this stream.

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Appendix Table A. Red Lake Peatlands Area Summary (Sheet 1 of 7)

QUADRANGLE	PEATLAND AND PEATLAND-UPLAND TRANSITION TYPES — WITHOUT RIDGE AND POOL PATTERN — FOREST TYPES — Black Spruce										Total
	Spa'	Spa''	Spa'''	Spa-'	Spa-''	Spa-'''	Spb'	Spb''	Spb'''	Ms	
OAKS CORNER SW	3	21	8	-	-	-	-	-	12	-	44
HILMAN LAKE	132	107	91	287	479	1,362	176	82	1,226	1,046	4,988
CHASE BROOK SW	88	101	139	932	1,585	3,212	102	335	1,628	3,754	11,876
LUDLOW LOOKOUT TOWER	1,318	2,354	985	108	204	158	434	486	1,434	546	8,027
WAYLAND SW	1,601	1,742	1,109	363	1,117	1,606	541	586	1,989	1,572	12,226
PONEMAH NW	20	-	-	-	-	-	15	-	50	-	85
PONEMAH NE	-	65	31	15	63	135	37	0	125	1	472
WASKISH NW	165	211	343	113	180	520	-	11	433	198	2,174
WASKISH NE	92	513	59	43	16	-	61	33	113	71	1,001
Totals	3,419	5,114	2,765	1,861	3,644	6,993	1,366	1,533	7,010	7,188	XXXXXX
											40,893

Appendix Table A. Red Lake Peatlands Area Summary (Sheet 2 of 7)

QUADRANGLE	PEATLAND AND PEATLAND-UPLAND TRANSITION TYPES...CONT'D									
	WITH RIDGE AND POOL PATTERN...CONT'D									
	FOREST TYPES...CONT'D									
	Tamarack									Total
	Ta'	Ta''	Ta'''	Ta-'	Ta-''	Ta-'''	Tb'	Tb''	Tb'''	
OAKS CORNER SW	319	202	-	1,184	1,140	349	86	93	19	3,392
HILMAN LAKE	828	633	222	363	193	76	389	113	411	3,228
CHASE BROOK SW	224	100	70	845	129	144	179	7	149	1,847
LUDLOW LOOKOUT TOWER	752	475	292	851	60	-	466	141	239	3,276
WAYLAND SW	425	129	90	1,479	61	75	204	91	61	2,615
PONEMAH NW	574	281	14	-	-	257	306	462	1,439	3,387
PONEMAH NE	506	141	-	-	-	-	194	104	64	1,009
WASKISH NW	66	8	-	18	-	-	21	-	-	113
WASKISH NE	220	48	10	16	15	-	57	53	-	419
Totals	3,914	2,017	698	4,756	1,598	901	1,596	1,064	2,382	XXXXX
										19,286

Appendix Table A. Red Lake Peatlands Area Summary (Sheet 3 of 7)

QUADRANGLE	PEATLAND AND PEATLAND-UPLAND TRANSITION TYPES...CONT'D — WITHOUT RIDGE AND POOL PATTERN...CONT'D — FOREST TYPES...CONT'D — Spruce and/or Tamarack										Total
	Sca'	Sca''	Sca-'	Sca-''	Sca-'''	Scb'	Scb''	Spa'Ta'	Spa-'Ta-'	Spb'Tb'	
OAKS CORNER SW	-	1	16	-	-	91	-	1	-	22	131
HILMAN LAKE	211	18	586	-	-	93	-	6	103	-	1,017
CHASE BROOK SW	313	92	1,999	282	62	8	-	59	12	59	2,886
LUDLOW LOOKOUT TOWER	1,968	18	250	8	-	106	-	81	9	25	2,465
WAYLAND SW	602	-	938	5	-	239	20	-	12	-	1,816
PONEMAH NW	8	-	-	-	-	-	-	-	-	47	55
PONEMAH NE	83	1	165	-	-	3	-	14	25	-	291
WASKISH NW	149	-	194	5	-	29	-	-	-	-	377
WASKISH NE	342	-	6	-	-	35	-	-	-	-	383
Totals	3,676	130	4,154	300	62	604	20	161	161	153	XXXXX
											9,421

Appendix Table A. Red Lake Peatlands Area Summary (Sheet 4 of 7)

QUADRANGLE	PEATLAND AND PEATLAND-UPLAND TRANSITION TYPES...CONT'D							
	WITHOUT RIDGE AND POOL PATTERN...CONT'D							
	FOREST TYPES...CONT'D							Total
	Other Forest Types						Total	
	Cb'	Cb''	Cb'''	P or F	Lg	L		
OAKS CORNER SW	-	-	-	31	-	-	31	3,598
HILMAN LAKE	-	-	-	12	-	350	362	9,595
CHASE BROOK SW	-	13	-	-	119	120	252	16,861
LUDLOW LOOKOUT TOWER	20	48	65	424	257	938	1,752	15,520
WAYLAND SW	-	24	-	147	26	1,145	1,342	17,999
PONEMAH NW	-	-	-	-	-	-	0	3,527
PONEMAH NE	-	-	-	-	-	215	215	1,987
WASKISH NW	-	-	-	-	59	127	186	2,850
WASKISH NE	-	-	-	78	-	163	241	2,044
Totals	20	85	65	692	461	3,058	XXXXX	XXXXXX
							4,381	XXXXXX
								73,981

Appendix Table A. Red Lake Peatlands Area Summary (Sheet 5 of 7)

QUADRANGLE	PEATLAND AND PEATLAND-UPLAND TRANSITION TYPES...CONT'D						
	WITHOUT RIDGE AND POOL PATTERN...CONT'D						Total
	NONFOREST TYPES					Total	
	Shrub	M	S or G	E, MH Ut, Ph	AA		
OAKS CORNER SW	598	-	420	1,374	-	2,392	5,990
HILMAN LAKE	2,748	724	188	3,924	-	7,584	17,179
CHASE BROOK SW	155	4,564	538	996	-	6,253	23,114
LUDLOW LOOKOUT TOWER	2,949	525	265	3,533	108	7,380	22,900
WAYLAND SW	1,617	2,219	250	3,866	201	8,153	26,152
PONEMAH NW	77	-	5	228	-	310	3,837
PONEMAH NE	108	217	28	1,227	-	1,580	3,567
WASKISH NW	4	190	10	10	-	214	3,064
WASKISH NE	1,058	38	33	397	-	1,526	3,570
Totals	9,314	8,477	1,737	15,555	309	XXXXXX	XXXXXXX
						XXXXXX	XXXXXXX
						35,392	XXXXXXX
							109,373

Appendix Table A. Red Lake Peatlands Area Summary (Sheet 6 of 7)

QUADRANGLE	PEATLANDS AND PEATLAND-UPLAND TRANSITION TYPES...CONT'D										Total
	WITH RIDGE AND POOL PATTERN (R)									Total	
	S or G	10-90% S or G			Total	<10% S or G			Total		
	Total S or G	w/o Trees	With T	With Sp or Sc		w/o Trees	With T	With Sp or Sc			
OAKS CORNER SW	3,778	1,355	180	-	1,535	50	60	29	139	5,452	11,442
HILMAN LAKE	3,925	6,050	838	67	6,955	938	429	142	1,509	12,389	29,568
CHASE BROOK SW	508	5,157	320	29	5,506	193	136	227	556	6,570	29,684
LUDLOW LOOKOUT TOWER	806	4,800	64	-	4,864	551	165	5	721	6,391	29,291
WAYLAND SW	190	660	-	-	660	262	7	17	286	1,136	27,288
PONEMAH NW	-	-	-	-	0	-	-	-	0	0	3,837
PONEMAH NE	167	1,052	-	-	1,052	19	15	-	34	1,253	4,820
WASKISH NW	-	-	-	-	0	-	-	-	0	0	3,064
WASKISH NE	-	-	-	-	0	-	-	-	0	0	3,570
Totals	XXXXX	19,074	1,402	96	XXXXXX	2,013	812	420	XXXXX	XXXXX	XXXXXX
	9,374				20,572				3,245	XXXXX	XXXXXX
										XXXXX	XXXXXX
										33,191	XXXXXX
											142,564

Appendix Table A. Red Lake Peatlands Area Summary (Sheet 7 of 7)

QUADRANGLE	NONPEATLAND		Total	Grand Total
	Upland	Open Water		
OAKS CORNER SW	-	-	-	11,442
HILMAN LAKE	-	3	3	29,571
CHASE BROOK SW	-	-	-	29,684
LUDLOW LOOKOUT TOWER	734	36	770	30,061
WAYLAND SW	683	-	683	27,971
PONEMAH NW	-	-	-	3,837
PONEMAH NE	-	-	-	4,820
WASKISH NW	-	-	-	3,064
WASKISH NE	207	6	213	3,783
Totals	1,624	45	XXXXX	XXXXXXX
			XXXXX	XXXXXXX
			XXXXX	XXXXXXX
			XXXXX	XXXXXXX
			1,669	XXXXXXX
				144,233

APPENDIX B

Following is a nearly complete listing of all the individual cover type designations actually used on the 1:24,000 scale vegetation classification overlays. Each cover type is listed under the appropriate acreage summary category from Appendix A. The conventions used in making the groupings are explained in the text of this report.

I. PEATLAND AND PEATLAND-UPLAND TRANSITION TYPES

A. Without Ridge and Pool Pattern

1. Forest Types

a. Black Spruce Categories

Spa'	Spa'L, Spa'B", Spa'E
Spa"	Spa"L, Spa"M, Spa'Sca'L, Spa'Sca'Ut, Spa"Sh', Spa'Ta-'M
Spa"'	Spa"'. Spa"Ta', Spa"Sca'
Spa-'	Spa-'M
Spa-"	Spa-"M, Spa-'Sca-'M
Spa-"'	Spa-"', Spa-"Ta-'
Spb'	Spb'L, Spb'Ta'M, Spb'Sca'M, Spb'Ta-'Ut, Spb'Ta-", Spb'Ta'Ut, Spb'Spa", Spb'M, Spb'Spa'M, Spb"Spa'L, Spb'Sca'Mh, SpCb'LgSh", Spb'Sca-'L, Spb'LgSh', Spb'Spa-'M, Spb'Ta-'M, Spb'Sca'Ut
Spb"	Spb"M, Spb"Sca', Spb"Ta-', Spb"Ta', Spb"Spa', Spb"L, Spb'Scb'M, SpCb"Sh', Spb'Scb'Sh'
Spb"'	Spb"'. Spb"Tb', Spb"Cb', SpCb"'
Ms	Ms

b. Tamarack Categories

Ta'	Ta'Ut, Ta'E, Ta'M, Ta'B", Ta'PhE, Ta'L, Ta'WB"
Ta"	Ta"E, Ta"Ut, Ta'Sca'M
Ta"'	Ta"', Ta'Sca"
Ta-'	Ta-'M, Ta-'Ut, Ta-'Mh, Ta-'SMh, Ta-'G, Ta-'MhS, Ta-'E
Ta-"	Ta-"M, Ta-"Ut, Ta-"Mh, Ta-'Sca-'M
Ta"'	Ta-"'
Tb'	Tb'Ta'Ut, Tb'Ta'E, Tb'Ta", Tb'Sca'M, Tb'M, Tb'E, Tb'L, Tb'Sca", Tb'Ta'Mh, Tb'Ta'Mh, Tb'B", Tb'Spa'B', Tb'Sca'Ut, Tb'Sh", Tb'Ta-", Tb'Ta-'Ut
Tb"	Tb"Ut, Tb"B', Tb"Ta', Tb-"Ut, Tb"E, Tb"Sca', Tb"Sh', Tb"LgSh'
Tb"'	Tb"', Tb"Spb', Tb"Scb'

c. Spruce and/or Tamarack Categories

Sca'	Sca'L, Sca'E, Sca'Ut, Sca'B"
Sca"	Sca"L, Sca"M, Sca"Ut, Sca"WB'
Sca-'	Sca-'M, Sca-'E, Sca-'Ut, Sca-'Mh
Sca-"	Sca-"M, Sca-"Ut
Sca-"'	Sca-"'

Spruce and/or Tamarack Categories - continued

Scb'	Scb'M, Scb'Ta'', Scb'Sca'L, Scb'Ta'Ut, Scb'B'', Scb'Sca'B', Scb'Sca-'M, Scb'E, Scb'Sh'', Scb'Ut, Scb'Sca'Sh'
Scb''	Scb''Ut
Spa'Ta'	Spa'Ta'E, Spa'Ta'L, Spa'Ta'Ut
Spa-'Ta-'	Spa-'Ta-'M
Spb'Tb'	Spb'Tb'M, Spb'Tb'Sca', Spb'Tb'Sh', Spb'Tb'LgSh'

d. Other Forest Categories

Cb'	Cb'Sh''
Cb''	Cb''Ut, Cb'Scb'Sh', Cb'Spb'Sh'
Cb'''	Cb''Fb', Cb''Spb'
P or F	Pb'W'G, Pb'B'', Pb'Pa'B', Pb''Spb', Pb'B'WB', Pa'WB'G, Pa'B'', Pa-'B'', Pb''Pb', Pb'Pa'W, Pa'B'WB', Pb'Pa'WB', Pa-'W'G, Fb''', PFb''', Pb'Spb'WB', Pa-'W'', Fb''Cb', Pb'W'B', Pb'W'', Pa-''Sh', Pb'B'', Pb'W'Sh', Pb''Sh', Fb''SpCb'
Lg	LgSca'', Lg, Ta'Lg, LgScb'Sca', LgB''G, LgTa'Sh'', LgSpa''', LgSh''', LgSpa'Ta'Sh', LgSca'Sh',LgB''', LgSca'
L	L

2. <u>Nonforest Categories</u>

Shrub	WB''G, WAI''', WAI'G, WB''', W'G, WB'G, W'B'', W''G, W''', W'B'G, W'B'WB', W'B'', B''WB', B''G, B''', WAI''G, B'WB'G, B'G, B'G, WB'Ut, WB'G, Sh''', W''Sh', Sh'G, Sh''', Sh''G, B'Ut
M	M
S or G	S, G, SMh, SSpi, STi, SUt, GUt, GMh
E,MH,Ut,Ph	E, Mh, Ut, EPh, MhS, PhE, MhSSpi, UtS, UtG, UtMh
AA	AAWB'G, AAE, AAB''G, AAB'W'G, AAPb'W'B', AAB''WB', AAW'WB', AAW''', AAG, AAW'WB'G, AATa-'E, AASh''', AASpa'Sh'G, AAW'G

B. <u>With Ridge and Pool Pattern</u>

1. <u>S or G</u>

S or G	RS,RG, RSTi

2. <u>10-90% S or G</u>

W/o Trees	RB'G, RB'S, RB''S, RB'STi, RB''G, RB''STi, RMhS, RSMh, RSMhTi, RSUt, RSMhSpi, RUtS, RWB'G, RB'WB'G, RGMh, RMhG
With T	RTa-'MhS, RTa-'SMh, RTa-'B'S, RTa'B'S, RTa'MhS, RTa'S, RTa'UtS, RTa''S, RTb'Ta'S, RTb'Ta'S, RTb'B'S, RTa'B'G, RTa'SMh, RTb'SMh, RTa-'UtS, RTb'MhS
W/Sp or Sc	RSpa-'MhS, RScb'UtS, RScb'Sca'Mh, RSpb'S

3. <u><10% S or G</u>

W/o Trees	RB''', RL, RM, RE, RUt, RMh, RB'Mh, RB'Ut
With T	RTa-'Mh, RTa-''Ut, RTa'E, RTa'Ut, RTb'Ta'', RTb'Ta'Ut, RTa'M, RTa-'Ut, RTa-'M, RTa''B', RTa''Ut, RTa''E, RTb'Ut, RTa''', RTa'B''

W/Sp or Sc — RSpa'M, RSpb'M, RSpb'Sca'M, RSpb''M, RSpa-'M, RSpa-''M, RSca'M, RSca-'M, RScb''M, RScb'Ta'Ut, RSpa''M, RSpb'''

II. NONPEATLAND

A. Upland — D, DSd, AAu, Dv, Sd, N, ND, DNSd, DN, NDSd

B. Open Water — Shading Film

o o o o o o o o o

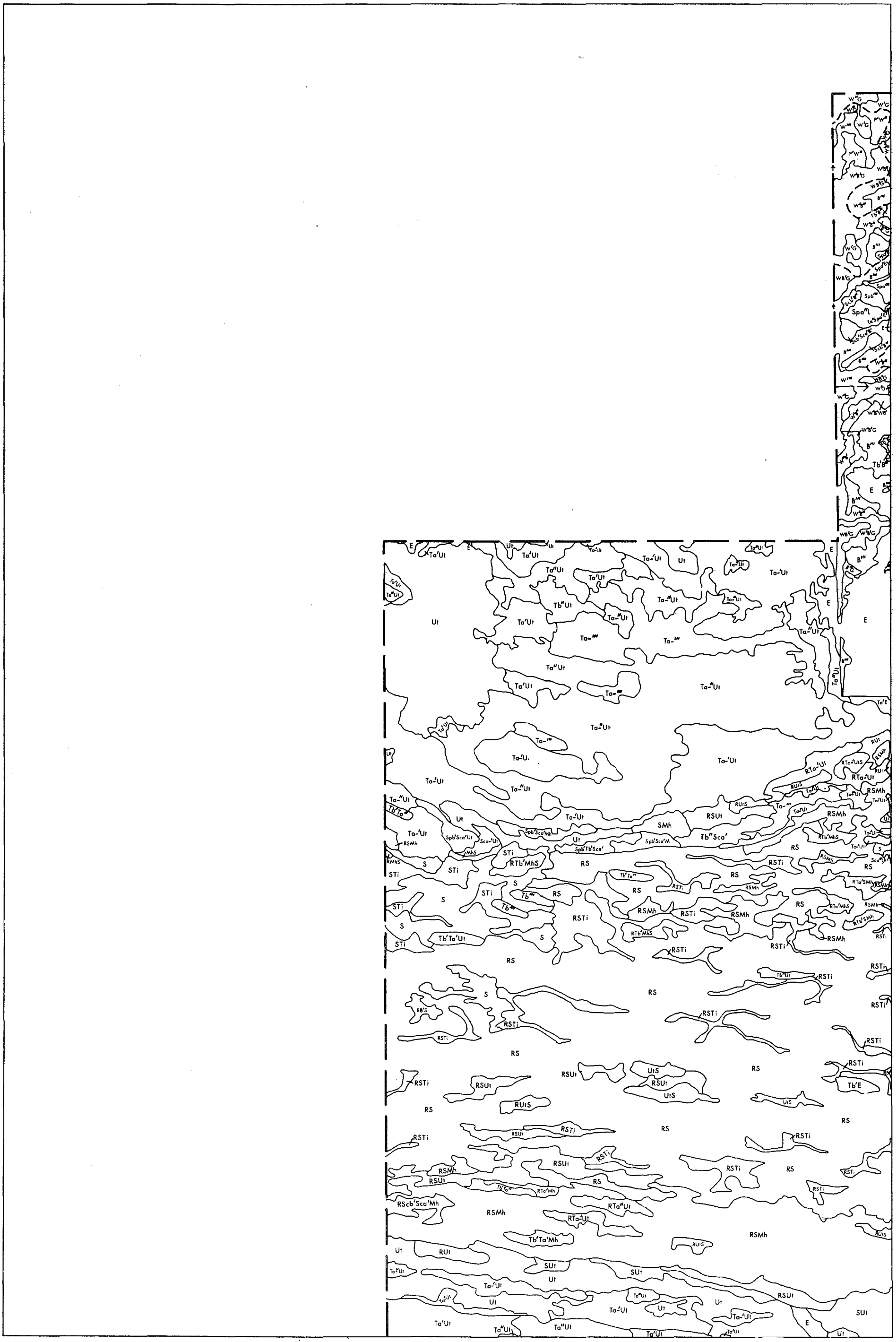

Figure 9. Oaks Corner Quadrangle

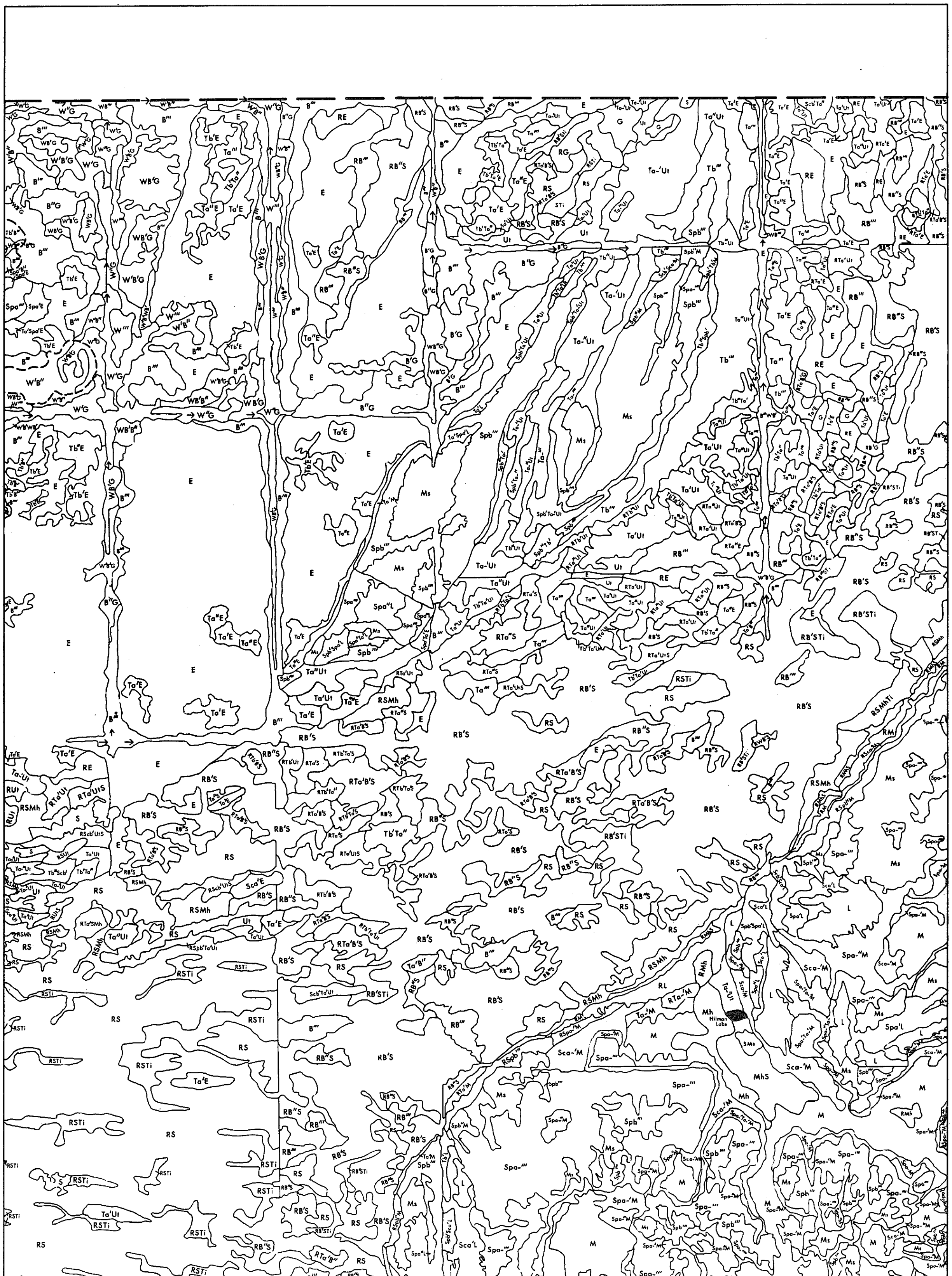

Figure 10. Hilman Lake Quadrangle

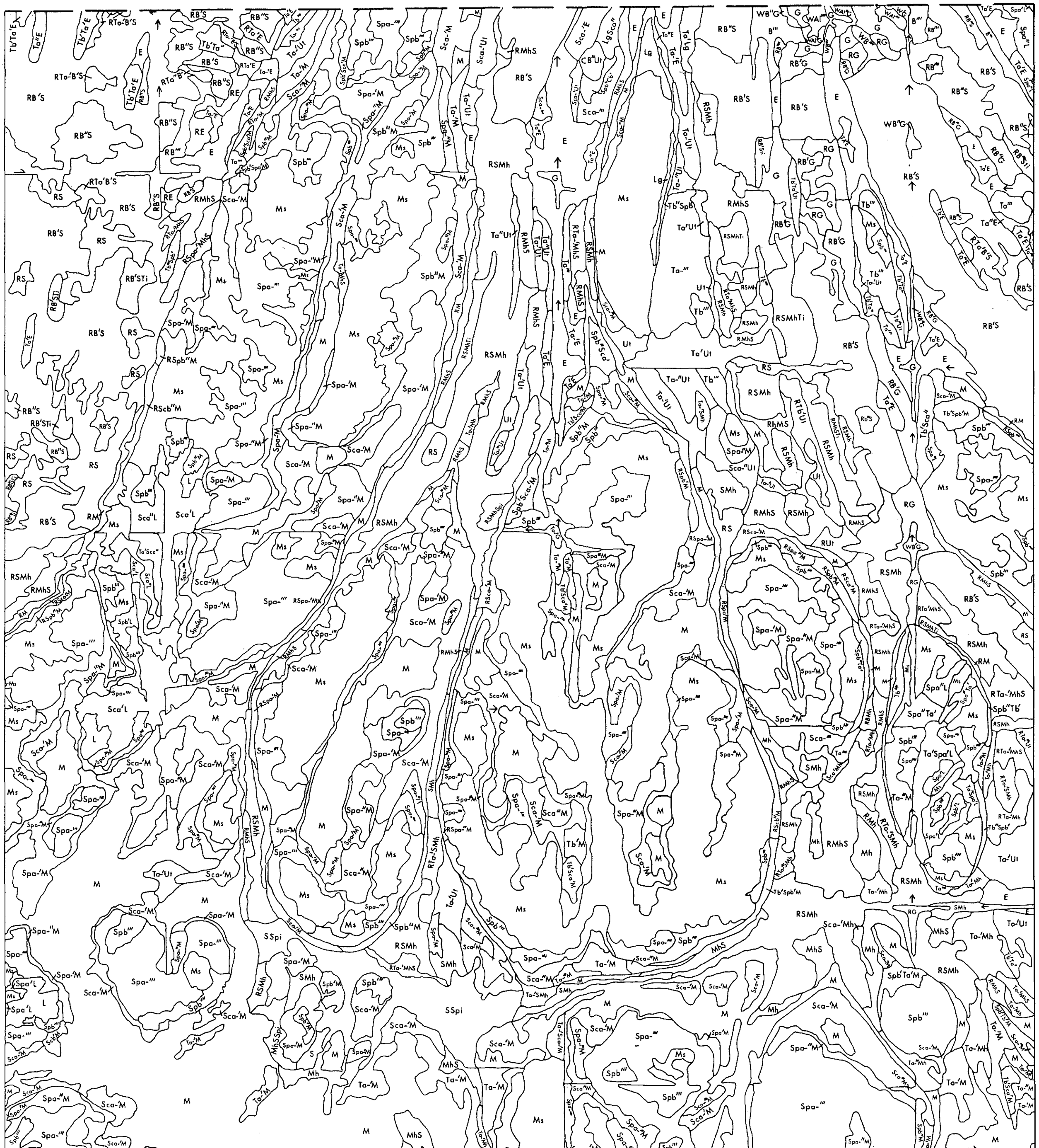

Figure 11. Chase Brook SW Quadrangle

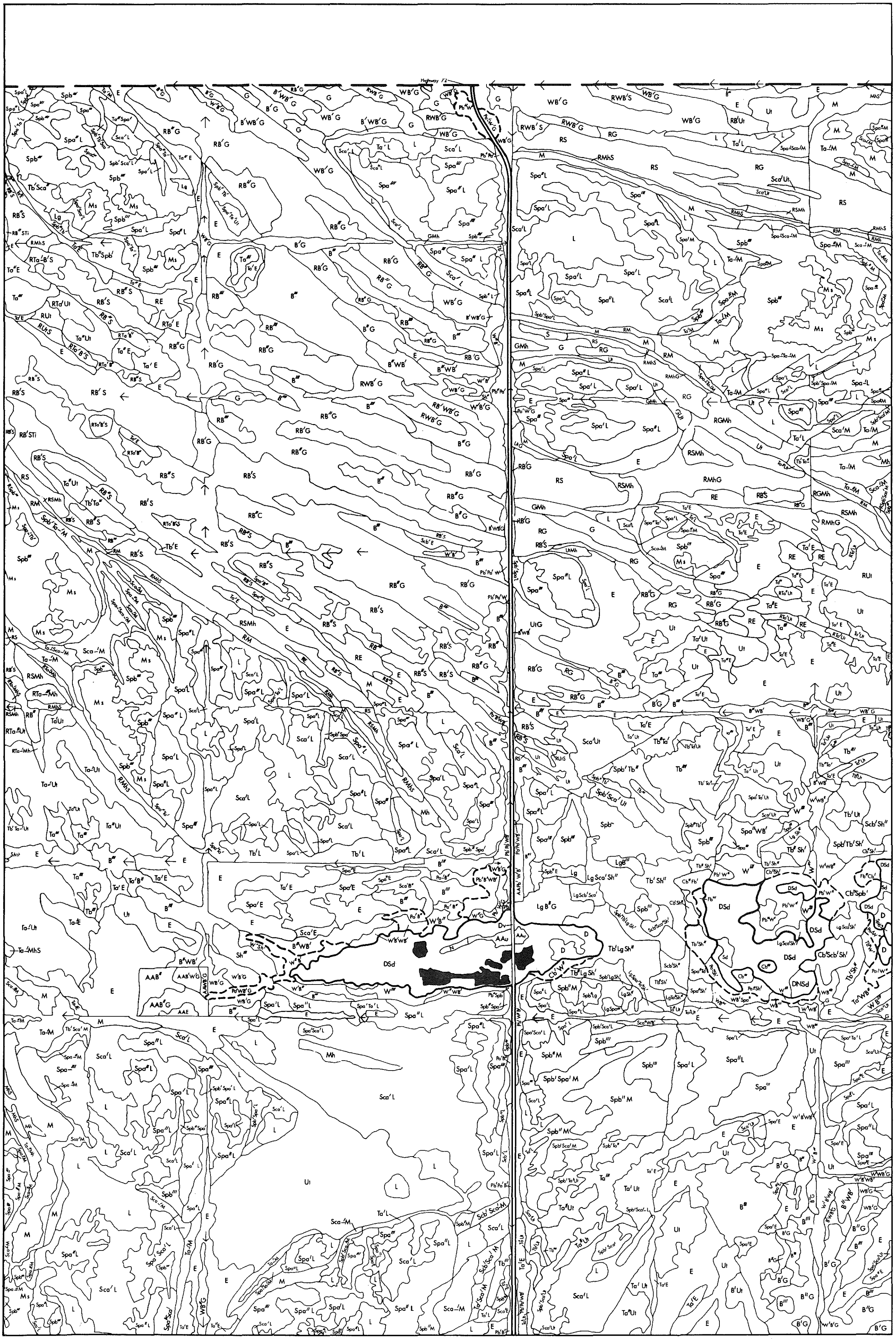

Figure 12. Ludlow Lookout Tower Quadrangle

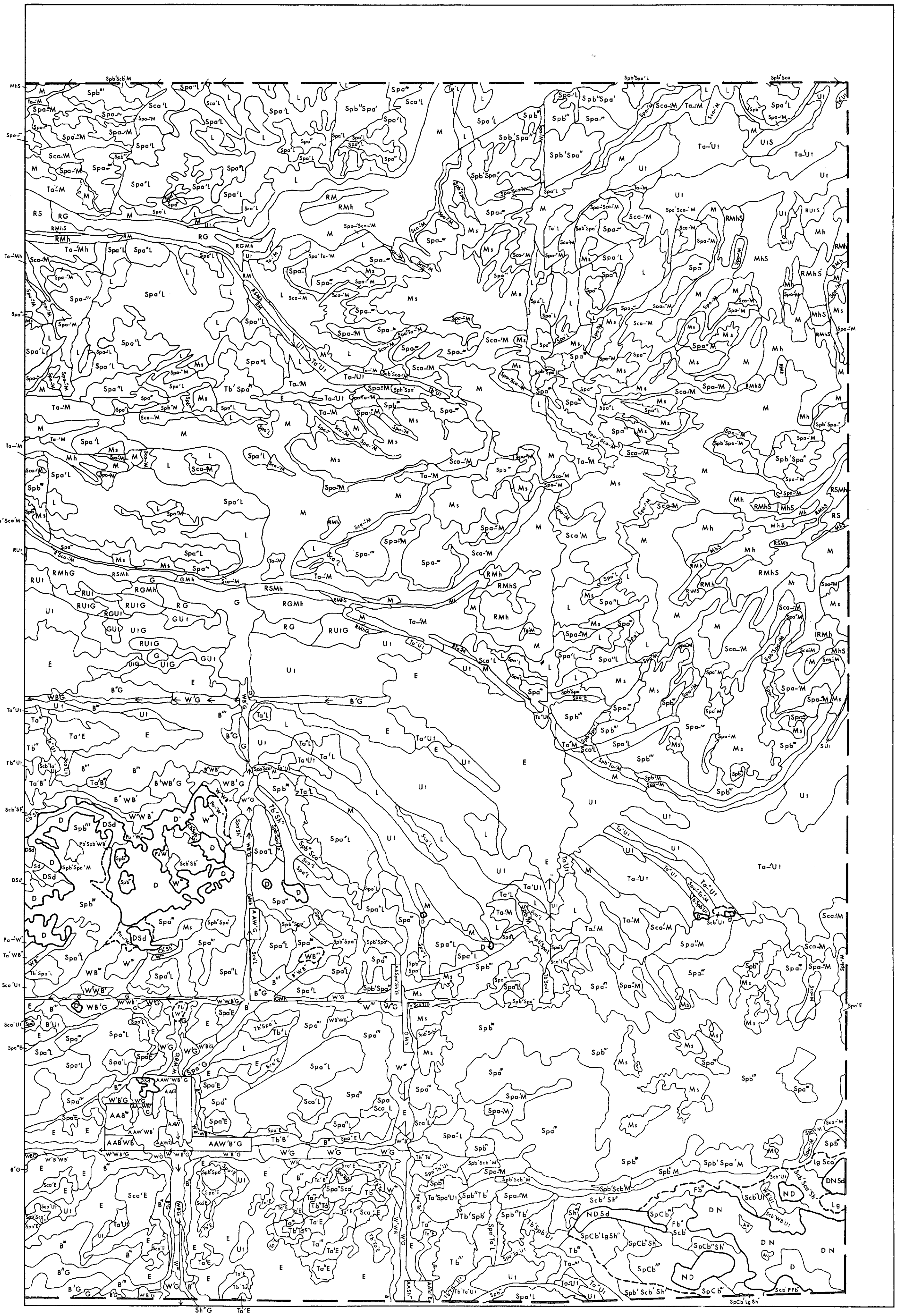

Figure 13. Wayland SW Quadrangle

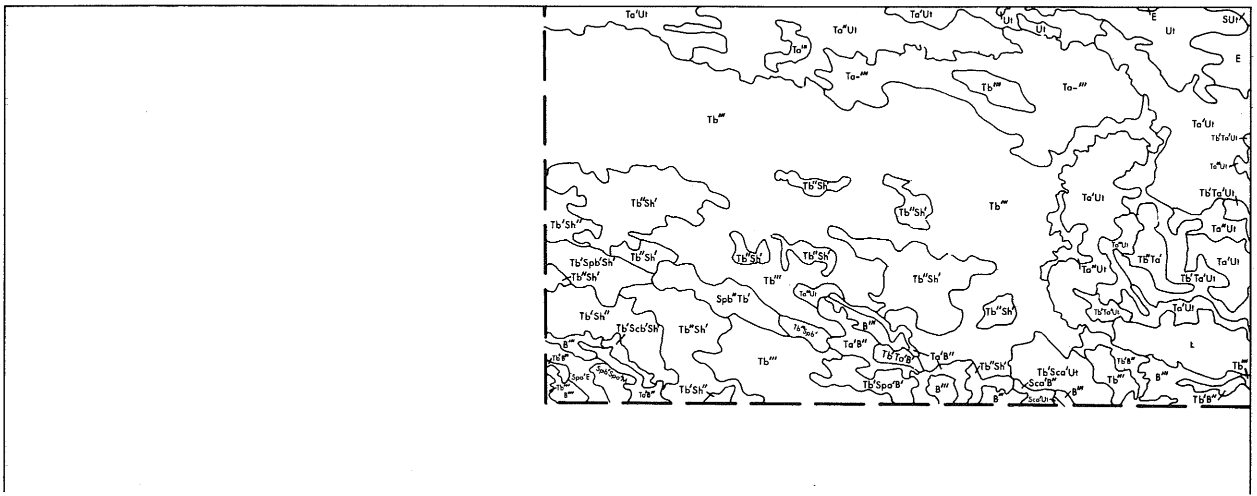

Figure 14. Ponemah NW Quadrangle

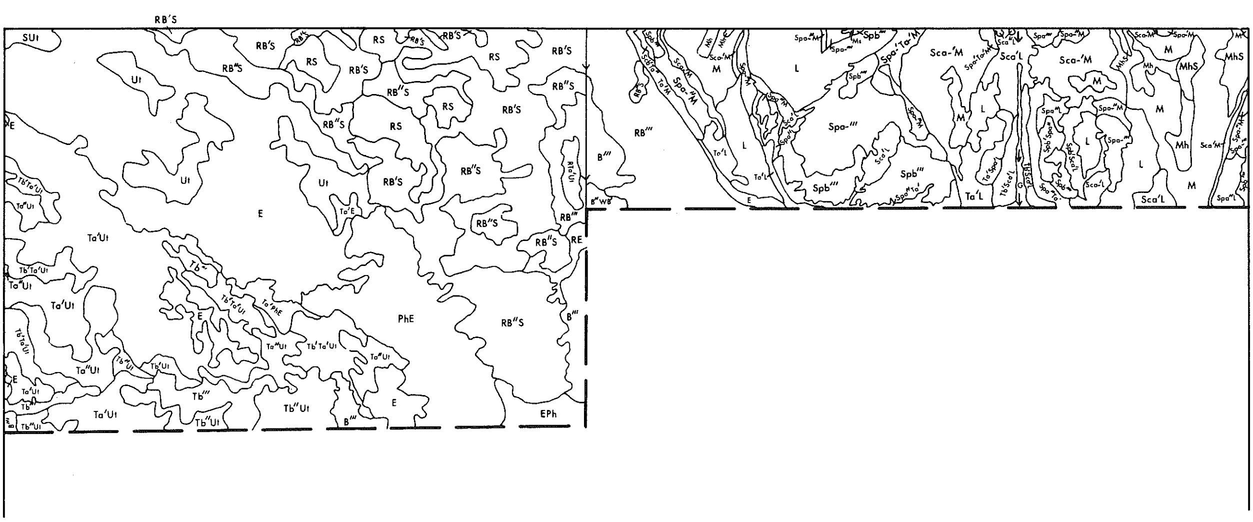

Figure 15. Ponemah NE Quadrangle

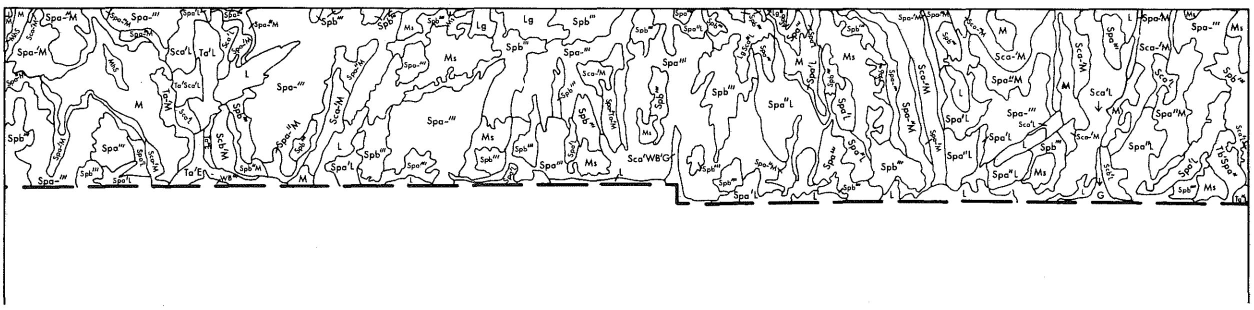

Figure 16. Waskish NW Quadrangle

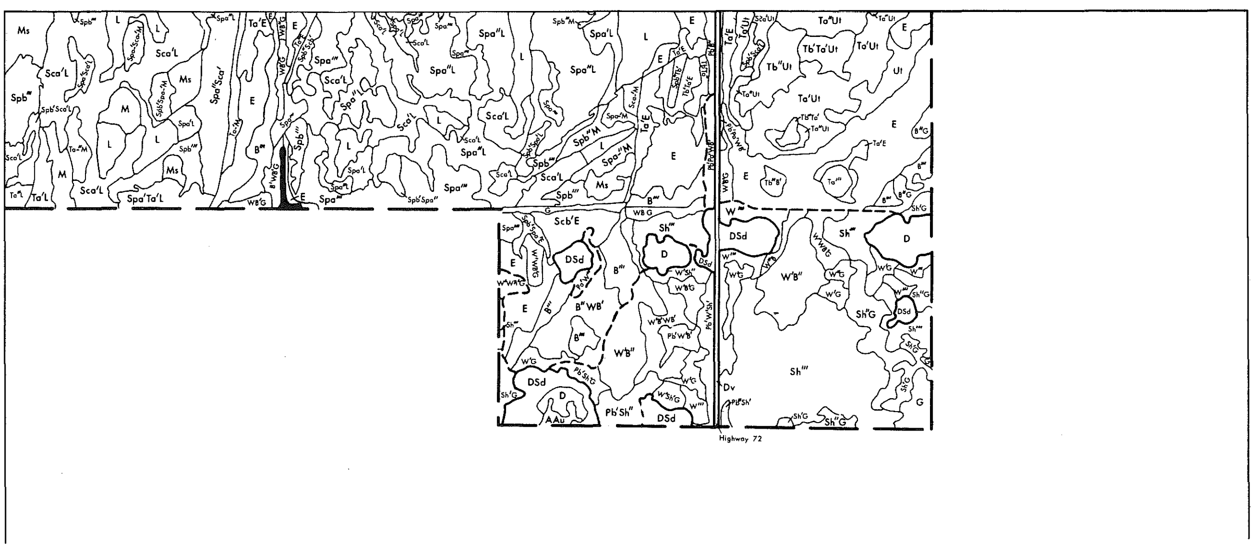

Figure 17. Waskish NE Quadrangle