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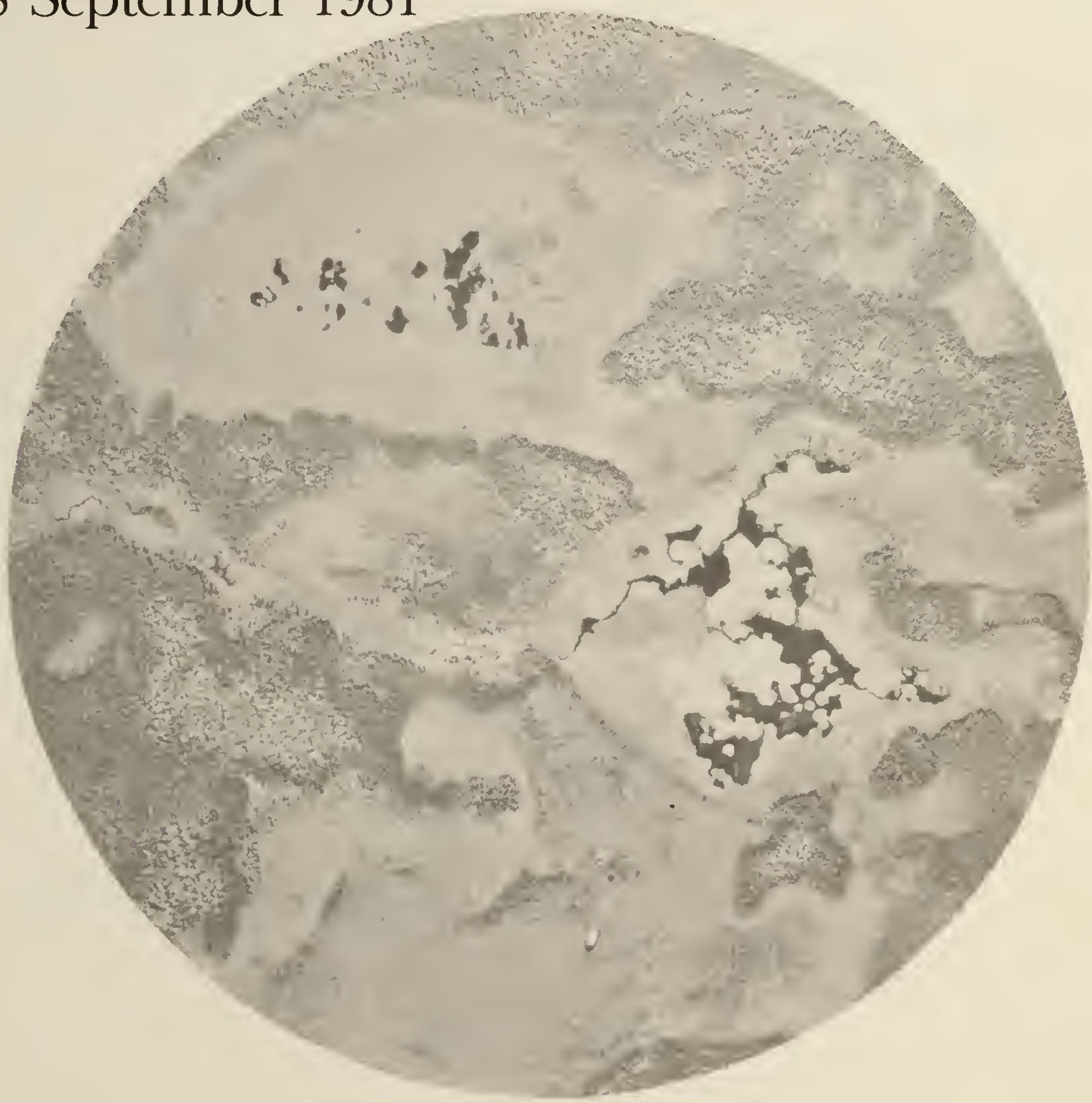
Proceedings of the organic soils mapping and interpretations workshop

Fredericton, New Brunswick
15-18 September 1981



Canada

Cover: Cranberry Bog, located in New Brunswick's Maritime Plain (after Bostock, Geological Survey of Canada), latitude 46°08", longitude 66°11", consists of two ombrotrophic domes separated by a wet minerotrophic lagg area. The central lagg contains a series of interconnected lakes and has well defined boundaries suggesting that it was once a lake which is in the process of being filled in by peatland vegetation.

Peat stratigraphy is comprised of 1 to 3 metres of fibric sphagnum peats overlying 1 to 2 metres of mesic to humic sedge peats.

Vegetation on the domes includes shrubs with lichens and dwarf trees. Taller trees are present along dome slopes. The lagg area is covered by shrubs and sedges, often forming floating mats. There is a rapid transition from ombrotrophic to minerotrophic vegetation indicating an encroachment of ombrotrophic species into the lagg area.

(Note: Information compliments of the Peatland Inventory Section, New Brunswick Department of Natural Resources)

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SUMMARY

A workshop was convened by the Land Resource Research Institute of Agriculture Canada, in cooperation with the Peatland Inventory Section of the New Brunswick Department of Natural Resources, 15 to 18 September, 1981 at Fredericton. The general theme was the methodology for characterization, mapping and interpretation of peatland. The sessions included:

A. Examples of mapping of organic soils in British Columbia, Alberta, New Brunswick and Newfoundland.

B. Characterization and classification of peat materials.

C. Interpretation and use of organic soils.

D. Exercises on interpretation of aerial photographs and on the construction of legends.

E. Tours of Bull Pasture bog and of Benton Marsh.

RESUME

Une période d'études sur la cartographie et l'interprétation des sols organiques, sanctionée par l'institut de recherche sur les terres d'Agriculture Canada en coopération avec la Section de l'inventaire des tourbières du départment des resources naturelles de Nouveau-Brunswick, a eu lieu du 15 au 18 septembre, 1981, ;a la station de recherches d'Agriculture Canada à Fredericton, Nouveau-Brunswick. Le théme général de cette période d'études fut la méthodologie de la caractérisation, la cartographie, et l'interprétation des tourbières. Les séances comprenaient:

A. Exemples de cartographie des sols organiques Colombie Britanique, Alberta, Nouveau-Brunswick, Terre Neuve.

B. Caractérisation et classification de matières de tourbe.

C. Interprétation et utilisation des sols organiques.

D. Exercices sur l'interprétation des photos et sur la constructions des légendes.

E. Tournées de:
le marais "Bull Pasture"
lat. 46° 02' long. 66° 19'

le marécage "Benton" (trasitionel)
lat. 45° 59' long. 67° 37'

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Acknowledgments

On behalf of the Land Resource Research Institute, the editor would like to thank all persons who have contributed to the success of this workshop. We extend our gratitude to the authors of the many technical papers for their stimulating presentations, and as well to the workshop participants whose active involvement gave rise to a fruitful exchange of ideas and opinions. Several individuals and agencies deserve special recognition for their contributions. These include: Mr. John Day, L.R.R.I., who initially proposed that the workshop be undertaken and provided suggestions for content and organization; Mr. Charles Tarnocai, L.R.R.I., who assisted greatly in organizing and conducting the workshop; Mr. David Keys and his colleagues from the Peatland Inventory Section of the New Brunswick Department of Natural Resources whose extensive knowledge and experience in organic soil mapping in New Brunswick played a major role in the overall outcome of the workshop; and Dr. C. Bernard, Director, Agriculture Canada Research Station, Fredericton, N.B. for providing the facilities for holding the meetings.

H. W. R.

Opening Remarks

J.H. Day

At a previous organic soil mapping and interpretation workshop held in St. John's, the objective was to pursue a better comprehension among soil surveyors of ways and means to map and interpret organic soils. This was, and still is held to be, an important objective because by and large we soil surveyors as a group have not provided to the public as much information for organic soils as for mineral soils.

In the past year, I think the lessons learned have been applied to our current mapping projects in at least some areas where peatlands are present. In spite of this minor improvement I fear that, overall, the higher level of mapping accuracy, the more extensive descriptions in legends for greater clarity, and the more useful information about the whole peatland that is required for use interpretations and development recommendations, have yet to become visible to the public.

I guess none of us expected there would be a giant leap forward after only the first workshop. There are other methods or pathways to know and explore. One of the most important of these is the work performed here in New Brunswick by the personnel of N.B. Ministry of Natural Resources. This group, I understand, has mapped and characterized a large portion of a very important provincial resource under active utilization for horticultural peat and development as an energy feedstock.

The N.B. soil survey group then led by Russell Wells with Herb Rees assisting, was in 1980 requested to solicite the active participation of the N.B. Resource group, led by Mr. Dave Keys, in the organization of a second workshop devoted primarily to methodology for characterization, mapping and interpretation of peatland resources.

I think you will agree that the agenda before you promises a rich diet in the next two days, followed by two days in the field directed toward interpretations of the resource. During the field work active participation by all is the key to progress. I wish to compliment Herb Rees and Dave Keys and their associates for their efforts in preparing this workshop for us, and also the speakers to follow for their contributions in support of the resource inventory program.

This workshop is timely. You may be aware of the possibility of future funding by federal agencies (specifically NRC) for research on the role of peatlands in the national energy program. This workshop may enable us all to more effectively react to and service future demand for an expanded and improved resource data base and recommendations for its development for production of energy, food or fiber.

I sincerely hope that in 1982, the surveyors from Quebec, Ontario, Alberta and B.C. will organize and convene similar organic soil mapping and interpretation workshops in their areas.

AN OVERVIEW OF THE NEW BRUNSWICK PEAT RESOURCE

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Canada

SUMMARY

The New Brunswick Department of Natural Resources has carried out a detailed evaluation of the Province's peat resource. This evaluation has shown significant regional variation in the type of peat present. This variation is reflected by a gradual change in peatland stratigraphy with increased distance from the coast.

The coastal peatlands are strongly domed bogs with thick layers of poorly humified sphagnum peats overlying thin basal layers of well decomposed peats. These bogs contain large quantities of excellent quality horticultural peat. In the central part of the province, the peatlands are again mainly domed bogs and are commonly located on the divide between major drainage systems. The doming is less pronounced, surficial layers of poorly humified sphagnum peats are thinner, and the basal layers of well decomposed peats are thicker, than in the coastal region. These peatlands have good potential for horticultural peat development and many could be used for fuel peat extraction after the horticultural peat has been removed. In the western region, the peatlands are commonly associated with a slow moving stream or lake. When present, domed areas of poorly humified sphagnum peats are generally thin and of limited extent. The deposits are comprised mainly of well decomposed peats. This region has low potential for horticultural peat development but good potential for fuel peat extraction. Several large marshes in the south-central part of the province have little potential for development due to their thin peat layers and periodic flooding.

Eighteen peatlands, all in the coastal region, are currently leased for horticultural peat development. The requirements for obtaining a peat lease under the provisions of the Quarriable Substance Act are outlined. Studies carried out on a number of other development options are discussed.

INTRODUCTION

Recent estimates (Kivinen and Pakarinen 1980) place the total area of peatlands in the world at over 420 million hectares. The extent of Canadian peatlands is not accurately known but the estimate has recently been raised to 170 million hectares (*op. cit.*). A figure of 150 million hectares is commonly used for the U.S.S.R.

In New Brunswick, a horticultural peat industry and an interest in the use of peat as a fuel led to a detailed inventory of the resource. The details of the inventory procedure are presented elsewhere in these Proceedings in the paper by Keys and Ferguson. This paper will deal with variation in the type of peat and peatlands that was noted in the course of the inventory. Present and potential utilization of the resource will be discussed relative to the type of peat available.

DISTRIBUTION OF THE RESOURCE

A preliminary distribution map of muskeg occurence in New Brunswick, produced using computer plotting techniques, estimated 10% of the surface area (about 700,000 ha) was peatland (E. Korpijaakko 1975). Langmaid (1962) estimated the extent of peatlands from available soil, forest inventory, and peatland maps and felt 125,000 ha to be "a reliable estimate". Airphoto Ananysis Associates (1975) report about 85,000 ha of peatlands. During the course of the inventory carried out by N.B. Natural Resources, a figure of "in excess of 100,000 ha (250,000 acres)" (Gemmell and Keys 1979; Keys 1980) was used. Based on the inventory results, a figure of approximately 140,000 ha is now felt to be accurate.

Figure 1 shows the distribution of peatlands in the Province. It is based on the 1:50,000 scale maps which accompany the Airphoto Analysis Associates report with updates from the N.B.D.N.R. inventory.

REGIONAL FEATURES OF THE RESOURCE

The peatlands of New Brunswick can be said to be confined as opposed to the unconfined muskegs of Canada's north. Peatland complexes, which occur as the result of the merging of several nearby peatlands, are found in the province. The largest of these is in the Escuminac area of eastern New Brunswick and exceeds 6,000 ha (15,000 acres).

Peat depths of 10 metres have been recorded by the N.B.D.N.R. inventory. The rate of accumulation of the peat layer has been determined at two sites using radiocarbon dates. The accumulation rate of 0.5 to 1.7 mm per year indicates peat must be considered a non-renewable resource.

The available data show a gradual variation in peatland stratigraphy from east to west. However, to facilitate a description of the resource, a grouping of peatlands displaying similar characteristics is desirable. This grouping has been made primarily on the basis of the stratigraphy of peatlands as displayed on the profiles produced by N.B.D.N.R. Peatland zones have not as yet been accurately defined. Thus, this report describes a number of regions containing peatlands with similar characteristics.

Since every peatland has individual characteristics, a generalized regional description will have exceptions. Variations in regional characteristics are reported in an attempt to outline features which could lead to

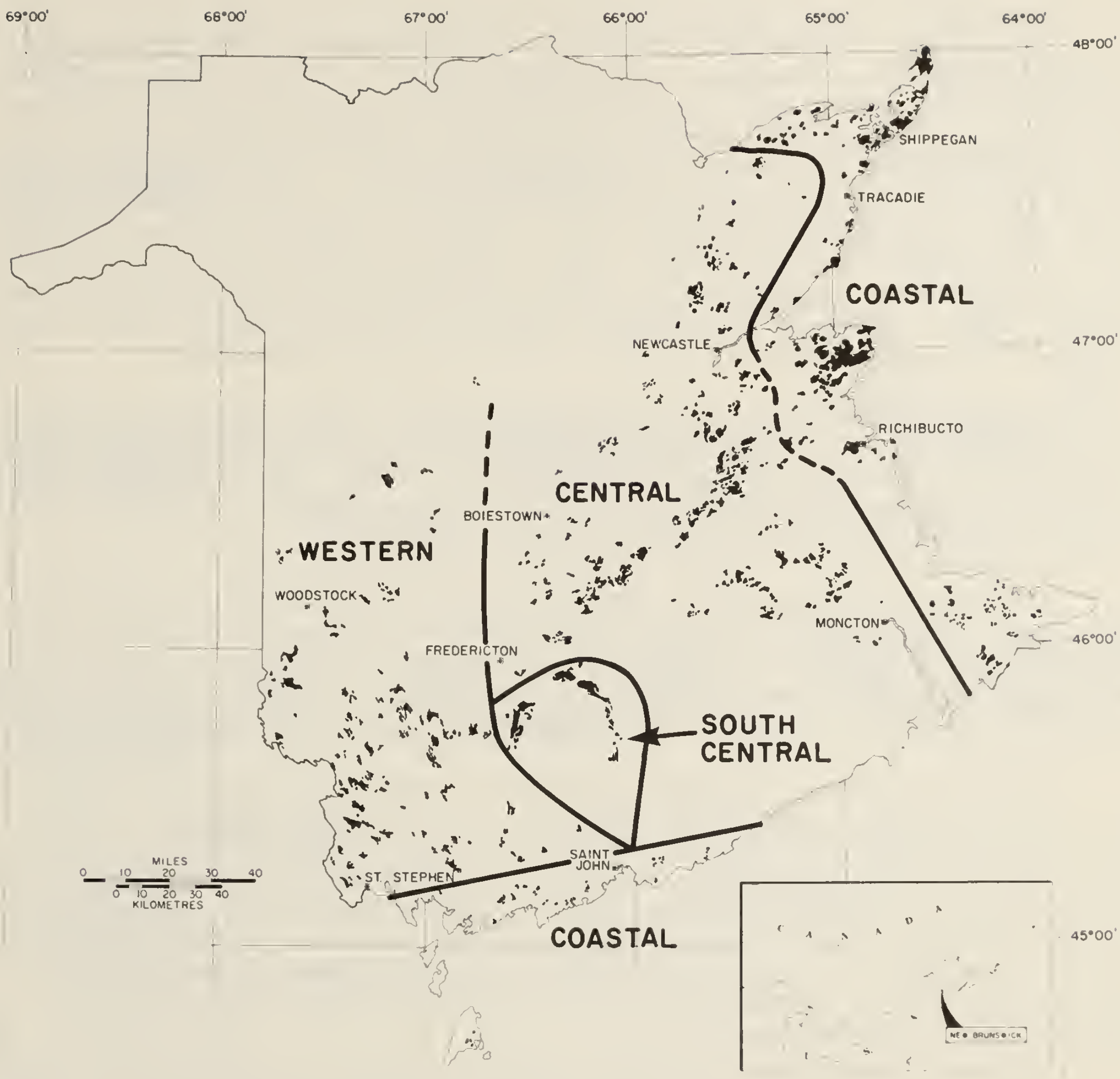

Figure 1. Distribution of peatlands in New Brunswick. The regions shown are described in the text.

further subdivisions when data compilation is completed by the N.B.D.N.R. inventory.

While variation in stratigraphy is well suited to the selection of peatland zones, other factors can be used to refine these selections. In particular, surface vegetation can be used as a differentiating criteria.

COASTAL PEATLANDS

Ombrotrophic peatlands are present along the east and southwest coasts of New Brunswick. In general, they are well developed raised bogs showing concentric patterns of doming. Peat stratigraphy in these regions commonly consists of thin (less than 1 m) basal layers of sedge group peats overlain by thick (2 to 7 m) layers of poorly decomposed sphagnum peats (Figure 2). Surface vegetation is commonly low shrubs and mosses. Shrub species include huckleberry (*Gaylussacia dumosa*), black crowberry (*Empetrum nigrum*), cloudberry (*Rubus chamaemorus*), sheep laurel (*Kalmia angustifolia*), and leatherleaf (*Chamaedaphne calyculatta*). Lichen (*Cladonia* spp.) is common on drier parts of the dome. *Scirpus coespetosus* lawns occur frequently in extreme coastal areas. *Sphagnum fuscum* and *S. rubellum* are the dominant moss species, while *Polytrichum* and *Dicranum* species occur sporadically.

A dense tree cover of tall (over 5 m) black spruce (*Picea mariana*) and/or tamarack (*Larix laricina*) is common on the edge of the peatlands but is generally sparse on the centres and margin slopes. When present in these areas, the tree cover is usually stunted to shrub height. In extreme coastal areas, this may partially be due to wind exposure.

Bedrock along the east coast is gently dipping sandstones of Carboniferous age. Mapping of surficial deposits in the northeast peninsula indicate isostatic rebound following deglaciation was as great as 240 feet (Gauthier 1978). Radiocarbon dates at a marine fossil locality indicate marine deposition was still occurring at Shippagan at 12,600±400 years B.P.

The uplift of the land mass relative to sea level following deglaciation probably was a contributing factor in peatland development. It has been suggested (M.L. Korpijaakko 1976; M.L. Korpijaakko and Radforth 1972) that small shallow ponds, which formed following recession of the sea, functioned to initiate peat formation which was sustained by the moist climate. Pollen diagrams supported by radiocarbon dates were used to determine that peat growth began in a bog near Tracadie (No. 516A) about 8,500 years B.P. Wood fragments from the base of a bog at Point Escuminac (No. 338) have been dated at 4,300±130 years B.P.

After considerable development of the peatlands, the land mass along the northeast coast has subsided in relation to sea level. Over 20 peatlands have been partially eroded resulting in the formation of peat cliffs up to 4 metres high. The base of some deposits is presently 2 metres below sea level. These peat cliffs offer a rare opportunity to observe the stratigraphy of the peatland.

The group of peatlands east of Moncton (Shediac-Sackville area) are separated geographically from those north of Richibucto (see Figure 1). As

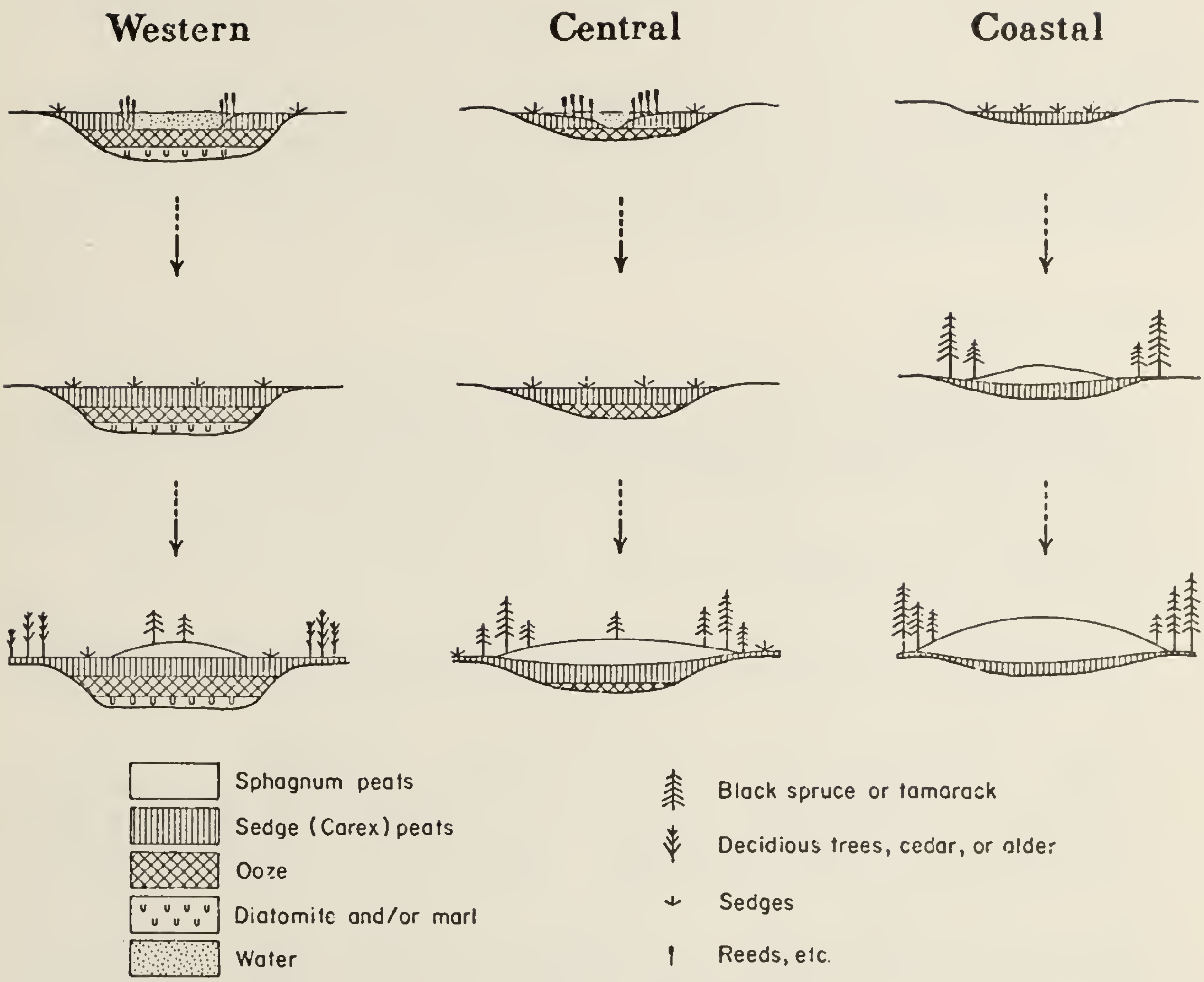

Figure 2. Development sequences and generalized stratigraphy of three peatland regions in New Brunswick.

well, the basal layer of well decomposed peats is thicker than in the northern part of the zone. Peatland boundaries are fairly distinct in the north, whereas there is often a merging into shallow marsh deposits in the Sackville area. Interbedded clay layers are found in some deposits. Slopes and domes are generally less pronounced, and wetter than the northern region. Vegetation is comprised of similar species, with the inclusion of more water oriented plants such as beak rush (*Rhyncospora alba*), bladderwort (*Utricularia cornuta*), pitcher plant (*Sarracenia purpurea*), and sundew (*Drosera rotundifolia*). A subdivision of the coastal zone could be considered for the Shediac-Sackville area.

The peatlands along the southwest coast form an extension of the coastal raised bogs of southeast Maine as described by Damman (1977) and Worley (1980). These bogs are generally smaller in all dimensions than those along the east coast. Thin basal ooze layers suggest initiation of peat formation occurred in a shallow open water environment. Stratigraphy and vegetation closely parallel that described above for the east coastal bogs. The peatlands of M.L. Korpijaakko's (1976) Southern Coastal Zone (after Ganong 1897) are included in this region.

CENTRAL PEATLANDS

The areal extent and total thickness of the peatlands in the centre of the province are less than in the coastal regions. Most peatlands are domed ombrotrophic bogs although a few have not progressed beyond the minerotrophic stage. Peat stratigraphy (Figure 2) is comprised of a confined basal ooze layer overlain by 1 to 3 metres of sedge peats and/or well decomposed sphagnum peats. Uppermost layers usually are poorly decomposed sphagnum peats of 1 to 4 metres thickness. Woody layers are common at the base of the surficial layer.

The surface of the margin slope and dome of the peatlands is commonly characterized by dry hummock ridges alternating with wet hollows with the latter frequently forming shallow bog pools. Surface vegetation on the ombrotrophic centres is commonly shrubs and mosses with stunted black spruce or tamarack, and occasionally solitary white pine (*Pinus strobus*). Shrub species include leatherleaf, sheep laurel, bog laurel (*Kalmia polifolia*), and labrador tea (*Ledum groenlandicum*). Margin slopes often have a dense tree cover of tall (over 5 m) spruce or tamarack. Lagg areas (called bog moats by Damman 1979) are generally wet. Wide laggs with small streams (lagg brook) frequently occur. Vegetation on the laggs is comprised of many herbaceous plants including *Carex* and *Eriophorum* spp., false solomon's seal (*Smilacina trifolia*), bogbean (*Menyanthes trifoliata*), pitcher plant, and sundew. Members of the *Orchidaeceae* can be observed. Shrub cover is generally sparse, and includes bog rosemary (*Andromeda glaucophylla*), rhodora (*Rhododendron canadense*) and bog laurel. The edges of the peatlands normally have a dense cover of tall shrubs (mainly rhodora), and trees (black spruce or tamarack). Speckled alder (*Alnus rugosa*) is common along the margins, at times forming dense swamps.

The central zone is underlain primarily by Carboniferous age sandstones with generally flat topography. Concentrations of peatlands are commonly found on the divide area between major river systems.

Confined basal ooze layers indicate peatland development began around shallow post-glacial lakes. Once the lakes were filled, the peatlands had extensive lateral development by paludification of the surrounding areas.

Birch Ridge Bog (No. 41) was included in the coastal region by M.L. Korpijaakko (1976) mainly on the basis of its proximity (40 km) to the sea. It falls within the central region of this report. As well, Korpijaakko studied three sites in the western part of this region. She classified Timber Pond Bog (No. 363), Bull Pasture Bog (No. 389), and Regent St. Bog (No. 809B) as part of her Southern Inland zone and indicates peat development began 7,000 years B.P. at Timber Pond, 7,500 years B.P. at Bull Pasture, and 8,500 years B.P. at Regent St.

The area around Boiestown, Minto, and Fredericton contains extensive areas of paludified forest between major peatlands and peat depths are in the 10 to 50 cm range. Fire may have been a contributing factor in the development of these paludified areas. As well, the group of peatlands in the Bartibog area (north of Newcastle) may be a subgroup on the basis of variation in morphology and vegetation.

WESTERN PEATLANDS

The majority of peatlands in this region are associated with lakes or large streams. The surface of the peatlands is flat to slightly domed, rarely rising more than a few metres above the surface of the associated water body. Peatland boundaries are poorly defined. Heavily wooded swamps frequently border open peatlands.

Many of the peat deposits are underlain by thick (up to 4 metres) ooze or gyttja deposits including marl and diatomite (Figure 2). Overlying this are 2 to 5 metres of medium to well decomposed sedge peats with some woody sphagnum peats. Surface layers of poorly decomposed *Sphagnum* are generally thin (1 to 2 metres) and of limited extent.

Surface vegetation on the ombrotrophic areas is a shrub-moss community with trees 2 to 5 metres tall. Shrub species include leatherleaf, sheep laurel, rhodora, and labrador tea. Tree cover, composed mainly of black spruce and tamarack, is often dense. Narrow (5 to 10 m), open floodplains, covered with sedges and grasses, are common along stream and lake borders.

Lagg and margin areas are frequently extensive and often comprise the major portion of the peatlands. Surface cover of the laggs and margins ranges from open sedge-moss cover to thick shrub-brown moss associations. Shrub species include sweet gale (*Myrica gale*), meadowsweet (*Spiraea alba*), and hardhack (*Spiraea tomentosa*). Stunted trees are common, including willows (*Salix* spp.), northern white cedar (*Thuja occidentalis*), swamp birch (*Betula pumila*), red maple (*Acer rubrum*), black spruce and tamarack. Swampy areas are often heavily treed with northern white cedar, red maple, black spruce and occasional thick growths of mountain holly (*Nemopanthus mucronatus*) and alder. In general, these swamps have peat accumulations of less than one metre.

The bedrock underlying peatlands of the western region is mainly

Ordovician and Silurian sediments and Devonian intrusives. Present drainage systems in the zone reflect ice-controlled late-glacial drainage patterns. Streams are generally parallel to major glacial outwash and esker systems. Glacial retreat was in several stages (Gadd 1973).

The marl and diatomite deposits indicate deposition was initiated in a deeper water environment, possibly a post-glacial lake. As mentioned above, peatlands in this region frequently occupy a topographic valley in association with a large stream. Water and nutrients come from higher areas nearby and would have contributed to the development of the thick minerotrophic layers found in many deposits. In some cases, ooze layers are interbedded with the peat indicating a movement or overflow of the drainage channel.

The peatlands of M.L. Korpijaakko's (1976) Northern Inland Zone are included in this western region. Characteristics, such as the amount of doming and the presence of large swampy areas, etc., vary somewhat in peatlands of this region and further subdivision may be possible with a more detailed evaluation of the available data.

SOUTH CENTRAL PEATLANDS

These peatlands are riverside marshes situated along the Saint John and Oromocto Rivers to the southeast of Fredericton. The surface of the marshes is relatively flat and frequent flooding occurs. The vegetation present reflects an elevated water table.

The peat layer is comprised mainly of well decomposed herbaceous materials. Fine sediments are often found within the peat. Peat depths are irregular and range from a few centimetres to three metres.

Vegetation, often dense, is comprised of a wide variety of shrub and herbaceous species. An increase in the number, height, and density of plants is apparent with increasing distance from the river.

Woody plants include sweet gale, meadowsweet, dwarf willow, and speckled alder. Herbaceous plants include bogbean, royal fern (*Osmunda regalis*), swamp horsetail (*Equisetum fluviatile*), arrowheads (*Sagittaria* spp.), blue flag (*Iris versicolor*), sweetflag (*Acorus calumus*) and a wide variety of sedge and grass species. Trees are present along the border of marsh and mineral soil, including hardwood species such as dogwoods (*Cornus* spp.), maples, willows, and alders. Mosses are rare.

SURVEY FINDINGS AND RESOURCE RECOVERY

Of the approximately 140,000 ha of peatlands in the Province, some 132,000 ha have been investigated by the inventory project. Those peatlands not investigated include about 4,500 ha in Kouchibouguac National Park and numerous peatlands less than 25 ha in size. The investigated peatlands comprise a volume of 2.4 billion in situ cubic metres of peat.

Of the surveyed peatlands, some 67,500 ha (51%) have depths in excess of 1 metre and constitute a volume of 2.1 billion in situ cubic metres. This volume can be subdivided into 1.3 billion cubic metres (61%) of poorly humified (H1 to H4) peats and 0.8 billion cubic metres of well humified peats. Peatlands composed mainly of poorly humified peats have high potential for horticultural purposes. Peatlands comprised mainly of well humified peats have potential for fuel purposes.

It should be emphasized the volumes given represent the in situ resource. As with any geologic deposit, the mineable reserves must be determined to fully evaluate the potential. Reliable estimates can best be made on each individual peatland rather than on a regional basis. A peat depth of one metre is generally considered the minimum limit of economic mineability. As well, peatlands less than 50 to 100 hectares in size generally will not support a significant development unless they are in proximity to other deposits. The following parameters should also be considered: (1) botanical composition and decomposition of the peat required for the planned use; (2) drainability; (3) thickness of peat overlying the desired peat type; (4) method of mining; (5) resource management policies including environmental factors, wildlife and conservation areas, and reclamation requirements. The information compiled by the New Brunswick inventory project allows the examination of these factors.

OWNERSHIP OF PEATLANDS

Peat is classed as a surficial deposit in New Brunswick under the provisions of the Quarriable Substance Act. As such, ownership of the deposits rests with the landowner. However, few peatlands were included in the original applications for land grants. Hence, ownership of approximately 65% of New Brunswick peatlands remain with the province under the administration of the Department of Natural Resources.

The twelve companies presently producing horticultural peat products in New Brunswick lease all or parts of their production areas from the province. An acreage rental and a royalty on production is paid annually. The regulations governing leasing of peatlands were recently revised to ensure optimum management of the resource (Department of Natural Resources 1979). The objectives of the leasing policy are to maximize the contribution of the resource to the economic development of the province and to have development in a manner which does not jeopardize future utilization or rehabilitation of the peatlands.

To obtain a peat lease, it is first necessary to obtain a peatland exploration licence. This licence reserves an area of 800 hectares (2,000 acres) to allow the applicant sufficient time to ascertain that the quality and amount of peat in the proposed lease is suitable for the intended use. The exploration licence is granted only if the applicant: (1) has no other licence in effect; (2) can demonstrate the proposed development will not adversely affect the future availability of peat for an existing leaseholder or alternate user; and (3) can market the product without jeopardizing the existing industry in the province.

After determining the portion of the exploration area best suited for the proposed use, the applicant may then apply for a peat lease of 250 hectares (620 acres). This application must include a drainage plan, a harvesting and future expansion plan, and an abandonment plan. If all requirements are met a lease can be granted for a period of ten years. Renewal for further ten year periods is possible if certain minimum production requirements and other conditions are met. A security deposit to ensure compliance with production and abondonment plans is required.

The size and term of leases is designed to avoid the holding and underutlization of large tracts of peatlands for extended periods. However, to ensure the opportunity for expansion, the holder of a lease may negotiate a time limited option on an adjacent buffer zone.

PRESENT AND POTENTIAL UTILIZATION OF THE RESOURCE

Eighteen peatlands are currently leased to twelve companies for the extraction of horticultural peat. Over 2,500 hectares are in production. All companies currently use the vacuum method of milled peat production. Two companies also use the block cut method and another the ridge method.

Over 3 million six cubic foot bales of high quality sphagnum peat are produced annually. Soil mixes are produced by several companies. Artificially dried and compacted peat is marketed by one firm. Compressed peat pots are also manufactured in the province.

The peatlands of the eastern and central parts of New Brunswick have thick surficial layers of poorly humified sphagnum peats. Shrub content is generally low and most peatlands have good drainage possibilities. Surface tree cover is generally low, particularly near the coast. There is sufficient high quality resource to support a horticultural peat industry many times larger than the existing one.

The only fuel peat produced in the province to date has been used for testing purposes at a small peat-fired boiler at Lameque, New Brunswick. The boiler was designed to provide heat for a greenhouse operation. The feasibility of a 40 MW peat-fired steam-electric power station for the Shippagan area of northeast New Brunswick was investigated in a recent report for the Canada Department of Energy, Mines and Resources (Montreal Engineering 1980). The study concluded such a station would be economically feasible in relation to equivalent size oil or coal fired stations. Some 2,100 hectares on 21 peatlands would be required to supply the station.

Other uses of peat, including the production of metallurgical coke, activated carbon, building materials, and methanol, have been investigated in a report for the New Brunswick Department of Commerce and Development (A. Marsan et Associes 1980). Marketability of peat for manufacture of fertilizers, as a feedstock to chemical and fermentation industries, as an oil absorbent, and several other uses were also discussed.

The eastern and central parts of the province have certain deposits with good potential for fuel peat production. However, much of the fuel peat in these ares is overlain by thick layers of horticultural grade peat. In the southwestern part of the province most of the deposits are comprised of well decomposed peats with a reasonable potential for fuel uses. However, most peatlands in this area are associated with streams which have a water level well above the base of the deposit and drainage difficulties could be encountered. Ash contents are also somewhat higher than in other parts of the province.

One peatland is presently used for agricultural purposes in the province. Two other proposals are presently being evaluated and interest is increasing. There is little current interest in the use of peatlands for forestry.

Some 34 sites are presently used as wildlife management areas by Ducks Unlimited. They are the largest single user of wetlands in the province with a present use of about 10,000 hectares and several proposals for other areas. Twenty-two peatlands comprising 4,500 hectares are within the boundaries of Kouchibouguac National Park and are thus protected from development. Parks Canada has a nature study area on one of these peatlands including displays on bog development and vegetation, and a boardwalk across the centre of the bog. Selection of representative peatlands in other portions of the province for conservation purposes has been requested.

MANAGEMENT OF THE RESOURCE

The detailed knowledge of the resource provided by the inventory project places New Brunswick in a unique position for management of the peatlands. Now that the nature and extent of the resource is known, use of the peatlands can be planned to optimize the economic and social benefits to the province.

The existing legislation incorporates the necessary mechanism for the implementation of a comprehensive management plan. Such a plan can minimize conflict between current and proposed uses of peatlands while ensuring the resource makes the maximum contribution to the long term benefit of the province.

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SOIL AND VEGETATION SEQUENCES AS WETLAND MAPPING UNITS: COMPUTER ASSISTED DEFINITION

C.J. Selby & D.E. Moon*

INTRODUCTION

Land resource surveys, including biophysical, ecological, soil, and vegetation surveys, have generally left documented data analysis until the end of the survey. Data presented in the final reports is often based on modal sampling conducted towards the end of the survey and is designed to characterize the central concept of the map units. With notable exceptions (Wang, 1981; Steers and Hajek, 1979) sampling has not been designed to characterize the expected range or distribution of properties within or between map units and this information is often not recoverable. The purpose of this paper is to describe a computer assisted procedure which uses on going data collection and analysis to define mapping individuals (wetland components) and map units. In addition to facilitating definitions the procedure can also document ranges of properties both in mapping individuals and map units. This presentation is not a proposal for a set procedure for map unit definiton but rather a demonstration that available computer data handling packages are flexible enough to be readily adapted to survey problems.

SURVEY OBJECTIVES AND CONSIDERATIONS

The aim of the project is to produce a classification of wetland systems which will facilitate land use decision making and will be mappable at a scale of 1:15,000. The classes defined must be easily and unambiguously ground verifiable, interpretable from the air at a known level of confidence, and provide useful generalizations about wetland characteristics and potential uses. Major concerns are for production of waterfowl, ungulates, furbearers, and domestic forage (both managed and unmanaged). In addition the following points must be considered: 1) the major wetlands of concern are those which are as yet unmanaged, 2) all probable uses with the exception of managed forage production depend on natural vegetation, 3) due to access problems many, if not most, of the wetland systems will have to be classified without ground verification and 4) aerial classification of systems must be based in large part on vegetation which is the most readily identifiable characteristic of the map unit. For these reasons we decided to incorporate vegetation and soils at a comparable level in the classification.

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EXISTING CLASSIFICATION

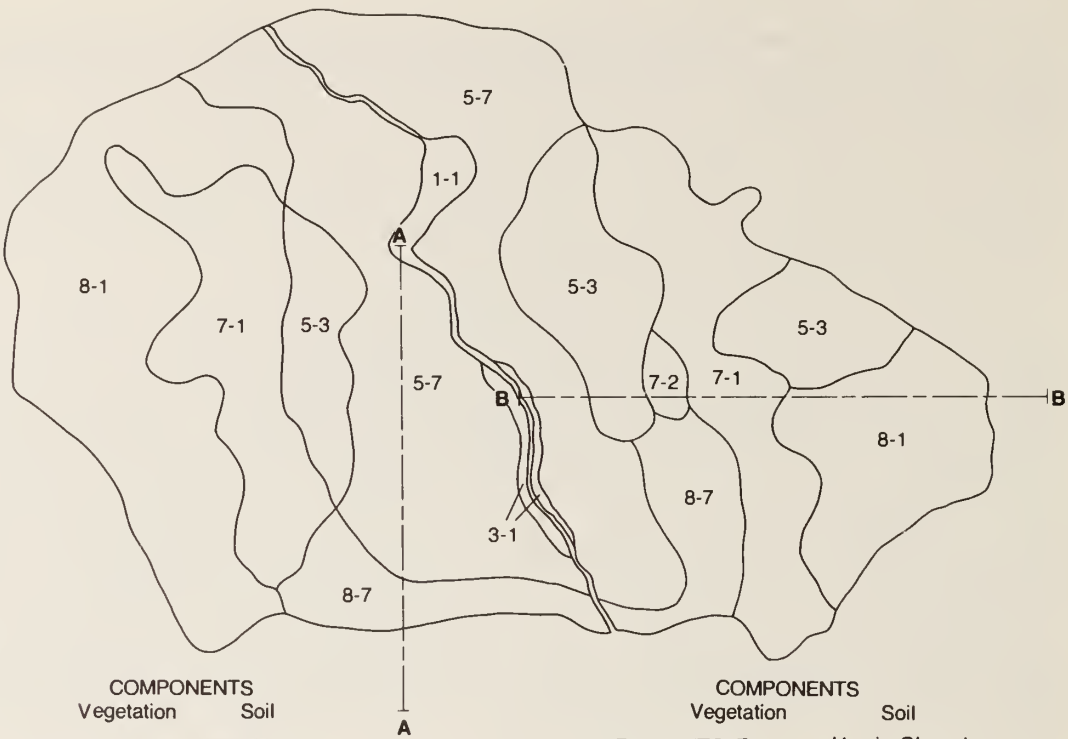
The current wetland classification for the study area (Runka and Lewis, 1981) appears to be a modification of wetland classifications presented by Slavinski (1979), Tarnocai (1979), and Zoltai et al. (1975). The first five of the seven classes presented (Shallow open water, Fen, Bog, Marsh, Swamp, Meadow and Shrub carr) are common to all publications but the definitions differ, in some cases markedly. The last two represent classes which are transitional to uplands and are not used in the Tarnocai or Zoltai et al. publications.

When evaluated against the objectives stated in this paper, a number of limitations are apparent in the present classification. In addition to the problem of inconsistent definitions for the same class names, the definitions used are sometimes ambiguous and often difficult to verify in the field. Aerial mapping is problematic since classes are defined and described in terms of criteria not visible from the air. Most importantly the current classification does not define wetland systems, rather it defines components or segments of wetlands. This approach fails to characterize the interdependence of wetland components occurring in the same system. For example the wetland system represented by Figure 1 is a commonly occurring system which would be mapped as a single unit at a scale of 1:15,000. Using the Runka and Lewis (1981) classification it would be characterized, according to dominance, as a Fen-Shrub carr -Marsh(?)-Swamp-Meadow-Shallow open water and yet it represents a single type of recurring wetland system. Missing from this designation is information on the occurrence and distribution of vegetation types, an adequate description of the hydrologic system, or an indication of the extent of ecotones or boundary types which are important to wildlife.

Interpretations for the wetland system described above become problematic since the components cannot be treated in isolation. For example, the shallow open water component will show higher values for waterfowl nesting if surrounded by Bulrush and Cat-tail vegetation than if surrounded by forested upland. Thus the assigning of a single value for waterfowl nesting suitability to shallow open water components becomes somewhat questionable. Furthermore, draining the fen component of the system also entails draining the other components and thus influences their respective uses.

APPROACH USED IN THIS STUDY

In attempting to meet the problems outlined above we approached the problem of wetland classification from a new perspective. Rather than developing a classification based on wetland components we decided to use the sequence in which these components occur as the basis for the classification. Existing class names were not used because of the problem of different definitions for the same wetland classes. The interpretive needs of potential users and the natural distribution of characteristics important to these interpretations were allowed to shape the classification. The existence of data collected by Slavinski *et al.* (1979) and the development of analytical procedures demonstrated



COMPONENTS

	Vegetation	Soil
1-1	Aquic	Sedimentary
3-1	Cattail	Typic Mesisol
5-3	Sedge	Peaty-Gleysol
5-7	Sedge	Typic Mesisol

COMPONENTS

	Vegetation	Soil
7-1	WTG/F	Humic Gleysol
7-2	WTG/F	Peaty Gleysol
8-1	Shrub/GF	Orthic Gleysol
8-7	Shrub/ Sedge	Typic Mesisol

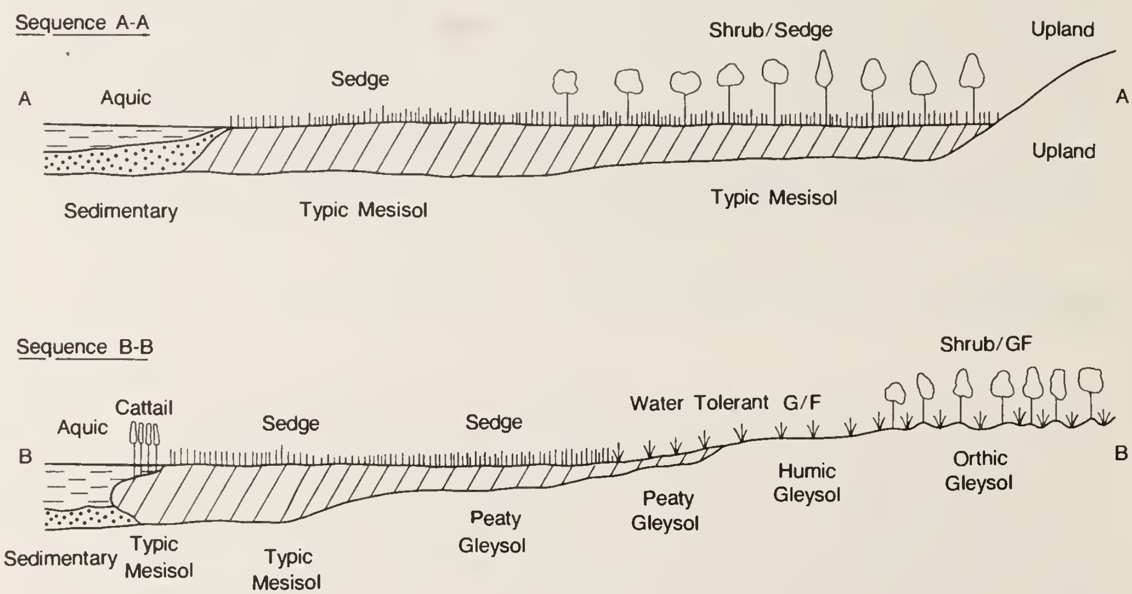


Figure 1: An example of a Chilanko Forks (Cf) map unit with 8 component classes and two sequences. *LRRI*

by Moon and Selby (1981a, 1981b) greatly facilitated the rapid completion of the project.

ANALYSES AND CLASSIFICATION PROCEDURES

The classification is based on a number of levels of integration where each level is dependent on the classification at the preceding level. Figure 2 outlines the levels of integration and the classification sequence.

A. DEFINITION OF A WETLAND COMPONENT

A wetland component is that portion of a wetland area which shows uniform vegetation cover, depth to mineral soil, decomposition of the middle tier, decomposition of the surface tier, and humus form. Each component of a minimum area is sampled. The minimum area requirement is determined by the scale and needs of the survey (in this case identifiable at a scale of 1:5,000).

CLASSIFICATION OF WETLAND VEGETATION COMPONENTS

The vegetation component classes were defined by plant communities grouped into physiognomic classes. Plant communities were defined using computer assisted tabular analysis (Ceska and Roemer, 1971) which facilitates the identification of groups of species that occur together consistently. The species within each group are assumed to have comparable ecological tolerance ranges. The occurrence of more than one species group in a segment implies overlapping tolerance ranges or microsite differences, for example hummocky microtopography. Plots are classified by the combination of species groups present. These community types were then grouped into physiognomic classes and species groups were combined to form physiognomic species groups. Table 1 provides an example of the computer output using physiognomic species groups to define vegetation classes. Note that the original species groups can still be identified and that the interpretations of overlapping species groups is still the same. Species group 2 for example consists of shrub species that occur in two sets of plots. Some of the shrub species tend to be found along with Group 1 which is composed of sedge species. The Sedge Group is restricted to more poorly drained systems (plots 16 through 161). We may hypothesize that plots 158 through 214 represent a complex of habitats (hummocky) or intermediate drainage conditions suitable for the growth of both sedges and shrubs.

A total of 200 plots and 207 species were analysed to define the species groups and vegetation classes. Nine major vegetation classes (defined using nine species groups) were recognized. Twenty-eight vegetation sub-classes or dominance types, defined by combinations of species groups, were defined (Moon and Selby, 1981b). These sub-classes represent the vegetation input to the next level of classification in the wetland systems.

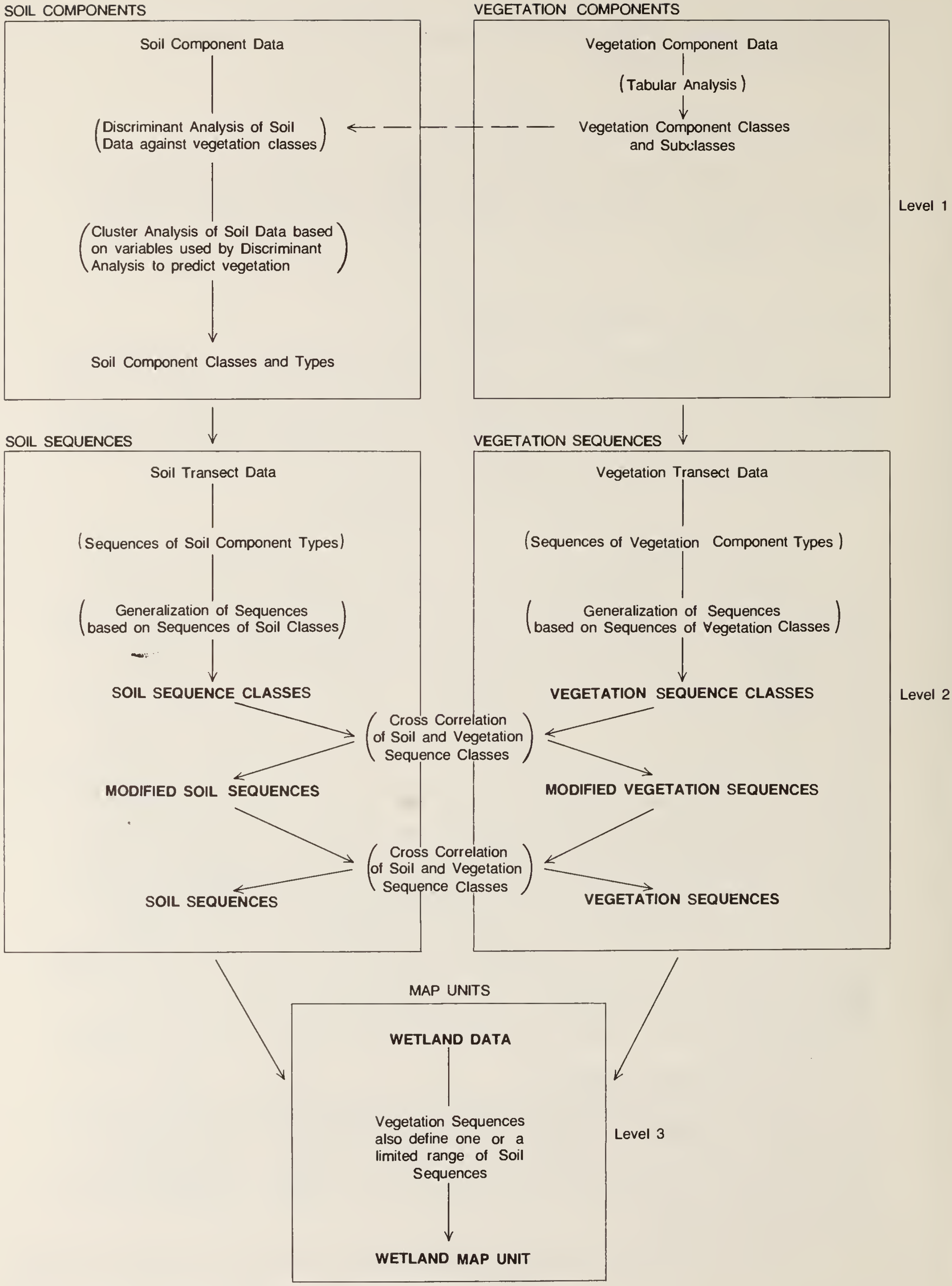


Figure 2: Levels of integration and flow diagram of wetland classification.

LRRI

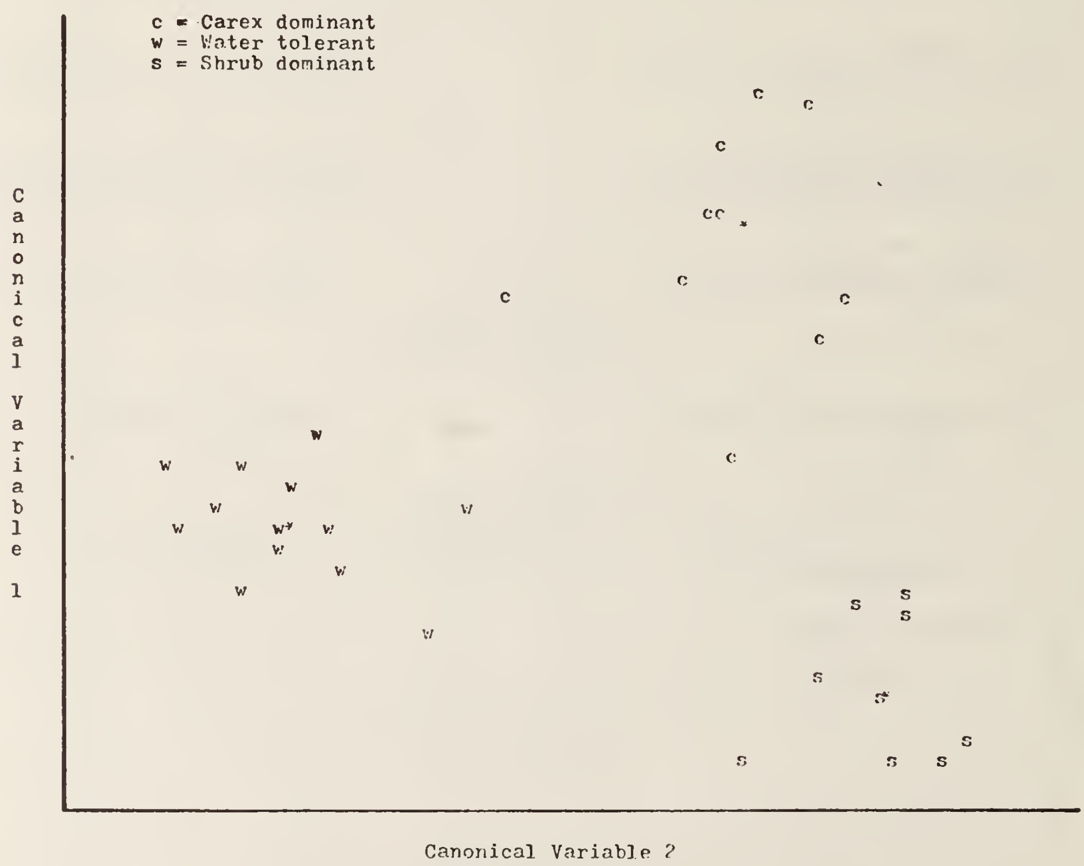
Table 1. Example of a Vegetation Table using Physiognomic Species Groups. Cover is estimated using Daubenmire's cover classes.

		0016	0027	0089	0161	0158	0096	0134	0214	0005	0045	0057	0181	0194	0207	0007	0232
	NO. OF SSP.	03	03	03	01	07	04	08	06	11	09	09	13	05	08	08	08
	GROUP 1	*	*	*	*	*	*	*	*							*	
14	CARE AQUA	2	5	3		4	3	2	1								
15	CARE ATHE			2													
18	CARE ROST	4	2	3	5	1	4	4	3							1	
		*	*	*	*	*	*	*	*							*	
	GROUP 2					*	*	*	*	*	*	*	*				
42	ARCT UVA-									2	2	2	2				
43	BETU GLAN					2		1	2	3	3	3	3				
47	SALI BRAC								2		3	2	2				
48	SALI GLAU							1		1							
49	SALI MACC						3	2	3				2				
50	SALI PEDI					3	2										
						*	*	*	*	*	*	*	*				
	GROUP 3									*	*	*	*	*	*	*	*
17	CARE PRAE					2								2			
16	CARE DOUG									1	1				2	5	
22	AGRO PAUC									1			1		1		1
24	DESC CAES												1	1	2	1	1
25	HORD JUBA													2	2		2
26	KOEL MACR										1	1	1			1	
27	MUHL RICH											1			1		
28	POA PRAT	1						1		1		1	1		1	2	
29	ACHI MILL									2	1	2	2			1	
31	FRAG VIRG							1		2	2	2	2				
34	POTE ANSE									1	1			5	4		4
36	TARA OFFI									2	1			1	2	1	1
										*	*	*	*	*	*	*	*

CLASSIFICATION OF WETLAND SOIL COMPONENTS

Soil properties which are related to the vegetation classes were determined by running a multiple stepwise discriminant analysis (UBC:BMDO7M,1976)of selected vegetation segment sub-classes against twenty-three soil variables. Three sub-classes which had only one species group present were chosen. The lack of overlapping species groups ensures distinct ecological tolerance ranges. Figure 3 is a graphical presentation of the results in which 91% of the vegetation component classes were correctly identified using equations whose variables are - depth to mineral soil, microtopography, humus form, depth to carbonates, and depth of the surface organic horizon (Selby, 1981). These soil variables provide the basis of a soil classification which can be tied to vegetation.

Figure 3. Discriminant Analysis of Vegetation Classes by Soil Properties



A cluster analysis (UBC:CGROUP, 1978) of component soils based on the five variables listed above produced a number of soil classes formed on the basis of overall similarity of the soil variables in each class. Eight major soil component classes with sixteen sub-classes and sixty-six detailed soil types were recognized (Moon and Selby, 1981b). Class limits at the component class and sub-class level were based largely on the groups formed by cluster analysis.

The classification of these soil and vegetation wetland components provides the first level of integration necessary to classify wetland systems which are composed of more than one component type. A knowledge of the sequence in which these wetland components occur and a classification of these sequences is necessary for the next level of wetland classification.

B. CLASSIFICATION OF WETLAND SEQUENCES

Wetland sequences are defined by the sequence of vegetation and soil component classes occurring on a transect running from the hydrologic low of the system to the wetland-upland boundary. The total characterization of a wetland system requires the description of all sequences found in the system. For example the wetland system represented by Figure 4 requires two transects to characterize it since there are two sequences present: A-A and B-B. In addition to soil and vegetation sequences a number of other characteristics were considered potentially important enough to record:

1) Nature of associated water bodies if present
2) Landscape form (i.e. depression vs. seepage track)
3) Zonation or distribution of components (i.e. concentric vs. interspersed)
4) Special features (i.e. dammed, drained)
5) The proportion of the system occupied by each wetland component
6) Complete vegetation species list with cover classes and data on fifteen soil variables for each component type found at the first 100 systems. This data was used as a test of the segment classifications.

Data for a total of 135 wetland systems, including 191 transects and 235 components were collected following definitions and coding procedures outlined by Moon and Selby (1981b). Data were coded in computer readable form (UBC:OMR, 1980) while in the field and were on file and being analysed within two days of completion of the field work.

ANALYSIS OF SEQUENCE DATA

The primary objective of this stage of classification is to define sequence classes for soil and vegetation that will show a strong correlation between soil and vegetation sequence types. If this can be accomplished, reliable mapping of wetland systems based on vegetation

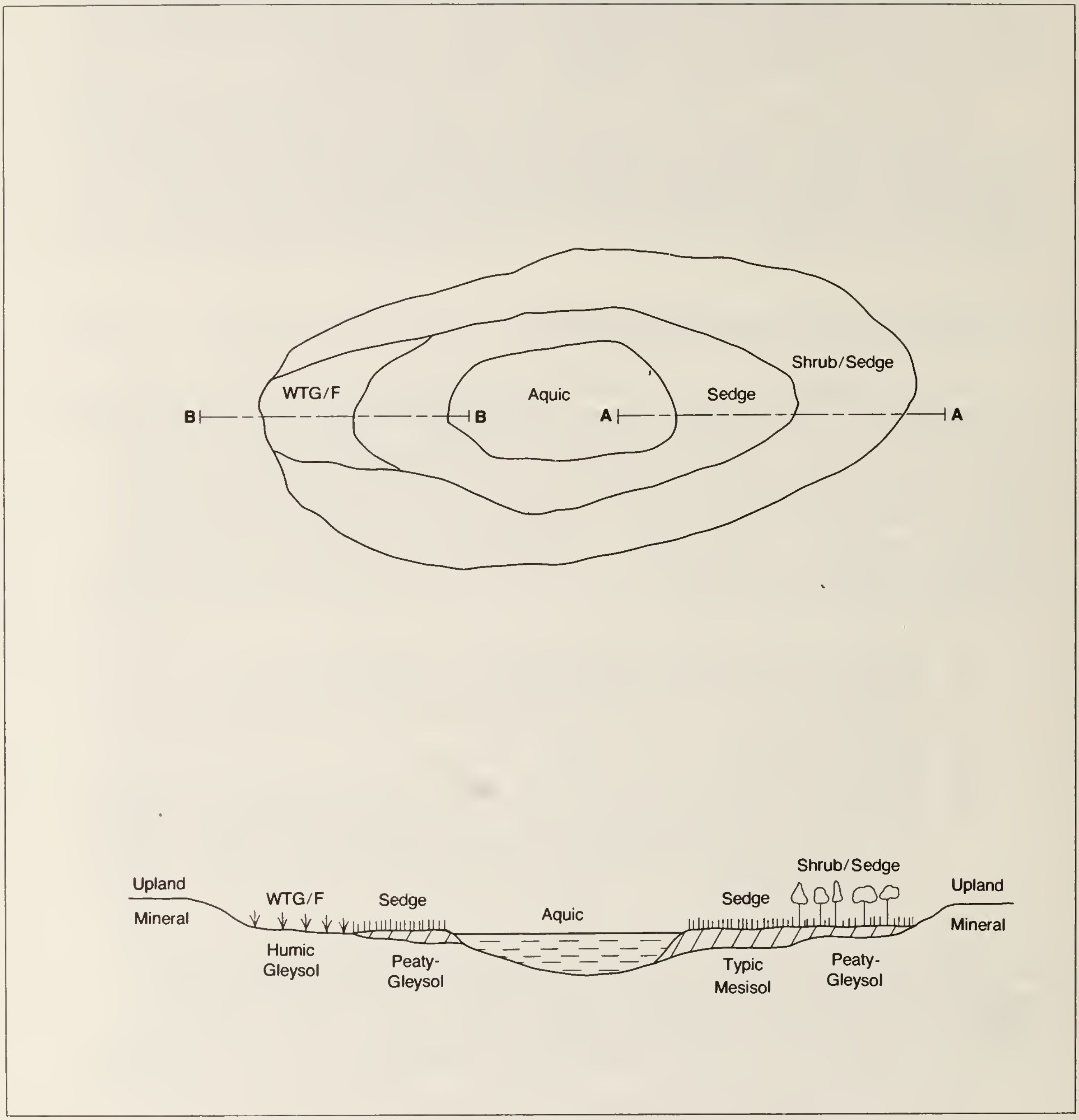


Figure 4: Representative of a wetland system requiring two transects. *LRRI*

patterns will be possible. A number of procedures available as standard statistical packages were used. The following procedures and control features available in SPSS (UBC:SPSS:8, 1980) were used extensively; XCROSSTABS, XFREQUENCIES, SORT CASES, and WRITE CASES.

XCROSSTABS: provides cross tabulation values for one variable against values for a second variable. For example a cross tabulation of soil component types against vegetation component sub-classes produced 146 unique combinations out of a total of 587 observations. Examination of the tables indicated many of the combinations occurred only once or twice and that soil and vegetation classes rather than sub-classes or types could be used with little information loss. Table 2 represents the results of a cross tabulation of soil component classes against vegetation component classes. The number of unique combinations has been reduced to 38 and it can be seen for example that the MOSS-DR vegetation class is largely restricted to the ORGANIC soil class whereas the SH-EMERG vegetation class occurs across the full range of soil types. This table then provides useful insights into which vegetation classes might be important in defining vegetation sequences that will be useful in predicting soil sequences or types.

XFREQUENCES: provides frequency distributions and histograms of variable values. For example, a plot of depth to mineral soil for all soil component data collected indicated that depth to mineral soil had a trimodal distribution and that while the 30 cm depth limit used to separate shallow peaty phase gleysols from deep peaty phase gleysols was appropriate, the 40-60 cm break used to separate the organic soils was not. The 50 cm depth class represented the second modal or second most frequently occurring value in the data set and was interpreted as the modal and mean value of a second population to which both shallow organic and deep peaty phase gleysols belonged. Deep peaty phase gleysols were then grouped into a class of shallow organic soils whose depth class limits were 30 and 90 cm.

SORT CASES: provides a control feature which reorders a data set according to a dictated hierarchy. For example, our data set can be sorted into blocks which all have the same soil component class in position one, each one of these blocks can then be sorted into sub-blocks which have the same soil component class in position two, and so on for as many sorting criteria as desired. Table 3 represents a subset of data sorted first on vegetation sequence class, followed by soil sequence class, and then by the entire vegetation sequence. After sorting, the reordered data set was written to a new file and numerical codes translated to verbal equivalents. Several sorting strategies including soil component sequences, vegetation component sequences, and soil and vegetation sequences were evaluated to produce the present classification. It is probable that the new REPORT procedure available in SPSS will streamline this aspect of the data evaluation.

Following the definition of soil and vegetation sequences the relationship between the two is easily checked using the XCROSSTABS procedure. Table 4 presents the results of a cross tabulation of four soil sequence classes against seven vegetation sequence classes. The range of soil sequences occurring with each vegetation sequence defines the range of soil types mappable without ground verification if the vegetation classes are used to identify map units.

Table 2. Crosstabulation of Generalized Soil Segment Classes against Vegetation Classes

	COUNT / ROW PCT / COL PCT / TOT PCT	AQUATIC 1.	MOSS-DR 2.	DP-EMERG 3.	SH-EMERG 4.	CAREX 5.	VS-EMERG 6.	WT-GF 7.	SHRUB 8.	TREED 9.	ROW TOTAL
MINERAL	1.	20	0	6	7	2	3	36	51	3	128
		15.6	0.0	4.7	5.5	1.6	2.3	28.1	39.8	2.3	21.8
		19.8	0.0	25.0	17.1	1.4	15.8	45.0	33.1	30.0	
		3.4	0.0	1.0	1.2	0.3	0.5	6.1	8.7	0.5	
MINORG	2.	22	0	3	15	16	9	33	15	0	113
		19.5	0.0	2.7	13.3	14.2	8.0	29.2	13.3	0.0	19.3
		21.8	0.0	12.5	36.6	11.5	47.4	41.3	9.7	0.0	
		3.7	0.0	0.5	2.6	2.7	1.5	5.6	2.6	0.0	
SPTY-GL	3.	4	0	0	5	42	2	7	28	3	91
		4.4	0.0	0.0	5.5	46.2	2.2	7.7	30.8	3.3	15.5
		4.0	0.0	0.0	12.2	30.2	10.5	8.8	18.2	30.0	
		0.7	0.0	0.0	0.9	7.2	0.3	1.2	4.8	0.5	
MARL	6.	14	2	12	8	8	5	3	2	0	54
		25.9	3.7	22.2	14.8	14.8	9.3	5.6	3.7	0.0	9.2
		13.9	10.5	50.0	19.5	5.8	26.3	3.8	1.3	0.0	
		2.4	0.3	2.0	1.4	1.4	0.9	0.5	0.3	0.0	
ORGANIC	7.	41	17	3	6	71	0	1	58	4	201
		20.4	8.5	1.5	3.0	35.3	0.0	0.5	28.9	2.0	34.2
		40.6	89.5	12.5	14.6	51.1	0.0	1.3	37.7	40.0	
		7.0	2.9	0.5	1.0	12.1	0.0	0.2	9.9	0.7	
	COLUMN TOTAL	101	19	24	41	139	19	80	154	10	587
		17.2	3.2	4.1	7.0	23.7	3.2	13.6	26.2	1.7	100.0

Table 3. Example of data reordered by the SORT procedure of SPSS. All of the transects represent the Sedge 1 Vegetation Sequence on the Organic Soil Sequence. Underlined Components represent diagnostic Components presented in Tables 5 and 6.

AQUIC CENTERED					
456 2	AQVE-P NO DATA 2	DEM-CT N-MES-M 3	SEDGE F-MES-M 1	SEDGE S-SMG-C 1	LSH-SE S-SMG 2
440 2	AQVE-P S-SMG-C 6	DEM-CT F-FIB-M 1	SEDGE F-FIB-M 2	LSH-SE N-MES-M 3	TSH-SE S-SMG 1
27 2	AQVE-P S-MIN-N 8	EMERG. S-MIN-N 3	SEDGE F-FIB-F 3	LSH-SE S-MOR-N 3	
308 1	AQVE-P SEDIMT 4	SEDGE FFI-SED 2	EMERG. MES-SED 6	TSH-SE FIB-SED 2	
456 3	AQVE-P NO DATA 2	SEDGE F-MES-M 1	SEDGE S-SMG-C 1	LSH-SE S-SMG-C 2	
313 2	AQVE-P SEDIMT 1	SEDGE FFI-SED 1	SEDGE FIB-SED 4	LSH-SE N-FIB-M 2	
313 1	AQVE-P SEDIMT 1	SEDGE FFI-SED 1	SEDGE FIB-SED 4	TSH-GF M-MIN-D 1	
325 3	AQVE-P N-FIB-M 1	SEDGE N-FIB-M 2	LSH-SE N-FIB-M 6		
32 1	AQVE-P SEDIMT 7	SEDGE FFI-SED 4	LSH-SE N-FIB-F 6		
440 1	AQVE-P S-SMG-C 6	SEDGE F-FIB-M 3	LSH-SE N-MES-M 4	TSH-SE S-SMG-C 2	
315 1	AQVE-P SEDIMT 1	SEDGE DEEP-FG 5	LSH-SE N-FIB-M 1	TSH-SE N-MES-M 3	
325 2	AQVE-P N-FIB-F 1	SEDGE N-FIB-F 2	LSH-SE N-FIB-F 2	LSH-GF M-MIN-D 1	
14 4	AQVE-P NO DATA	SEDGE N-FIB-F	TSH-GE S-MIN-D		
NON-AQUIC CENTERED					
30 1	EMERG. SEDIM-N 7	SEDGE N-MES-M 3	TSH-SE S-SFG-G 1		
309 1	EMERG. N-FIB-M 1	SEDGE N-FIB-M 6	LSH-GF M-MIN-N 1		
8 2	EMERG. N-FIB-M 2	SEDGE N-FIB-M 6	LSH-SE N-MES-M 2		
432 1	EMERG. DH-MARL 1	SEDGE N-MES-M 2	LSH-SE N-FIB-M 6	TSH-SE N-MES-M 1	
432 3	EMERG. DH-MARL 1	SEDGE N-MES-M 2	TSH-SE N-MES-M 1		
2 1	SEDGE N-MES-M 3	SEDGE DEEP-FG 3	LSH-GF S-MIN-C 3		
16 1	SEDGE N-FIB-M 8	LSH-SE M-MIN-N 2			

Table 4. Crosstabulation of soil sequence class against vegetation sequence classes

SOILT	COUNT / ROW PCT / COL PCT / TOT PCT	MOSS 11.	SE-SHRUB 21.	SE-WTGF 22.	SCIRPUS 31.	WTGF 32.	SHSE 41.	SHGF 42.	ROW TOTAL
11. MINERAL	COUNT	0	2	9	2	20	2	3	38
	ROW PCT	0.0	5.3	23.7	5.3	52.6	5.3	7.9	19.9
	COL PCT	0.0	3.6	15.5	16.7	83.3	9.5	100.0	
	TOT PCT	0.0	1.0	4.7	1.0	10.5	1.0	1.6	
31. PTY-GL1	COUNT	0	10	28	0	1	5	0	44
	ROW PCT	0.0	22.7	63.6	0.0	2.3	11.4	0.0	23.0
	COL PCT	0.0	17.9	48.3	0.0	4.2	23.8	0.0	
	TOT PCT	0.0	5.2	14.7	0.0	0.5	2.6	0.0	
61. MARL	COUNT	1	3	9	9	3	0	0	25
	ROW PCT	4.0	12.0	36.0	36.0	12.0	0.0	0.0	13.1
	COL PCT	5.9	5.4	15.5	75.0	12.5	0.0	0.0	
	TOT PCT	0.5	1.6	4.7	4.7	1.6	0.0	0.0	
71. ORGANIC1	COUNT	16	41	12	1	0	14	0	84
	ROW PCT	19.0	48.8	14.3	1.2	0.0	16.7	0.0	44.0
	COL PCT	94.1	73.2	20.7	8.3	0.0	66.7	0.0	
	TOT PCT	8.4	21.5	6.3	0.5	0.0	7.3	0.0	
COLUMN TOTAL		17	56	58	12	24	21	3	191
		8.9	29.3	30.4	6.3	12.6	11.0	1.6	100.0

SOIL SEQUENCE CLASSES

A total of six soil sequence classes were recognized and are described below. Note that in Table 4 Sedimentary was grouped with Organic and Transitional was grouped with mineral since this distribution requires ground verification.

Organic: Organic sequences are defined as sequences which have segments of organic (peaty) deposits greater than 30 cm deep across 20% or more of the wetland. These deposits will generally be moderately decomposed (Mesisols), if derived from sedges, or poorly decomposed (Fibrisols), if derived from mosses. Two depth classes are recognized; shallow if between 30 and 90 cm and deep if greater than 90 cm. Sedimentary and marl components may be present provided they occupy less than 20% of the wetland while any other component types may occur.

Sedimentary: Sedimentary sequences are defined as sequences which have components of sedimentary peat deposits greater than 30 cm deep across 20% or more of the wetland. Sedimentary deposits are generally well decomposed (Humisols) but may show mesic or fibric tops. Marl components may be present provided they occupy less than 20% of the wetland. Any other component types may occur and organic components are frequent associates.

Peaty-Gleysol: Peaty-Gleysol sequences are defined as sequences which have organic deposits 5-30% deep over mineral soil (Peaty-Gleysols) across 20% or more of the wetland. Sedimentary, Organic, and Marl components if present must each occupy less than 20% of the wetland. All other component types may occur.

Marl: Marl sequences are defined as sequences which have marl deposits within 30 cm of the surface and at least 30 cm deep across 20% or more of the wetland. All other segment types may occur in the transect.

Mineral-Gleysol: Mineral gleysol sequences are defined as sequences which have components of Gleysolic soils across 20% or more of the wetland. Organic, Sedimentary, Marl, and Peaty-Gleysol components must, if present, each occupy less than 20% of the wetland. Mineral-gleysol systems are generally Rego-Humic Gleysols which show organic matter rich (10-30%) mineral surfaces with dark greyish brown to black colours which may be confused with organic surfaces. Dark coloured mineral surfaces will either have a distinctly sandy feel or will be distinctly plastic but not sticky. Rego-Gleysols with obvious mineral surfaces are also common but usually support alkaline tolerant vegetation.

Transitional: Transitional sequences are defined as sequences which do not have a greater than 20% component of Sedimentary, Organic, Marl, Peaty-Gleysol, or mineral-Gleysol components. Transitional sequences are generally mineral soils with well aerated surface layers showing relatively bright colours and lacking prominent mottles. Surface layers generally show weak to moderate structure and organic matter enrichment (5-10%). Ant mounds are frequent and soils are classified as Orthic Humic Gleysols or Gleyed Melanic Brunisols.

Table 5 presents a summary of soil sequence classes.

Table 5 Soil Sequence Classes defined by Soil Component Classes

Sequence Class	Soil Component Class					
	Sediment	Organic	Marl	Peaty-Gley	Mineral-Gley	Transitional
Organic	-	*	-	+/-	+/-	+/-
Sedimentary	*	+/-	-	+/-	+/-	+/-
Marl	+/-	+/-	*	+/-	+/-	+/-
Peaty-Gleysol	-	-	-	*	+/-	+/-
Mineral-Gleysol	-	-	-	-	*	+/-
Transitional	-	-	-	-	-	*

* component must occupy 20% or more of the wetland
\- component must occupy less than 20% of the wetland
+/- component may or may not be present

VEGETATION SEQUENCE CLASSES

Vegetation sequence classes are defined by the sequence of diagnostic vegetation components. To be considered diagnostic the vegetation component must occupy greater than 10% of the wetland area. Certain component types are not used in the definition of sequence classes but rather are considered indicators of the water regime. These may be found in association with any of the vegetation sequence classes. They will be discussed in the following section.

Sedge 1: The Sedge-Shrub sequence class has a sedge dominated component class (refer to Moon and Selby, 1981b for a detailed description of wetland components) bordered by a shrub dominated vegetation class. This sequence class does not contain a component dominated by a mixture of graminoids and forbs (the water tolerant vegetation class).

Sedge 2: This sequence class contains a component dominated by sedges adjacent to a component consisting either of a mixture of graminoids and forbs or to upland vegetation. A shrub component class may border the wetland but is not diagnostic.

Water Tolerant (WT): The Water Tolerant sequence class lacks a sedge dominated component. It contains one or more components dominated by a mixed graminoid-forb vegetation. There is no Deep Emergent Bulrush (*Scirpus lacustris*) component. A shrub component may or may not be present. This class may require subdivision based on the presence of alkaline tolerant species. In addition, further sampling may justify a separate class for wetlands with extensive areas of cat-tail.

Bulrush: The Bulrush sequence class contains a component dominated by Bulrush (Scirpus lacustris) adjacent to a component dominated by water tolerant graminoids and forbs. This sequence type lacks a sedge component although in disturbed systems (eg water table raised) a floating sedge mat may be present on the aquatic side of the Bulrush component. There is often an aquatic center and the wetland may be bounded by a shrub component.

Shrub 1: This sequence class is defined by the presence of a shrub-sedge component class and the absence of sedge or water tolerant component classes. Any of the components used to infer water regime may be present. A shrub-grass/forb component may or may not be present.

Shrub 2: A single component class is present in this sequence class. The shrub-grass/forb component may or may not be associated with an aquatic component. No other component types are found in this sequence class.

Moss: The Moss sequence contains a moss dominated component in any position along the sequence. This can be either a pure moss type or a shrub-moss type but Drepanocladus spp must be a major component of the vegetation cover. Aquatic, sedge or shrub component classes may also be present.

Both the soil and vegetation sequence classes will be subdivided on the proportional occurrence of the diagnostic segments. Thus segment classes that have a minor representation in a wetland will not be heavily weighted. Table 6 presents a summary of vegetation sequence classes.

Table 6 Vegetation Sequence Classes defined by Vegetation Component Classes

Sequence Classes	Component Classes						
	Moss	Scirpus	Sedge	WTFG	Shrub-SE		Shrub-GF
Sedge 1	-	+/-	*	-	*	or	*
Sedge 2	-	+/-	*	*	+/-		+/-
or	-	+/-	*	-	-		-
Water Tolerant	-	-	-	*	+/-		+/-
Bulrush	-	*	-	*	+/-		+/-
Shrub 1	-	+/-	-	-	*		+/-
Shrub 2	-	-	-	-	-		*
Moss	*	-	+/-	-	+/-		+/-

* component must be present
\- component must not be present
+/- component may or may not be present

C. WATER REGIME CLASSES

The presence of aquatics, deep emergents or emergents[1] (Moon and Selby 1981b) provides additional information of value to resource managers. The relative water tolerance of each vegetation type was determined by analysing the hydrologic position in which each class occurred in relation to the other classes ie cat-tail always occurred in a lower position than sedge. From this analysis five possible hydrologic systems were defined (Table 7) as follows:

Drawdown: Emergent vegetation present but lacking deep emergent or moss component. Water level on the diagnostic unit draws down to below the soil surface for only short periods during the summer. Water levels are relatively stable during the remainder of the year.

Permanent: Deep emergent vegetation present but lacking a moss component. Water level on the diagnostic unit is rarely at or below the surface. Fluctations in depth of water are variable.

Seasonal: Sedge or Sedge-Shrub classes represent the lowest hydrologic position in the wetland aside from the aquic component if present. Water level on the diagnostic units is below the soil surface for a significant portion of the growing season.

Floating: Must contain either a moss component or a sedge component which has a floating sedge mat >30 cm. Water level on the diagnostic unit fluctuates but the soil surface rises and falls with the water levels so that the soil is always saturated but never flooded.

Ephemeral: A water tolerant component is at the hydrologic low point of the wetland (aside from the aquic component if present). Water level on the diagnostic unit is generally below the soil surface throughout the growing season. The diagnostic unit may be inundated for short periods in the spring.

Upland: A shrub-grass/forb component class is the only water regime indicator present. Saturated conditions within 50 cm of the soil surface are rare. Gleyed colours or mottles are not present within 50 cm of the surface.

[1] Deep emergents = Cat-tail (<u>Typha</u>)or Bulrush (<u>Scirpus</u>)
Emergents = Horsetail (<u>Equisetum</u>)
or Manna grass (<u>Glyceria</u>)
or Spike rush (<u>Eleocharis</u>)

Table 7 Water Regime Classes defined by Vegetation Component Classes

Water Regime	Moss	Deep Emergent	Emergent	Sedge	Shrub Sedge	WTFG	Shrub Grass/Forb
	Component Classes						
Upland	-	-	-	-	-	-	*
Ephemeral	-	-	-	-	-	*	+/-
Seasonal	-	-	-	-	*	+/-	+/-
or	-	-	-	*	+/-	+/-	+/-
Drawdown	-	-	*	+/-	+/-	+/-	+/-
Permanent		*	+/-	+/-	+/-	+/-	+/-
Floating	*	+/-	+/-	+/-	+/-	-	+/-
or	+/-	+/-	+/-	F*	+/-	-	+/-

* component must be present
F* if a sedge may >30 cm thick is floating
\- component must not be present
+/- component may or may not be present

D. WETLAND MAP UNITS

Specific sequences have been used to define the vegetation, the soils, and the water regime of a sequence but the classification of sequences still does not define a wetland system. Problems arise because more than one vegetation, soil, or water regime sequence type is present within a single wetland (Figure 1 is an example of this). To deal with this problem, the concept of the wetland system is used. The characteristic pattern or occurrence of sequences is used to classify wetland systems in the same way that the characteristic pattern of components was used to define sequence classes. These wetland systems are the individuals which are grouped to form wetland map units.

The definition of wetland map units is based on the soil and vegetation sequence classes. Each wetland type is defined by a diagnostic vegetation sequence class which occurs on a limited range of soil sequence classes. An emphasis on the vegetation sequence facilitates the mapping of wetlands by remote sensing techniques.

The presence of more than one diagnostic vegetation sequence characterizes a compound system. The more frequently occurring compound systems have been classified as distinct map units. The less frequently occurring compound systems have been handled by establishing precedence levels where by the presence of one diagnostic sequence is considered to take precedence over others which may occasionally be present. For example, if a Shrub 2 (Shrub/Grass/Forb) sequence is found in association with a Water Tolerant sequence, the Water Tolerant sequence takes precedence and is considered diagnostic. Precedence levels were established to ensure that the most critical management characteristics would not be ignored in the classification of the wetland system. The precedence sequence is as follows: Bulrush>Moss>Sedge 1> Sedge 2>Water Tolerant>Shrub 1>Shrub 2.

Nine wetland map units (Table 8) were defined. Seven map units are defined on a single diagnostic sequence but may include occasional subordinate sequence types. Two map units were defined as having two diagnostic sequences in the same system.

The Wetland map unit provides the most generalized level of knowledge about a wetland. For example the Stum Lake (St) map unit is the Sedge 1 (Sedge to Shrub) vegetation sequence and has an 86% chance of being the Organic soil sequence. Sub-classes of the map units based on the diagnostic component provide more specific information. For example Stum Lake 1 (St 1) is a Stum Lake unit where the diagnostic (Sedge) component occupies greater than 50% of the wetland area. A "2" signifies that the diagnostic component occupies 20-50% of the area, and a "3" that the diagnostic component occupies less than 20% of the area.

Two phase criteria are incorporated to provide additional information. The first indicates the degree of interspersion (Golet and Larson, 1974). Three levels of interspersion are defined in terms of zonation patterns (Moon and Selby, 1981b). Interspersion levels are as follows:

Low (L) - zonation concentric, concentric banded, or banded
Medium (M) - zonation islanded or fingered
High (H) - zonation interspersed

Figure 1 represents high interspersion while Figure 2 represents low interspersion. The second phase criterion defines the aquic component of the wetland. Three classes are recognized

Flowing (F) - the aquic component is moving or flowing water (stream or river)
Still (S) - the aquic component is standing or still water (lake or pond)
None (N) - there is no aquic component

For example St1-LS is a concentrictly zoned, lake or pond centered Sedge 1 vegetation sequence and has an 86% probability of being an organic soil sequence. This level of classification can be verified from the air.

Remote sensing can also aid in water regime classification but two classes might be ambiguous because one of the deep emergent communities can be readily confused with the emergent communities when viewed from the air. To emphasize the requirement for ground verification water regime and ground verified soil sequence classes are presented in the denominator of the map unit symbol. Water regime classes have already been defined (Table 7). The first letter of each class is used in the

Table 8 Wetland Map Units

a) Diagnostic Vegetation Sequences

Map Unit	Vegetation Sequence						
	Bulrush	Moss	Sedge 1	Sedge 2	WT	Shrub 1	Shrub 2
Sapeye Lake	*	+/-	+/-	+/-	+/-	+/-	-
Nazko Lake	-	*	-	-	-	-	-
Anahim Creek	-	*	*	+/-	-	+/-	-
Stum Lake	-	-	*	-	-	+/-	-
Chilanko Forks	-	-	*	*	+/-	+/-	-
Ragan Lake	-	-	-	*	+/-	-	-
Tatla Lake	-	-	-	-	*	-	-
Nimpo Lake	-	-	-	-	-	*	-
Ant Hill	-	-	-	-	-	-	*

b) Defined Soil Sequences[1]

Map Unit	Marl	Organic/Sedimentary		Peaty Gleysol	Mineral	Transitional
Sapeye Lake	*	+/-		+/-	+/-	-
Nazko Lake	-	*		-	-	-
Anahim Creek	-	*		+/-	-	-
Stum Lake	-	*		-	-	-
Chilanko Forks	-	*	or	*	-	-
Ragan Lake	-	-		*	+/-	-
Tatla Lake	-	-		-	*	-
Nimpo Lake	-	*		+/-	-	-
Ant Hill	-	-		-	-	*

[1] Defined Soil Sequences have a stated probability of occurence

map symbol. When the map unit has been ground verified, the soil sequence class (Table 5) follows the water regime class in the map symbol. For example, a wetland with an organic soil sequence class and a permanent water regime (ie deep emergents present) would have the following symbol:

$$\frac{\text{St1 - LS}}{\text{p - Org.}}$$

If there was no ground verification, the wetland map unit type is repeated and the same map unit would be symboled as follows:

$$\frac{\text{St1 - LS}}{\text{p - St}}$$

By the definition of a Stum Lake map unit the soil sequence is expected to be organic but there is a 15% chance of being wrong. For some management decisions ground verification is essential.

The map units were defined with the intention of maximizing their information content. The following map unit description is provided as an example of the information contained in the map symbol. The Stum Lake map unit represented 24% of the wetlands sampled.

STUM LAKE (St):

Diagnostic Vegetation Sequence	Vegetation Component Classes						
	Moss	Scirpus	Sedge	WTFG	SHSE		SHGF
Sedge 1	-	+/-	*	-	*	or	*

The Stum Lake Map Unit is characterized by the Sedge-Shrub vegetation sequence. This sequence class is comprised of a sedge component bounded by a shrub component. Water tolerant grass/forb or moss segments will not be present. The shrub component can be either a shrub/sedge or shrub/grass/forb type. Three phases are defined by the proportion of the wetland occupied by the sedge component:

St1 - The sedge component is dominant and occupies greater than 50% of the wetland.

St2 - The sedge component is subdominant occupying 20-50% of the wetland .

St3 - The sedge component is a minor component of the wetland, occupying less than 20% of the unit.

Characteristic Soil Sequence

Soil Sequence	Soil Component Class: Sedim	Organic	Marl	Peaty Gleysol	Mineral	Trans
Organic	-	*	-	+/-	+/-	+/-
or	*	+/-	-	+/-	+/-	+/-

The Stum Lake map unit is defined as having an organic or sedimentary soil sequence. At least 20% of the wetland area has organic deposits greater than 30 cm deep. Decomposition of the organic material will be moderate (Mesic) if organic or high (Humic) if sedimentary although the surface often shows a strong fibric character due to the abundance of live roots. Two distinct depth classes were apparent; shallow-between 30 and 90 cm and deep-greater than 90 cm. The vegetation sequence cannot be used to predict these classes however larger Stum Lake 1 (St1) map units are generally deep where as smaller wetlands and St3 are generally shallow. Marl deposits may occupy up to 20% of the area. Peaty Gleysols, Mineral Gleysols and Gleyed Mineral soil types will increase as a proportion of the wetland area from St1>St2 to St2>St3. Soils are generally alkaline (pH 7.8).

The vegetation sequence correctly predicted the soil sequence for 86% of the wetlands classified as Stum Lake. Those which are not organic are Peaty-Gleysols and still have an organic surface.

Water Regime Indicators

There are four possible water regime classes associated with the Stum Lake unit. The water regimes range from seasonal inundation to permanent or floating. The diagnostic Sedge will have a seasonal regime but segments with more prolonged saturation may occur.

INTERPRETATIONS

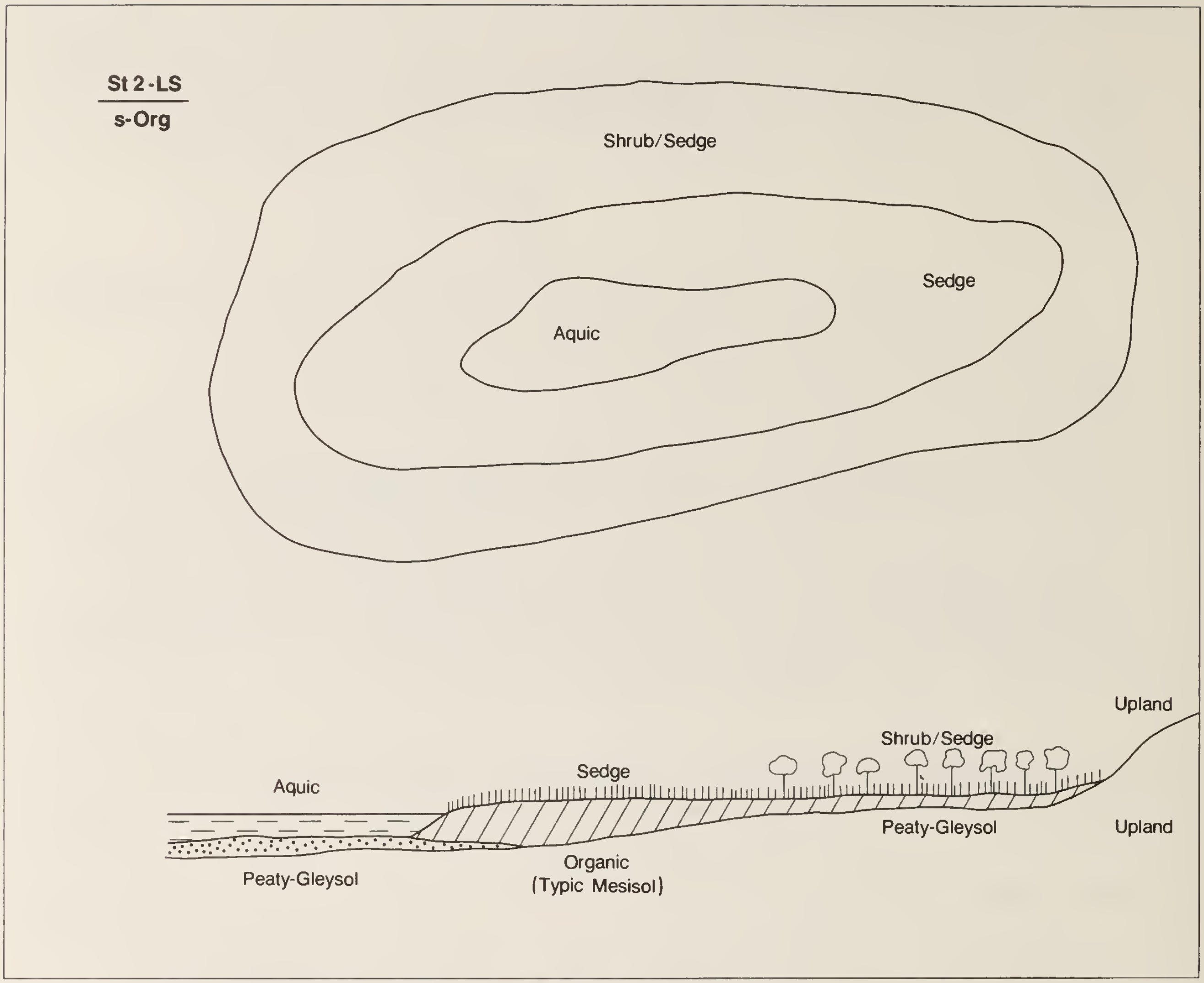
Interpretations have not yet been completed however the following brief discussion of possible uses of a specific wetland and the characteristics which will influence these uses may serve to demonstrate the applicability of the classification. Figure 5 represents a specific Stum Lake map unit whose complete map symbol would be

Map Unit Sub-class — Interspersion Class

Map Unit —— St2 - LS —— Water Class

s - Org

Water Regime — Soil Sequence



LRRI

Figure 5: Example of a Stum Lake map unit $\frac{\text{St 2-LS}}{\text{s-Org}}$

Diagnostic Vegetation Sequence

	Moss	Bulrush	Sedge	WTG/F	Shrub/Sedge		Shrub G/F
Sedge 1	–	+/–	*	–	*	or	+/–

Defined Soil Sequences

	Sedimentary	Organic	Marl	Peaty Gleysol	Mineral Gleysol	Transitional
Organic	–	*	–	+/–	+/–	+/–
or	*	+/–	–	+/–	+/–	+/–

Water Regime

	Moss	Dp. Emerg.	Emerg.	Sedge	WTG/F	Sh/Sedge	Sh G/F
Seasonal	–	–	–	*	+/–	+/–	+/–

Some possible interpretations are as follows:

Waterfowl - The presence of a still water aquic centre, as indicated by the "S", indicates potential waterfowl use however a number of characteristics make it suboptimal. The seasonal "s" water regime indicates that the vegetation surrounding the aquic component is sedge dominated. While the sedge community type is more useful to waterfowl than upland forest vegetation it is not as useful as a mixture of Cat-tail and Bulrush which provides more suitable nesting areas. The low interspersion class "L" indicates that habitat diversity and boundary areas will be low thereby further reducing waterfowl values. The degree to which the wetland is considered suboptimal is of course contingent on the availability of superior systems.

Unmanaged Forage Production - The sedge component will provide the only hayable forage production. It occupies 20% to 50% of the non-wetland area "St2". The seasonal water regime "s" indicates that water levels will fall enough to allow harvesting in most years. Possibilities for unmanaged forage production are dependent on the area of the wetland.

Ungulate Use - The sedge dominated component (less than 50% of the non aquic area) has low values for ungulate production however the Shrub/Sedge component (greater than 50% of the non-aquic area) will have much higher values due to diversity of suitable browse species and some protective cover. The aquic centre may provide some limited food material and will provide areas for moose to cool-off in summer.

Managed Forage Production - A number of management decisions need to be based on information not recoverable from the classification however the following points would bear consideration:

1) Organic materials are moderately decomposed and likely to supply reasonable levels of N, P, and possibly S if drained and decomposed
2) Some form of water control is advisable but excess drainage is likely to lead to rapid subsidence
3) Decomposition losses under domestic forage will be low
4) Clearing and possible leveling of the Shrub/Sedge component may be required
5) The high pH values and probable presence of carbonates may lead to micro-nutrient deficiencies (Fe, Bo, Cu, etc.). If carbonates are present phosphorous may also show deficiencies
6) With clearing and appropriate water control the unit would support long term domestic forage production on the organic soils but may present future problems on the Peaty Gleysol soils if the underlying substrate is not suitable for cultivation.
7) If water level is reduced to only facilitate harvesting, N.P.K., and possibly S supplements will be required to increase productivity and maintain domestic forage species.

While the above interpretations should indicate the possible applications of the classification, we do not presume to suggest these as specific interpretations. The input of professional wildlife biologists, agriculturalists, and drainage specialists is necessary to propose specific interpretations for this area.

CONCLUSIONS

Wetland map units were defined using three levels of integration. Areas of uniform soil and vegetation characteristics were grouped into soil and vegetation component classes. The sequence and pattern in which component classes occurred were grouped into diagnostic sequence classes of soil and vegetation. Sequence classes were in turn grouped, on the basis of distribution within wetland areas, into wetland map units. Successive levels of integration of soils and vegetation and the final integration of soils with vegetation produce wetland map units which are mappable using aerial reconnaissance.

The wetland map unit description and provisional interpretations presented demonstrate the level of information and application available in a wetland classification based on systems rather than components.

The classification presented here will be tested againest independent data collected for an additional one hundred wetland systems and if valid will be presented as a wetland classification mapping legend for use in the Cariboo-Chilcotin area of British Columbia. The report will contain detailed map unit descriptions and possible interpretations relevant to land use planning.

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ORGANIC SOIL MAPPING IN ALBERTA

Larry W. Turchenek

Peatlands occupy a large proportion of the land area of central and northern Alberta (Figure 1). It has been estimated by the Alberta Soil Survey (1967) that roughly 10 million hectares of Organic soils occur in Alberta. This accounts for about 15 percent of Alberta's land area and is a sizeable proportion of the Canadian total of close to 100 million hectares (Clayton et al 1977). The study of the general properties, genesis, classification, and mapping of Organic soils has not received the attention that has been given to mineral soils. For mapping purposes, these soils have simply been designated as 'Organic' or as being derived from sphagnum mosses (Kenzie soil complex) or from sedges (Eaglesham soil complex).

Soil surveys carried out prior to about 1950 were mainly in the agricultural areas of the province. Few of these areas contained Organic soils, but where they occurred, the basic differences between sedge and moss peats were recognized. However, sedge and moss peats were not separated on maps because they were so intermingled. Thus, only one map unit, 'Organic', was used to show the location and extent of these soils. This was also the only unit used to describe Organic soils in central Alberta, reports for which were published in the 1960's. Throughout the 1950's, 1960's and 1970's, in mapping projects of the Peace River area and parts of west-central Alberta, the Kenzie and Eaglesham soil complexes were used to distinguish the two major Organic soil types. The soil survey of the Hinton-Edson sheet (NTS sheet 83F) was an exception in that a new soil complex name (Fickle) was used to map all Organic soils in the area (Dumanski et al 1972). This was done to distinguish the somewhat different Organic soils of the upland Alberta Plateau and Rocky Mountain Foothill areas from Kenzie and Eaglesham soils which occur in the lower lying plains of the rest of northern Alberta. In the Tawatinaw (NTS sheet 83I) survey, Organic soils were differentiated into Fibrisols and Mesisols (Kjearsgaard 1972). Organic soil map units were not described according to type of parent material because a variety of materials could generally be found at any one site in the region.

The first attempt at more detailed mapping of Organic soils was made in the soil survey of the Sand River sheet (NTS sheet 73L) in east-central Alberta (Kocaoglu 1975). The basic unit of description was the soil complex, and map units consisted of individual complexes or of combinations of complexes. A complex is defined as a mapping unit where two or more defined taxonomic soil units are so intimately mixed geographically that it is impossible, because of the scale used, to separate them. Within each complex, predominant soil members (similar to series) were identified and described by their subgroup classification, and type and depth of parent materials. Ten complexes - four with mainly Fibrisols, four with Mesisols, and two with Humisols - were recognized and mapped in this soil survey.

The soils of most of northern Alberta (the nonagricultural area or Green Zone) were surveyed at an exploratory level during the 1950's and

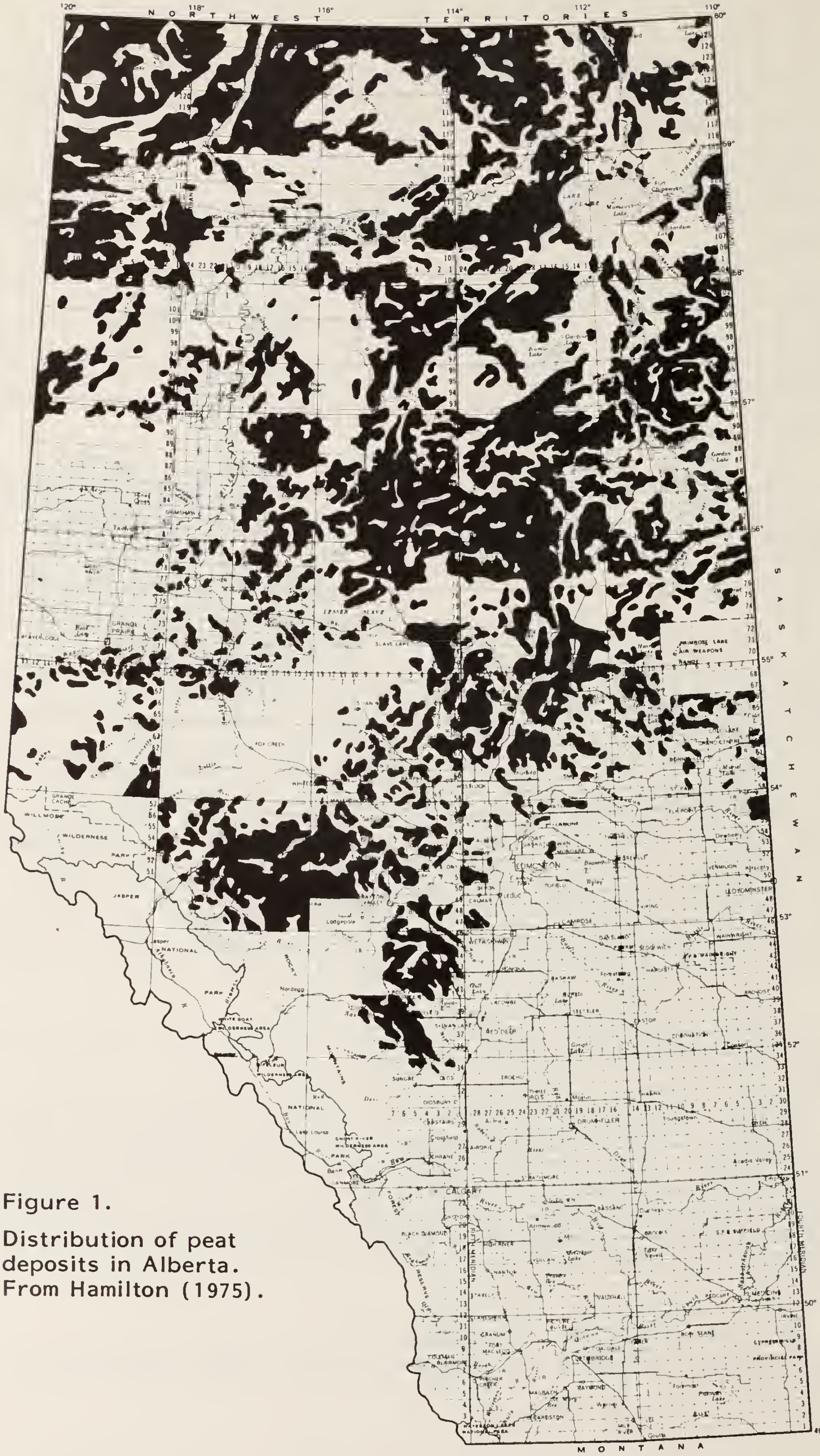

Figure 1.

Distribution of peat deposits in Alberta. From Hamilton (1975).

1960's by Lindsay and others (1958 - 1964). Maps at a scale of about 1:750,000 show major landforms and surficial materials, including organic deposits. The soil types and estimates of percentage of Organic soils are presented in the descriptive parts of these reports.

During the northern exploratory soil surveys, the presence of frozen layers was recognized as an important property of Organic soils and a study of the distribution and some characteristics of frozen soils was subsequently carried out. The results indicated that in the uplands of the most northerly parts of the province, the Organic soils were permanently frozen. The depth of the active layer or the depth of annual thaw in these soils was about 50 to 60 cm. In the lower lying regions, the Organic soils in about 60 percent of the sites examined were permanently frozen with the depth of the active layer averaging 60 cm. Further south, a third area was recognized in which Organic soils thawed at a relatively rapid rate and the frozen layer usually disappeared by mid or late July (Lindsay and Odynsky 1965).

Other soil surveys conducted relatively recently in northern areas are those of NTS sheets 83K (Twardy and Corns 1980) and 83L (Knapik 1981) and of the Alberta Oil Sands Environmental Research Program (AOSERP) study area (Turchenek and Lindsay 1981). Soil maps for these areas were published at a scale of 1:126,720. The Eaglesham and Kenzie soil complexes described previously were used in mapping Organic soils. In a soil survey of the Mount Watt and Fort Vermilion area (NTS sheets 84K and J), Organic soils with frozen layers were grouped into a new soil complex (Dizzy) to distinguish them from Kenzie and Eaglesham soils mapped in the area (Scheelar and Macyk 1972). Similarly, large areas of Organic Cryosols (Mikkwa complex) were mapped in the AOSERP study area. In this latter project, complexes of Organic and Cryosolic soils were subdivided into five map units as follows: Fibric Mesisols and associated subgroups of deep bogs; mainly Terric Mesisols of shallow bogs; Typic Mesisols and associated subgroups of fens; mainly Fibric Organic Cryosols of peat plateaus; and mixed Organic and Cryosolic subgroups on complex bog-peat plateau landforms.

Soil surveys in Alberta are presently being carried out on a county basis, mainly at a scale of 1:50,000. The areas being mapped are mainly agricultural, but Organic soils occur in some of these. The practice in mapping Organic soils in these is to use the map units already established in the Sand River sheet, if they occur within the same ecological region, or to establish new map units.

There are several concerns and current research needs regarding Organic soil mapping in Alberta. Research is needed to assist mappers encountering Organic soils in surveys of both agricultural and forested areas. Guidelines are required for establishing map units and information is required for comparing Organic soils with those of previously mapped areas. A much larger data base, as exists with mineral soils, must be developed. In one research project initiated this year, sites in previously mapped areas (such as the Sand River sheet) and in a current project area will be sampled and studied for the purpose of comparison. Methodology involves inspection and sampling along transects; in this way, data should be generated such that variability within map delineations of peatlands, as well as comparisons between peatlands, can be made.

With regard to mapping in the forested regions of northern Alberta, there may be a need in the near future for additional reconnaissance surveys as well as for some detailed surveys of peatlands. The main concern in that part of the province is environmental; that is, the impact of emissions from oil sands and gas plants on vegetation, soils, and water bodies. There is concern about impacts both in areas adjacent to plants and in areas distant from the emission sources. Reconnaissance mapping as carried out in the AOSERP study area, for example, may be inadequate for some types of studies and predictions of impacts. Organic soil-landform units need to be studied and mapped in more detail. Along with the mapping, much chemical, physical and biological data needs to be gathered to enlarge the data base on these soils.

Another problem involves identification and characterization of organic materials in the field. Because they have not worked in forested areas, some soil surveyors are inexperienced in identifying peat types and in using methods such as the von Post humification test. The von Post method has been difficult to apply by means of following descriptions in the literature, and preliminary indications are that it does not correlate well with other measures of decomposition such as rubbed fibre content and pyrophosphate index. Thus, research is required on methodology for easily and accurately characterizing materials in the field as well as in the laboratory. There is need for much more data and for comparison with data from other parts of the country where larger amounts of information have been accumulated.

Only limited information about depth of Organic deposits can be obtained from soil survey reports and maps. Most information for soil surveys is based on the control section, and depths of deposits are not usually investigated. Such information is required in locating deposits for the commercial peat moss industry and in planning gas and oil pipelines. Interpretations for agriculture and forestry also require depth information.

The peat moss industry is growing in Alberta and presently ranks fifth in production among the provinces (Hamilton 1975). In 1980, about 168,000 cubic metres of peat moss worth about $10 million was produced in Alberta. Possibilities for expanding markets are excellent and, therefore, more peatland inventory information would appear essential. However, because of the vast areas involved, it is not likely that such an inventory could be initiated for this purpose alone. There is also little likelihood of initiating inventories for determining fuel peat reserves in the province.

To summarize the situation regarding Organic soil mapping in Alberta, relatively detailed mapping is only beginning. However, unlike Eastern Canada, there appears to be little need for relatively detailed surveys of peatlands over large areas as little agricultural use is being made of peatlands. In addition to unsuitable soil climate, this may also be due to the fact that some areas of mineral soils are still available for agricultural development. There is interest in improving peatlands for forest production and small scale pilot projects in draining peatlands are currently underway.

As noted above, fuel peat and peat moss concerns are not likely to generate extensive inventory work. Possibly, one of the most pressing current needs is the determination of impacts of industrial emissions on peatlands. Recently, a pilot project was conducted in which soils were rated in terms of sensitivity to acidic deposition (Holowaychuk and Lindsay 1980; Holowaychuk et al 1981). On a scale of high, moderate, and low sensitivity, soils of fens were rated as having moderate to low sensitivity, but soils of bogs were rated as highly sensitive. The reason is that cation exchange capacity and buffering capacity of sphagnum peat is quite low when considered on a volume basis. Moreover, exchange capacity is found to be quite low when determined at soil pH rather than at an upwardly adjusted pH as is the case with some methods of measurement. The data source by which these ratings were determined is literature from elsewhere. There is little data to support these interpretations from within the province.

A research project on Organic soils and peatlands was recently initiated. Some objectives, as stated previously, are to expand the data base, to characterize Organic soils generally, and to provide some guidelines for mapping these soils. Data relevant to interpretations of sensitivity of Organic soils to industrial emissions will be collected. Data relevant to other soil interpretations, particularly for agriculture and forestry, will also be collected. For example, soil temperature monitoring stations will be established at various sites. Detailed Organic soil mapping will be carried out during the course of routine surveys of agricultural areas. More relatively detailed surveys than presently exist for northern areas will likely be carried out at the request of and in cooperation with various agencies whose main concerns are environmental.

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PEATLAND INVENTORY METHODS IN NEW BRUNSWICK

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SUMMARY

The Department of Natural Resources has carried out a detailed inventory of the peatlands in New Brunswick. On major peatlands grid systems were planned and cut. Sites were located at 100 metre intervals along these lines. The elevation of grid sites was determined. A sample core was recovered at each site and divided into intervals on the basis of change in peat type. Each sample was classed by its botanical composition, degree of humification (decomposition) and other factors. Representative samples were analyzed for various physical and chemical properties.

Peat isopach (depth) and elevation maps with one metre contour intervals were produced for each peatland. Two cross-sections, showing the distribution of peat types and humification, were produced for each grid line. A computerized data compilation system was implemented to calculate various factors for each peatland as well as to produce regional reports. The final reports of the project are in preparation. The inventory completed by New Brunswick is one of the most comprehensive in North America and provides the basic information for long term management of the resource.

INTRODUCTION

The mining of peat on a commercial scale was first carried out in New Brunswick in 1894. Some of the existing horticultural peat operations have been in continuous operation since 1942. This industry, combined with increasing interest in the use of peat as a fuel, indicated a need for an assessment of the peat resource. Various researchers have published assessments of selected deposits. However, a comprehensive evaluation of the entire province had never been attempted.

As the first phase of such an evaluation, an airphoto study was completed (Airphoto Analysis Associates 1975). A detailed field assessment has been carried out between 1975 and 1981. The methods used in this assessment and data compilation procedures are outlined in this paper. Regional features of the peatlands, and the present and potential utilization of the resource are outlined in the paper by Keys *et al.* elsewhere in this proceedings.

PROJECT HISTORY

In 1975 and 1976 small field crews operating on provincial funding began the inventory. The northeast of the province was selected as the starting point since most of the peat mining operations were in this area. The program was accelerated in 1977 when funding from the Canada Department of Regional Economic Expansion became available. This funding has continued under various subagreements.

The field work continued down the east side of the province and concluded in the southwest in 1981. Field staff exceeded 20 persons at the height of the project. Due to difficulties in obtaining experienced personnel, an exchange program was initiated with the Geological Survey of Finland in 1977. This exchange was continued until 1980. The experienced personnel who came to Canada trained project staff and made a significant contribution to the quality of work completed by the project.

SURVEY METHODS

The peatland inventory techniques used by the Geological Survey of Finland (Lappalainen 1979) have been modified for use in New Brunswick. The initial step is to examine each peatland in detail on airphotos. The approximate extent of the peatland is outlined and domed areas, vegetation changes, etc. are noted.

On major peatlands a grid network is planned in a manner which obtains the maximum information with the minimum of points.

LINECUTTING

Grid lines normally cross domed areas recognizable on the airphoto but avoid areas of heavy tree cover or high pond density to minimize linecutting difficulties. The baseline follows the long axis of the peatland. Perpendicular sidelines are normally at 500 metre intervals but this is somewhat dependent on the configuration of the peatland, vegetation changes, etc. The baseline is designated as B for computerization purposes and each site along the line is noted according to its distance (in metres) and direction (north, etc.) from the origin, *e.g.* B0900N. The sidelines are designated as L with the distance along the baseline and the distance to the side of the baseline, *e.g.* L0900N+0400E. To differentiate when more than one grid system is used on the same peatland, additional lines are designated as F and G, H and I, etc. Figure 1 illustrates a typical grid pattern and indicates line designations. On small peatlands grid systems are not used but a series of traverse points are selected and given the designation "T". In some cases a combination of grid and traverse points are used.

Field crews cut the grid lines and place pickets at 100 metre intervals along the lines. Topofil measuring instruments reel out a disposible thread and enable one person to chain distances. Brush hooks with a long

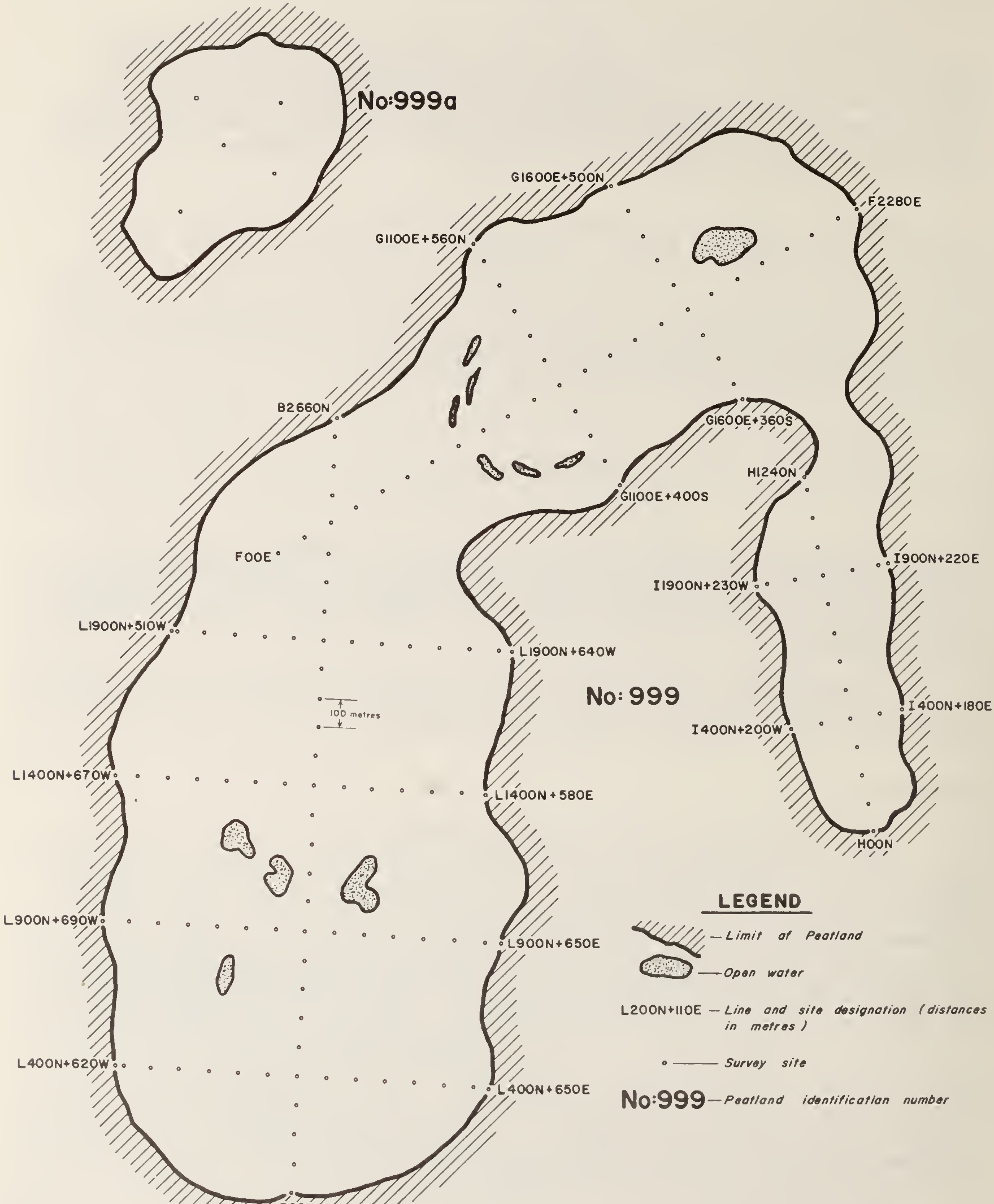


Figure 1. Typical survey pattern showing Site No. of the last point on each grid line.

hooked blade have been found to be a very effective tool for linecutting. Grid lines ideally are cut until the margin of the peatland (mineral soil) is intersected. In practise, lines are terminated if peat depth is less than one metre and dense cover is encountered or if an extensive area of shallow peat occurs. Linecutters probe for peat depth and exercise their judgment in these situations. Traverse points can be used to continue the lines if necessary.

LEVELLING

The elevation of each grid site is determined using self-compensating levels. Levelling rods with a bold "E" pattern (height of the "E" is 5 cm) give the required accuracy and have good visibility in the high temperature (*i.e.* heat waves) situations often encountered on the peatlands. Base stakes are driven at the intersection of grid lines and at the end of each line. These are used as control points when closing loops, etc. The elevation of major lakes, drainage channels, etc. is also determined.

The levelling grids are tied to survey monuments when drainage difficulties, such as the base of the deposit being below sea level, are anticipated. Where poor access, etc. precludes tieing to a survey monument the elevation of a reference site is estimated from topographic maps (normally Land Registration and Information Service orthophoto maps) and the elevation of other sites are determined relative to the reference point. The elevation of traverse points is not determined.

DRILLING

At each site a drilling crew retrieves a top to bottom sample using a Hiller auger. To avoid sample contamination from the tip of the auger, two drill holes are used and the sampling alternates between holes with each depth increase. A standard data page (Figure 2) is completed for each site. Each line on the data sheet represents one 80 column card for computer input. Bog No. and Site No. comprise columns 3 to 20 and are common to all cards. The data page is divided into two parts. The site card (S1) includes the elevation, cover type, sediment type, surficial depth, calculation flag, and number of intervals. The interval card (C1, C2, etc.) includes the depth of the interval, the peat type, humification, wetness, fine and coarse fibres, wood remnants and remarks. One interval card is completed for each division made in the sample recovered. Each section of the data page is discussed in detail below.

Bog Number: The preliminary airphoto study of the provinces peatlands used an identification number for each. While this identification number should properly be termed "peatland number", the initial years of field work were primarily on bogs. Hence, the term bog number gained common usage and has been retained.

Site Number: Figure 1 shows a typical grid layout and gives site designation for the end site of each line. The numbering system for sites has been previously described under the section headed "Linecutting".

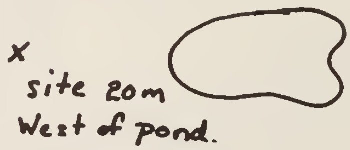
60-1937 (5/79) DEPARTMENT OF NATURAL RESOURCES PEATLAND INVENTORY

LOCATION SKETCHES, GENERAL REMARKS, Etc.

SHEET NO.		
1	2	3

DAY	MON	YEAR
14	7	79

J. B.
SURVEYOR



Bog No.	B,L,T	Site No.
999	L	1400N + 400E

	Elevation (m)	Cover Type	Snags (0-1 1-2 Tot)	Sediment	Surficial Depth (cm)	Calc Flag (Y/N)	No. of Intervals
S1	62.7	(AEI	112	CL	260	Y	12

Bryoles	B	Rock	RO
Trichophorum	TR	Gravel	GR
Scheuchzeria	SH	Sand	SA
Equisetum	EQ	Silt	SI
Phragmites	PR	Clay	CL
Ooze	OZ	Till	TI
Peat Type 100%	O	H_{10} = 0	

A = black spruce

Site Remarks (minor cover types, species, etc.)

	DEPTH (cm) From	To	PEAT TYPE % S	C	N	L	Er	Other	Specify	H 1-10	B 1-5	F 0-3	R 0-3	V 0-3	REMARKS Minor Peat Types, Charcoal, Stumps, etc
C1	0	20	9					1	TR	2	3				
C2	20	40	9		1					3	4				
C3	40	150	0							3	3				charcoal at 140
C4	150	170	9		1					5	3		1		shrub roots
C5	170	240	9				1			4	3	1			
C6	240	260	8		2					4	3				some C
C7	260	310	7	2	1					5	3		2		shrub+Carex roots
C8	310	370	6	2		2				7	3			2	
C9	370	430		9	1					5	3				
D0	430	460		0						6	3				
D1	460	470		8		2				8	3				
D2	470	490						O	OZ						Light brown
D3															

CALCULATIONS

Figure 2. Field data form with typical information (actual size is 8½ by 11 in.).

Cover Type: Cover type (surface vegetation) is recorded using the nine pure cover classes shown in Table 1 (Radforth 1952). Any combination of up to 3 letters constitutes a cover formula for that site. The method used in New Brunswick for determining the formula is a modification of that described by Radforth. The nine classes are divided into three groups on the basis of height and growth habit. In the New Brunswick situation the three groups correspond to tree cover (A and B), intermediate layer (C to F), and surface mat (G to I). The field investigator makes a visual estimate of the vegetation in the vicinity of the survey site and records one letter for each of the three groups (in order of decreasing height) if all groups are present. For example, an AEI formula could comprise a cover of tall spruce, low shrubs, and moss. The original system of Radforth did not include classes which constituted less than 25% of the total cover. In the New Brunswick system a class comprising 15-25 percent is indicated as a bracketed letter and the fourth column in the cover type section of the field sheet is used for the bracket symbol. The inclusion of cover classes of less than 25% is particularly significant in the case of A and B since these can be a deterent to peat mining.

If each of the three groups of cover classes are not present only 1 or 2 letters need to be recorded. For example, an EI cover type could consist of shrubs and mosses in amounts greater than 25%. However, if a group is absent and one of the remaining groups has 2 classes exceeding 25% three letters can be used to describe the formula. For example, an EFI cover type has all 3 classes present in amounts greater than 25% with a greater amount of F than E. Cover classes present in minor amounts can be noted in the remarks.

The Radforth cover classes do not identify species, bog type or trophy level. However, in a restricted area such as New Brunswick, the species comprising a particular class is relatively constant. Anomalous situations can be recorded in the remarks. For example, cover class A is normally spruce or tamarack and the present of pine would be recorded in the remarks. Species which are good indicators of the trophy level of the peatland are also noted.

Snags: The term snags refers to stumps and wood remnants contained in the peat layer. A steel probe is inserted into the peat layer to a depth of 2 metres. If the probe intersects a stump (*i.e.* is snagged) and cannot penetrate the peat layer, then a snag is recorded for that probe location and a new location is probed. Normally ten probes (including the 2 auger holes) are made at each survey site. Thus, total snags at a site is a function of ten probes. Total snags is subdivided into those between 0 and 1 metre depth and 1 and 2 metres depth. The number of snags intersected is used to estimate the volume of wood in a peatland. As well, the number of intersections can be used to make relative comparisons between peatlands.

Sediment: The nature of the sediment underlying the peat layer is recorded using the 2 letter codes shown in Figure 2. The augers used in the field survey do not penetrate well into the sediment. Thus identification is often made on a small amount of sample and is somewhat limited.

Surficial Depth: A poorly decomposed peat comprised primarily of *Sphagnum* is considered a top quality horticultural peat. The term surficial

TABLE 1. The properties of the nine pure coverage types of the Radforth Cover Classification (Radforth 1952).

Coverage Type	Woodiness vs. Non-woodiness	Stature (approx. height)	Texture (where required)	Growth Habit	Example
A	woody	15 ft. or over		tree form	Spruce, Larch
B	woody	5 to 15 ft.		young or dwarfed tree or bush	Spruce, Larch, Willow, Birch
C	non-woody	2 to 5 ft.		tall grass-like	Grasses
D	woody	2 to 5 ft.		tall shrub or very dwarfed tree	Willow, Birch, Labrador tea
E	woody	up to 2 ft.		low shrub	Blueberry, Laurel
F	non-woody	up to 2 ft.		mats, clumps, or patches, sometimes touching	Sedges, Grasses
G	non-woody	up to 2 ft.		single or loose association	Orchid, Pitcher plant
H	non-woody	up to 4 in.	leathery	mostly continuous maps	Lichens
I	non-woody	up to 4 in.	soft or velvety	often continuous mats, sometimes in hummocks	Mosses

depth refers to the thickness of the upper strata of a peat deposit (*i.e.* surficial layer) with humification of H1 to H4. While the surficial depth often corresponds to the thickness of horticultural grade peat, the botanical composition must also be suitable.

The surficial depth is recorded at the conclusion of the drilling at each site. The boundary between the surficial layer and humified layer is determined by examining the humification of each interval. The depth at which the change between surficial peat and humified peat occurs is recorded. Thin layers of well humified peat can be included within the surficial layer.

Calculation Flag: Occasionally a depth probe is made at a site, but a description of the peat is not. Since the computer would treat the missing values as zero it is not desirable to include such a site in the detailed calculations. Thus, an "N" under calculation flag excludes the site from calculations.

No. of Intervals: The sample recovered by the Hiller auger is divided into intervals based on changes in peat type and decomposition. One line on the lower part of the field sheet is used for each interval. The number of intervals is recorded on the S1 card and used as an internal check during input of data on the computer.

Depth: The surface of the peatland at each site is considered zero depth. The thickness of each interval is recorded in centimetres. However, the intervals are normally divided to the nearest 10 centimetres.

Peat Type: Each interval is examined to determine the botanical composition (see compilation by Henderson elsewhere in this publication). The composition is estimated to the nearest 10 percent and recorded. For convenience, zero equals 100%, 9 equals 90%, etc.

The most common peat types form the first 5 columns; the percentages of S (*Sphagnum*), C (*Carex*), N (shrubs), L (wood), and ER (*Eriophorum*) are recorded in the appropriate columns. When the botanical composition includes additional constituents the percentage is recorded under "Other". If other is composed of only 1 species it is identified under specify according to the codes given on the top right of the data page. If other is comprised of more than one species the code MS (miscellaneous) is recorded and the species are identified in the remarks.

Humification (H): The degree of decomposition or humification is recorded according to the 10 step von Post scale. This scale and its use is outlined in the compilation by Henderson elsewhere in this publication.

Wetness (B): This is a relative estimate of the moisture of the interval. The scale ranges from 1 to 5 with 3 being normal. One is dry while 5 is very wet. A high value for B often indicates poor sample recovery, *i.e.* the sample is mainly water.

Fine Fibre (F), Coarse Fibre (R), and Woody Remnants (V): All of these scales range from 0 (nil) to 3 (high). A value greater than zero should also be evident in the peat type. Fine fibre is typically "root hairs" from species such as *Eriophorum* (the species responsible would be identifiable under peat type). Coarse fibres are commonly rootlets from *Carex* or shrubs and the species would also be identifiable under peat type. Woody remnants would be reflected by wood (L) in the peat type. Because of the strong relationship of peat type to these factors there is little emphasis placed on the values recorded during the data compilation.

Remarks: This section is used to record various parameters which do not readily fit any of the previous columns for each interval. Peat types which comprise less than 10% seeds, charcoal layers, etc. are recorded under remarks.

WILDLIFE

During the course of the inventory, it became evident that there was little information available on the use of the provinces peatlands by various wildlife species. For this reason, all field crews recorded wildlife sightings during the last 3 years of the project. When possible, the species, sex, maturity, and habitat use of each sighting was recorded. The information compiled could not truly be classed as a wildlife survey. However, some trends were recognizable and should provide an indication of the approach required if a detailed study becomes necessary.

SAMPLING FOR ANALYSIS

Using the data recorded on the field sheets, completed field maps, and if available, the profiles for each peatland, one or two representative sites on most major peatlands are selected for follow-up sampling. The sites are divided into two types: those with good fuel peat potential and those with low fuel potential. Efforts are made to have a good distribution of each type across the various peatland zones in the province.

From 1977 to 1979 the samples were collected using a 2 inch piston sampler. During 1980 and 1981 a 4 inch diameter MacCauley sampler was used. While the piston sampler was suitable for most applications, some difficulties were encountered with compaction of the sample which was undesirable for determination of "in situ" bulk density. The MacCauley sampler minimized this problem and was somewhat easier to operate in most peats. Neither sampler was particularly suitable for sampling of the uppermost 50 cm of the peat layer. This layer was sampled using a long knife or brush hook.

When using the MacCauley sampler only one quarter was used for analysis. The second quarter was used to divide the samples into intervals in the same manner as described previously in the section on "Drilling". When using the piston sampler an additional core was recovered if necessary, or a Hiller auger was used to determine intervals.

The depth of each interval was recorded and the samples were sealed in plastic for transportation to the laboratory. There the moisture content, and, in later years, bulk density were determined and the samples were finely ground.

At sites selected with fuel peat potential two cores were recovered to ensure the availability of sufficient volume of sample to complete all analysis. One half of the sample was used to determine calorific value, sulphur, and volatiles. On selected samples the following were determined: ultimate analysis (C, H, N, and O), ash melting point, total and available nitrogen and phosphorus, and chloride. The second half of the sample was used to determine ash content and the content of various metals in the was determined.

At sites with low fuel potential an acid extract of the peat was analyzed for various metals with results reported as a function of dry peat.

DATA COMPILATION

Orthophoto maps at 1:10,000 scale were used to prepare base maps. The location of the grid network and survey site was plotted on the base map. The extent (or limit) of the peatland was plotted based on airphoto interpretation and the field data. The resulting base map is similar to Figure 1. In most cases, peat isopach and elevation maps were prepared on a daily basis while in the field. Each is contoured on one metre intervals.

A depth of one metre is generally considered the limit of economic mineability of peat. For this reason, special care was taken in the establishment of the one metre contour on the peat isopach maps. Drilling crews often completed depth probes between survey points to accurately establish the location of the one metre contour. While the isopach contours are based on total peat depth (excluding ooze), the depth of the surficial layer at each site is also noted on the map. As well, the weighted average of the humification of each site is noted so that sites can be rapidily compared without referring to the field data.

Each of the three maps is later drafted using a standard legend and format. The standard map size is 24 inches by 34 inches (including 8 inch legend) and covers 3 seconds of latitude and 5 seconds of longitude. Approximately 290 map sets will be available at the completion of the project.

Using the completed maps, the total area of the peatland and the area where peat depth exceeds one metre is determined using a planimeter. The boundary of Crown and private lands is also plotted and the areas of each on the peatlands is measured. If the peatland is under lease, the area of the lease, area in production, etc. are also determined.

These areas, as well as location information, survey statistics, and other factors are compiled for each peatland and combined with the field data sheets for computer input.

COMPUTER PROCESSING

The compiled data is keypunched and entered into the computer. The data is checked, both visually and by the computer, for errors which occurred during the transfer of data. The average humification (weighted by depth) for the surficial layer, humified layer and combined thickness of each site is then determined. This information plus the data recorded on the field sheets constitute site level data and can be retrieved as such in a standard format.

The site level data is combined with information such as areas and locations, and numerous calculations are performed. A total of 25 tables are available at the bog level. Only a brief summary can be presented here.

The distinction between surficial layer (H1 to H4) and humified layer (H5 to H10) has previously been discussed. Most calculations are performed for each of these layers plus the combination of the two. Only sites with a depth of one metre or more are included in the detailed calculations. It was found that in most cases the number of sites with depths less than a metre was not large enough to provide a reliable average for calculation. In instances where it is necessary to perform calculations for the entire peatland, such as the total volume, the calculation is performed using the area and sites with one metre depth. The value obtained is totalled with a similar calculation for the portion of the peatland with depths less than 1 metre in depth. The average depth of this portion is assumed to be 0.5 m.

A computerized summary of the detailed bog level tables for each peatland is subdivided on the basis of the surficial, humified, and combined layers and includes the following:

Average depth and humification;

Percentage and volume of 22 peat types;

Percentage and volume of 3 dominant peat groups (*Sphagnum*, sedge, and *Bryales*);

Average humification of 22 peat types;

Percentage and volumes of layers where minor peat types (shrubs, wood, *Eriophorum*, etc.) exceed 10%;

Percentage of snags;

Percentage and volume of 10 degrees of humification.

In addition, a two page summary report is produced and is illustrated in Figures 3 and 4.

Bog level output is the summary of a number of sites on a particular peatland. Similarily regional level output is a summary of a number of peatlands in a specified group. The same tables as those listed above are available at the regional level. The information shown in Figures 3 and 4 is on a different format at the regional level but contains essentially the same data.

Over 600 variables can be used in combination to group peatlands at the regional level. For example, if one requires a peatland with an area

Figure 3. Page one of the summary report produced for each peatland.

BOG NO.: 999

PEATLAND MAP NO.: J99 | NAME: JONES HEATH

NTS NO.: 21 J/11 | COUNTY: CARLETON

LATITUDE: 463918 | LONGITUDE: 671125

PEATLAND TYPE: OMBROTROPHIC | TREE COVER: 20%

LOCATION AND ACCESS: 5 KM WEST OF DOGPATCH JCT. ACCESS BY BUSH ROAD FROM RTE. 99.

STATUS OF EXPLOITATION: VIRGIN

LEASED TO: -

OWNERSHIP AND LEASE DATA
(All Areas in Hectares)

	CROWN	PRIVATE	TOTAL
TOTAL AREA OF PEATLAND:	472	28	500
AREA WITH DEPTH EXCEEDING 1 M:	420	20	440
AREA IN PRODUCTION:	...	...	...
AREA ABANDONED:	...	...	...

TOTAL AREA OF LEASE: -

LEASE AREA WITH DEPTH EXCEEDING 1 M: -

Figure 4. Page two of the summary report produced for each peatland.

BOG NO.: 999

SURVEY TYPE: GRID

STUDIED: JULY 79

LENGTH OF GRID LINES: 13.8 KM

SURVEYOR: J.B.

NO. OF LINES: 11

NO. OF POINTS: 149

MAXIMUM ELEVATION: 102.7 M

MAXIMUM DEPTH: 62.0 DM

	ENTIRE PEATLAND	PORTION WITH DEPTH EXCEEDING 1 M
AREA (HECTARES):	500	440
AVERAGE DEPTH (DM):		
SURFICIAL:	23.5	24.2
HUMIFIED:	14.7	15.2
OVER-ALL:	38.2	39.4
AVERAGE HUMIFICATION:		
SURFICIAL:	3.1	3.1
HUMIFIED:	5.2	5.2
OVER-ALL:	4.3	4.3
VOLUME (MILLION CUBIC METRES):		
SURFICIAL:		10.65
HUMIFIED:		6.69
OVER-ALL:	17.64	17.34

STUMP CONTENT: 0.62%

larger than 200 hectares containing a volume of 1 million cubic metres of pure *Sphagnum* peat with humification less than 4, the computer will provide a regional level output of all peatlands meeting these criteria.

Compilation, calculation, and statistical treatment of all analysis data is also done with the aid of computers. As well, the time consuming process of drawing profiles (cross-sections) along each grid line is now carried out by the computer. Two profiles are produced for each line. One shows the distribution of humifications while the second displays peat type distribution, cover types, bottom sediment and snags. The computer plots the profiles in ink on drafting plastic and completes all lettering. Since some interpretation is required to outline the various layers and lenses of peat types and humifications, this is completed manually. Symbols are then added using letratone.

Required computer programs have been developed specifically for this project. Software development was carried out by Chary Kandalam. The authors gratefully acknowledge his efforts.

REPORT FORMAT

Annual open file reports were compiled at the conclusion of each years field work. Some were completed prior to the use of computers and do not contain the detailed calculations currently available. These reports are undergoing updates and all information will be compiled on the basis of 1:250,000 scale N.T.S. map sheets.

While all the information discussed in this manuscript is available to the public, the material available for general distribution consists of the 1:10,000 scale base, isopach, and elevation maps and the summary reports illustrated in Figures 3 and 4. The summary reports for each peatland are supplemented by a written description of the general characteristics of the peatland, the distribution of peat types and humifications, surface vegetation, drainage characteristics, recommendations for potential use, and a summary of analysis information.

General reports on peatland zones and vegetation, peat quantities and qualities, survey methods, computer methods, and chemical analysis will also be compiled.

APPLICATIONS OF THE DATA

The survey methods used in New Brunswick provide three-dimensional, multi-use information at a relatively low cost. The compiled information can be used: to assess the potential of extraction of peat for horticultural or fuel purposes; to select sites for "in situ" uses such as agriculture, forestry, wildlife habitats, and conservation; for engineering studies; and for academic research.

With regard to peat extraction, the quantities identified must be regarded as "in situ" or resource values. The recoverable reserves are substantially less but can be estimated with reasonable confidence by detailed examination of the compiled data.

An average density of one site per 6.4 hectares was attained in the inventory. Naturally an increased site density would allow greater confidence in the survey results but would be difficult to justify in a regional survey. However, it should be recognized that, in most instances, it would be advisable to supplement the data with additional depth probes and elevation readings before attempting to drain or develop a particular peatland.

The chemical data can be used to further define the suitability of a peatland for a specific use. In addition, the results can be used in biogeochemical prospecting.

New Brunswick is the first jurisdiction in North America to acquire such a knowledge of the peat and peatland resources. Development and utilization of the resource is increasing and indicates the need for long term management of the resource. The inventory provides the basic information to develop an effective management plan.

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NEWFOUNDLAND PEATLAND INVENTORIES

Jan van de Hulst

Summary

A peatland inventory was initiated in 1978 to locate and classify all organic deposits on the Island of Newfoundland and to arrive at an estimate of the volumes of organic materials. Classification of the organic deposits follows the Wetland Classification System. Additionally for bogs greater than 30 ha. and fens greater than 5 ha., information is given about drainage limitations, extent and distribution of open water, slope and aspect of slope. A biophysical approach was adopted for the inventory. The Island of Newfoundland is divided into six regions, and each region is divided into eco-districts. These eco-districts serve as a primary stratification, and field sampling intensity is dictated by the area of organic deposits within each district. Results obtained from the sampling are then extrapolated to the whole district. To date, the first three regions have been completed resulting in the mapping of a total of 43,509 organic deposits, covering 496,926 ha. The peatland inventory does not provide all the information that is needed to assess the suitability of organic deposits for development. One of the more important characteristics that is lacking in the inventory is information about the botanic origin of the organic material. It was also found that organic deposits with dense tree covers are often overlooked. Despite a lack of certain information, the peatland inventory can be considered as an important tool to land use planning and has proven to be useful in the preliminary assessment of organic deposits for development for agriculture and fuel peat mining.

Introduction

On the Island of Newfoundland alone there are an estimated 1,800,000 ha. of peatland, covering approximately 17% of the land area. In 1978, a peatland inventory was initiated by the provincial department of Forestry and Agriculture. Terms of reference were drawn up by the Department and the Canadian Forestry Service and the project was tendered out. The peatland inventory is a cost-shared project, funded under the planning subsidiary agreement between the Government of Newfoundland and Labrador and the Government of Canada.

Figure I. Peatland Inventory Schedule

Areas Covered

The peatland inventory of the Island of Newfoundland consists of six phases or regions (figure 1). To date, the first three regions have been completed. Region 1, Northeastern Newfoundland, was inventoried in 1978 and resulted in the mapping of 19,577 organic deposits, covering 135,493 ha.

Region II, Western Newfoundland, was inventoried in 1979 and resulted in the mapping of 6,407 organic deposits, covering 87,885 ha.

Region III, Eastern Newfoundland, was inventoried in 1980 resulting in the mapping of 17,525 organic deposits, covering 273,548 ha.

Region IV, Northern Newfoundland and Region V, South-central Newfoundland, are in progress and completion is scheduled for 1982 and 1983 respectively. Region VI, South-western Newfoundland is scheduled for 1983.

Selection of Methods

The peatland inventory is a multi-purpose survey. Along with depths of organic deposit, degree of decomposition, and volumes of the organic materials, some of the major characteristics important to agriculture are being recorded.

For logistic reasons, it was not possible to field-check all organic deposits. Therefore, the biophysical classification concept was adopted. Each of the six regions is divided into Eco-districts, characterized by a distinctive pattern of relief, geological structure, geomorphology and associated vegetational complexes. These eco-districts serve as a primary stratification of the land surface, and field sampling intensity is dictated by the area of organic deposits within each district. Results obtained from the sampling within a district are then extrapolated to the whole district.

The terms of reference as drawn up by the Department of Forestry and the Canadian Forestry Service were as follows:

> "mapping of all peatland areas at a scale of 1:12,500 and classification of these peatlands according to the Wetland Classification System. In addition to typing on the first level of classification, the mapping element of inventory will provide estimates of open water surface area and pattern of water distribution relative to surface morphology. A detailed peat sampling program will be undertaken to determine the depths, volumes and types of peat within

> each major deposit (exceeding 30 ha. in area for bogs; 5 ha. in area for fens). Peat sampling will require establishment of a grid system of 50 m. spacing initially but modified as the survey progresses and returns on such a grid sampling diminish."

Methodology

Mapping phase. The mapping phase consists of two distinct but related tasks. The first task is that of preliminary air photo interpretation using 1:50,000 scale black and white photography to provide an overview of the types and distribution of the various organic deposits within each eco-district. Field checking is undertaken to confirm the preliminary interpretation. The second task involves the delineation of the boundaries and classification of the deposits through air photo interpretation using 1:12,500 colour photography. This mapping phase also provides the basis for the design of the sampling methodology and planning of the field survey operations. All identified deposits are typed according to the first level of the Wetland Classification system, and their surface area is calculated. For all bogs greater than 30 ha. and fens greater than 5 ha., additional information is gathered using air photo interpretation. Slope and aspect of slope are indicated. Open water surface area is estimated and expressed as a percentage area of the deposit. Pattern of water distribution is indicated as Concentric pool pattern, Eccentric pool pattern, Irregular pool pattern, or Parallel pools. Drainage capability is rated as having no limitations for drainage, moderate limitations for drainage, and severe limitations for drainage. The drainage capability is assessed from the actual Wetland Classification type (e.g. marshes and fens are invariably assessed as having severe limitations), spatial distribution of surface water, slope of surface, whether the slope is single or complex, presence of flowing water (e.g. small brooks), and nature of substrate.

A typical designation for a deposit could be

1 DB 75 ha. b 10% C 2° NW,

this identifies organic deposit No. 1, which is a Domed Bog, 75 ha. in area, having moderate drainage limitations (b). Ten percent of the total surface area is open water in the form of Concentric pools (10% C). The slope of the bog is approximately 2 degrees and the aspect of the slope is Northwest (2° NW).

Field Survey. For the three completed regions, an average of 200 organic deposits per region have been field surveyed and sampled by two or three 2-man teams. The deposits to be surveyed and sampled were selected after an overview of the completed study area was completed. Field sampling is carried out by means of a variable grid system. The size of the grid varies with the size of the deposit. At each grid point, the total depth of the organic deposit, and the thickness of the strata are recorded. At each 300 m· point along the major axis of the deposit, or where changes in strata occur, the major strata (more than 50 cm. thick) are sampled using a Hiller Sampler, and the following additional information is recorded. Colour of strata (Munsell Colour Charts), Von Post Scale of humification for each stratum, type of material, surface topography, bottom material and vegetation. The samples are kept for chemical analyses.

Data Compilation. Final maps are drafted on 1:12,500 stable base forest inventory cover type maps, or 1:12,500 stable base corrected orthophoto maps. These maps contain information about location and boundaries of the organic deposits, Wetland type, surface area, and deposit number. Additionally, for bogs greater than 30 ha. and fens greater than 5 ha., information is given about drainage limitations, extent and distribution of open water, slope and aspect of slope.

Total volumes of organic material and volumes of the various strata are estimated using the volume calucations of the field surveyed deposits and extrapolating these volume calculations over all mapped deposits. To calculate the volumes of the field surveyed deposits, the areas completely enclosed by the survey grids are considered as a series of truncated rectangular prisms, whose volumes may be taken by multiplying the average of the four corner heights with the surface area. The volumes of the outside fringes are determined by averaging the depths around the periphery of the grid and multiplying by the fringe surface areas. The volumes of the various strata are calculated from the detailed measurements by constructing a profile of the depths of each profile type. The area of each profile is calculated and the proportion of each type determined. For all mapped deposits, the estimated volumes are tabulated according to deposit type and map section. For the field surveyed deposits, profile descriptions are made indicating the thickness and depth of strata, von post scale of humification and Munsell colour.

Use of the Peatland Inventory

The purpose of this peatland inventory is to locate all organic deposits on the Island of Newfoundland and to arrive at an estimate of the volumes of organic materials. Although the inventory does not provide all the information that is needed for the planning of organic deposits for different uses, it certainly allows us to form an idea about the extent and distribution of this resource, at a nominal cost of approximately 63¢ per hectare. One of the more important characteristics that has not been recorded in the first three phases of the inventory is the type of the material or its botanic origin. Whether the organic material is suitable for use as horticultural peat, as fuel peat or for agriculture, depends not only on the degree of decomposition but also on the type of organic material, e.g. sphagnum peat or sedge peat.

The peatland inventory is used by Newfoundland soil survey to a certain extent. The wetland classification of each deposit gives an indication of the landform, vegetation, nutrient status, and type of material, while the surface area and volume calculations may give an indication of depth and profile development. Since the peatland inventory relies mainly upon air photo interpretation, shallow organic deposits with a dense tree cover, often are overlooked. Figure 2 shows the difference between the organic soils mapped during a soil survey and the organic deposits mapped by the peatland inventory.

Despite the lack of certain information as mentioned above, the peatland inventory should be considered as an important tool to land use planning and has proven to be useful in the preliminary assessment of certain deposits for development for agriculture and fuel peat mining.

Figure 2. Comfort Cove Peninsula, Newfoundland.

A. Organic soils mapped in the course of a soil survey at a scale of 1:20,000

B. Organic deposits mapped by the Peatland Inventory.

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Characterization and differentiation of peat materials in the context of peat soils classification.

by
Marcel Lévesque

The vast peat resource of Canada, estimated as the second largest in the world, deserves sufficient attention to justify a gathering of basic information. An essential part of the gathering process is the characterization of peats.

The purpose in characterizing peats is multifold:

- to learn about the nature and properties of peats
- to select meaningfull criteria for differentiating and classifying peats
- to develop concepts and methodology applicable to the inventory, utilization, management and conservation of peats

The primary notion to get in characterizing peats is to identify and define peat materials (peat type or kind of peat) according to their botanical composition and inherited properties. So, the possibility of identifying peat materials through their macrofossil assemblages would be an important step in the characterization process. If the botanical composition is a key element in this process, other elements such as degree of decomposition, trophic status and peat landform are also very useful. The emphasis here is on peat materials because these have not been fully or even tentatively characterized with respect to botanical composition, macrofossil assemblages, association with specific peatland type and inherited chemical and physical properties. It should be realized, however, that the characterization and classification of peat materials is different from the classification of peat profiles per se, that is, the taxonomic classification of peat soils.

This paper aims at presenting the following:

a) a description of the main peat materials according to botanical composition, general chemical and physical properties, and trophic status;
b) a list of plants (taxons) associated with macrofossil assemblages, and a series of macrophotographs of macrofossils.
c) a discussion on the main physical and chemical properties of peat materials.

1. Peat Materials

Based on general botanical, chemical, physical and ecological considerations, there are 5 main peat materials from which the Canadian peats could be derived. These are Sphagnum, forest, fen and marsh peats respectively associated with the following peat landforms: bog, swamp, fen and marsh. The fifth peat material is the sedimentary peat which could include aquatic ooze, gyttja, sapropel or copropel. Each peat type develops under distinct ecological conditions imposed by climate, topography and nature of underlying or surrounding mineral soil materials. The main peat materials comprise a variety of materials differing mainly in their proportions of botanical components; these have properties inherited from peat-forming plants and from physical and biochemical transformations taking place in the peat body. In describing the peat materials, let us proceed with notions and concepts such as degree of decomposition, botanical composition and trophic status which have received some acceptance.

a) Sphagnum peat - this peat material forms on wet ombrotrophic (nutrient-poor) sites. The dominant peat-forming plants are Sphagnum mosses associated with *Eriophorum* sp.(cotton-grass), and some ericales such as *Ledum* and *Vaccinium*. It may contain some woody elements from *Picea* and *Larix*. The color of the material is pale to yellowish-brown and brown. When the material decomposes and looses its spongy nature, the brown color dominates. Decomposition changes its appearance, making it more difficult to identify; however, the Sphagnum stems resist decomposition better and these can be used as macrofossil indicators. This peat material is usually weakly matted, sometimes felted. It has a very high water holding capacity, high rubbed fiber content and C:N ratio, but the bulk density, pyrophosphate index, ash content and colorific value are quite low.

Depending on the proportions and kinds of botanical components present, a number of subgroups can be found. The main peat soils which develop from Sphagnum are fibrisols. Sphagno fibrisols are common in the Atlantic regions and along the St. Lawrence Coast.

Macrofossil assemblages - dominant: leaves, stems, branches primordia and protonema of *Sphagnum magellanicum*; stems, roots, rhizomes, epidermis and sclerenchyma of *Eriophorum*. - accessory or transitional: leaves, stems and roots of ericaceous shrubs (*Ledum*, *Kalmia*, *Vaccinium*, *Chamaedaphne*); wood fragments, bark, needles, terminal buds of *Larix*, and *Picea*; leaves and stems of *Polytrichum* and other Bryales.

b) Sedge fen peat - This peat material develops on very poorly drained sites of the fen peatland type (transitional fen, basin swamp), which are generally mesotrophic. It forms dominantly from sedges (Carex sp) grasses (Calamagrostis sp.), arrow-grasses (Scheuchzeria), certain Bryale mosses (Aulacomnium, Drepanocladus) - brown mosses - and some brushes (Salix). The material is dark greyish brown to dark reddish brown, depending on the concentration of the sedges which give a strongly matted structure. With the more decomposed sedge fen peats, one may find masses (aggregates) of fine roots holding together a matrix of finely desintegrated material.

A variety of peat materials are found in this group, depending on the proportional contribution of the different peat-forming plants, and the ecological conditions under which the peat had formed: woody fen, bryale sedge, carex, sedge bryale fen peats. Mesisols are the dominant soils formed from these peat materials. Being formed under mesotrophic conditions, intermediate values for most peat properties are generally associated with these materials, although they tend to be more decomposed than other peat materials. The peat soils economically used for agriculture (South-western Quebec) are generally mesisols developed from woody sedge fen peat materials.

Macrofossil assemblages - dominant: stems, roots, rhizomes, epidermis and sclerenchyma of Carex limosa, grasses (Calamagrostis), Scheuchzeria; stems and leaves of Bryales (Aulacomnium, Drepanocladus, Calliergon), etc.
- Accessory or transitional: fragments of Salix, ericales, Myrica; seeds of Menyanthes (bogbean); wood from Betula (birch).

c) Reed and sedge marsh peat - This peat material has been formed in grassy wet areas near important bodies of water. The peatland type is that of a marshland, the vegetation of which is dominantly emergent non-woody plants such as rushes, reeds, sedges and aquatic plants. These following taxons are the dominant peat-forming plants: Phragmites sp. Typha sp., Carex (rostrata), Cladium sp., Nymphea sp., and some Bryale mosses (brown mosses) such as Aulacomnium and Drepanocladus. Because mainly derived from grassy plants, the peat material is strongly matted. The proximity of the mineral substratum coupled with the presence of tall herbs make it a rich minerotrophic medium which gives rise to peat materials fairly well decomposed, high in ash content and in bulk density. Most of the valuable peat soils used for agriculture in southern Ontario are found on marshlands. The soils are usually mesisols.
Macrofossil assemblages - dominant: stems, roots, rhizomes of reeds, grasses and sedges; stems and leaves of brown mosses;

- Accessory or transitional: seeds of Menyanthes, Calla, Caltha, Nymphaea; some wood fragments in the basal material (Larix, Thuja, Alnus).

d) Forest peat - This material forms on nutrient-rich (minerotrophic) sites, and derives mainly from the forest vegetation of the swampy peatland. The color is dark brown to reddish brown. The structure is granular when the wood component predominates; sometimes it could be weakly matted or layered. The major peat-forming plants belong to the forest vegetation, either the coniferous type (Picea, Pinus Thuja, Larix) or the decidious type (Betula, Alnus). A mixture of Bryale mosses - feather mosses - (Hypnum, Hylocomium, Pleurozium, Dicranum), ferns (Osmunda, Dryopteris); some sedges complete the assemblage.
Bulk density, hydraulic conductivity, pyrophosphate index and ash content are quite high while C:N ratio, rubbed fibre, water-holding capacity and calorific values are rather low. These materials contain large amounts of phenolic compounds derived from lignin, and so they resist decomposition longer. In spite of a relatively low water retention and the presence of stumps and coarse wood fragments at times, the woody peats and their associated alder peats constitute very suitable materials for cropping, mainly because of their very favourable physical conditions.

There are several kinds of forest peat materials, containing various proportions of lignous constituents admixed with bryale mosses, ferns and herbs. Mesisols are the dominant soils derived from forest peats, but humisols could be frequently found.

Macrofossil assemblages - dominant: wood fragments, bark from Picea, Pinus, Larix and Alnus; needles from Larix and Picea; leaves, rachis and roots from ferns (Osmunda); leaves and stems of bryale mosses (Hypnum group); - Accessory or transitional: leaves and stems of Sphagnum squarrosum; stems and rhizomes of horsetail (Equisetum); some roots of ericales.

e) Sedimentary peat - This peat material develops under submerged conditions in shallow lakes and ponds. The finely devided and amorphous organic materials derives primarily from aquatic plant debris, aquatic animal remains (bodies and droppings) which were modified by the biological activities in the aquatic medium. Shells of the fresh water types (usually Pulmonate Gastropods) can be found in the coprogeneous materials.

This peat material is plastic and slightly sticky; it is usually grey in color, but dark reddish brown to light reddish gray is also found. The material has very low to low values for rubbed fiber, pyrophosphate index, organic carbon, C.E.C., calorific value and hydraulic conductivity; however, the ash content is quite high (50% and higher). Sedimentary peats shrink upon drying and re-wet with great difficulty. The acidity varies, but these materials could become very acidic (pH 2.5-3.0) upon oxidation because they characteristically contain reduced sulfur.

A variety of materials could be included in the generic group of sedimentary peats: aquatic ooze, gyttja, copropel, coprogeneous peat, etc. So far, the characterization of sedimentary peats is rather meager.

Very few plant and animal remains can be recognized without magnification. These macrofossils would be: roots and seeds of some aquatic plants such as Menyanthes, Nymphaea, Caltha; shells of Gastropods; fragments and even complete bodies of certain insects and animalcules.

2. Peat-forming and indicator plants

The peat-forming and indicator plants likely to be found in the 4 main groups of peat materials in Eastern Canada are listed in Table 1. This is not an exhaustive list, but most of the 70 plant species included are known to be important peat-forming plants, some others may be useful as indicator plants. The non-woody and woody plants are reported according to frequency of occurence (presence and abundance). In some instances, the letters - Rare (R), Common (C) and Abundant(A) - are marked with a subscript "t", indicating typical species for a particular peat material.

The plant species are listed according to main taxonomic grouping. Although there are loose and non-scientific terms, "feather mosses" and "brown mosses" are employed because they are used in the field, and provide a convenient reference.

Macrofossil assemblages - The identification as well as the connections between the different taxons of same assemblages could be quite difficult at times. Also, the use of a hand-lens and a certain sorting out of the materials would help. It is important to get a morphological knowledge of the common macrofossils (assemblage) associated with specific peat materials. In order to assist in the identification of macrofossils and, in turn, of peat materials, macrophotographs of individuals and assemblage mocrofossils are presented in a series of Plates (1 to 6). The peat fragments could be recognized as being or as derived from organs (leaves, stems, roots, rhizomes, seeds, primordia, terminal buds, rhizoids, protonema - moss roots -, rachis - fern stems -, needles, nodes, etc); tissues (epidermis, sclerenchyma, vascular bundles, cuticules, etc). They could be small fragments, group of cells difficultly associated with any specific organ or tissue; they may show up as loose fine material or held together as aggregates.

Table 1. Peat forming or indicator plants associated with four main peat materials - Frequency of occurrence.[1]

Systematic Grouping of plant species			Peat materials 1 Sphagnum peat	2 Forest peat	3 Sedge-fen peat	4 Reed marsh peat
Non-woody plants						
Pteridophytes						
Equisetum	sp.	(Horsetail)		Rt		R
Lycopodium	sp.	(club-moss)		R		
Osmunda	sp.	(fern)		A	F	R
Dryopteris	sp.	"		A	F	F
Polypodium	sp.	"		Rt		
Onoclea	sp.	"		F	R	R
Pteridium	sp.	"		R		
Bryophytes						
Sphagnum	cuspidatum		At	R	R	
"	magellanicum		At	F	F	R
"	fuscum		F			
"	rubellum		F			
"	imbricatum		F			
"	squarrosum			F	R	R
Bryales						
Hypnum	sp.	Feather Mosses		At	R	R
Ptilium	sp.	Feather Mosses		F	R	
Pleurozium	sp.	Feather Mosses	F	A	F	R
Hylocomium	sp.	Feather Mosses		A	R	R
Climacium	sp.	Feather Mosses		A	R	R
Polytrichum	sp.	Feather Mosses	R	F	F	R
Dicranum	sp.	Feather Mosses		F	R	
Pohlia	sp.	Feather Mosses		R		
Drepanocladus	sp.	Brown Mosses	R	F	A	F
Calliergon	sp.	Brown Mosses	R	F	F	F
Amblystegium	sp.	Brown Mosses		F	F	F
Aulacomnium	sp.	Brown Mosses		F	A	F
Rhacomitrium	sp.[2]		F		F	

Systematic Grouping of plant species	Peat materials 1 Sphagnum peat	2 Forest peat	3 Sedge-fen peat	4 Reed marsh peat
Lichens				
Cladonia rangiferina[3]	F	R	F	
Spermatophytes				
Sedges				
Carex limosa	F	R	F	R
" rostrata	R	R	F	F
" stricta	R	R	F	F
" trisperma	F	F	F	F
" oligosperma	F	F	F	R
Eriophorum spissum	A	F	F	R
" angustifolium	F	F	F	R
Scirpus coepitosus[3]	F		F	R
" cyperinus	F		F	F
Eleocharis canadensis			F	F
Cladium sp.				F
Dulichium sp.				R
Grasses				
Phragmites communis			R	Ft
Glyceria sp.			F	A
Calamagrostis sp.			F	F
Spartina pectinata				R
Arrow-grass				
Scheuchzeria palustris	F		Ft	R
Triglochin palustris[3]			R	F
Rushes - Juncus sp.			F	F
Bogbean - Menyanthes sp.	F	F	F	F
Berries - Rubus sp.	F	R	R	
Cattails - Typha angustifolia			R	Ft
Water-lily - Nymphaea sp.			F	F

Systematic Grouping of plant species		Peat materials 1 Sphagnum peat	2 Forest peat	3 Sedge-fen peat	4 Reed marsh peat
	Woody plants				
Shrubs					
	Ledum groenlandicum	A	F	F	
	Andromeda glacophylla	F	R	F	R
	Kalmia angustifolia	F	R	F	
(Ericales)	" polifolia	F	R	R	
	Chamaedaphne calyculata	A		F	
	Vaccinium angustifolium	F	F	F	
	" oxycoccos	F		F	
	Myrica Galle			F	F
	Empetrum nigrum[3]	F	R	F	
Brushes					
Viburnum cassinoides			F	F	
Nemopanthus mucronatus			R		
Salix sp.			R	A	F
Alnus rugosa			Fc	R	R
Trees					
Larix laricina		R	A	R	
Picea mariana		F	A		
Pinus strobus			F		
Thuja occidentalis			R		
Betula sp.			F	R	
Acer rubrum			Rt		

1 A - abundant
F - frequent
R - rare

2 Common in blanket bogs (NFLD)

3 Common in Atlantic regions

Plate I

1. Macrofossil assemblage of sedge fen peat - fraction >2000 μm: roots, rhizomes of sedges; a few fragments of ericale stems.

2. Macrofossil assemblage of reed marsh peat - fraction >2000 μm: segments of stems and rhizomes of grassy plants; some sclerenchymateous tissues.

3. Macrofossils assemblage of woody fen peat - fraction >2000 μm: stems and roots of ericales; woody fragments.

4.5.and 6. - Macrofossil assemblage of forest peat- A series of fractions derived from woody parent materials.

4 >2000 μm

6. 1000 - 2000 μm

5. 500 - 1000 μm

Plate I

Plate II

1,2,3, and 4. Macrofossil assemblage of Sphagnum peat-
A series of particle-size fractions obtained from
Sphagnum (acutifolia) and a mixture of ericales and
sedges; the macrofossils are segragated according to
size.

1. >2000 μm - mainly stems of ericales
2. 1000-2000 μm- stems and bark of ericales; roots and sclerenchymateous tissues of sedges.
3. 500-1000 μm - mainly stems and branches of Sphagnum
4. 150-580 μm - mainly leaves and branches of Sphagnum.

5.& 6. Macrofossils of sedge fen peat.

5. >2000 μm - leaf of *Myrica*, stem or rhizome of *Carex*.
6. 1000-2000 μm - roots, rhizomes and sclerenchyma of *Carex*; some aggregates of fine materials and roots.

Plate II

Plate III

1 & 2. Macrofossil assemblage of ericales (woody) and Sphagnum peat.

1. Fraction 2000 μm - stems and bark of ericales; stems and leaves of Polytrichum.
2. 1000-2000 μm - mainly leaves of Sphagnum (cymbyfolia).
3. Macrofossil assemblage of Sphagnum peat. 1000-2000 μm fraction: stem, branches and leaves of Sphagnum magellanicum.
4. Macrofossil assemblage of brown mosses sedge fen peat - 500-1000 μm fraction: stems of brown mosses, coniferous needle, rhizome of sedge.
5. Macrofossils of forest peat - >2000 μm fraction: roots of ferns (Osmunda), leaf fragments (?).
6. Macrofossils of woody fen peat - 500-1000 μm fraction: seed of Menyanthes (bogbean); moss stem, fragments of coniferous needle.

Plate III

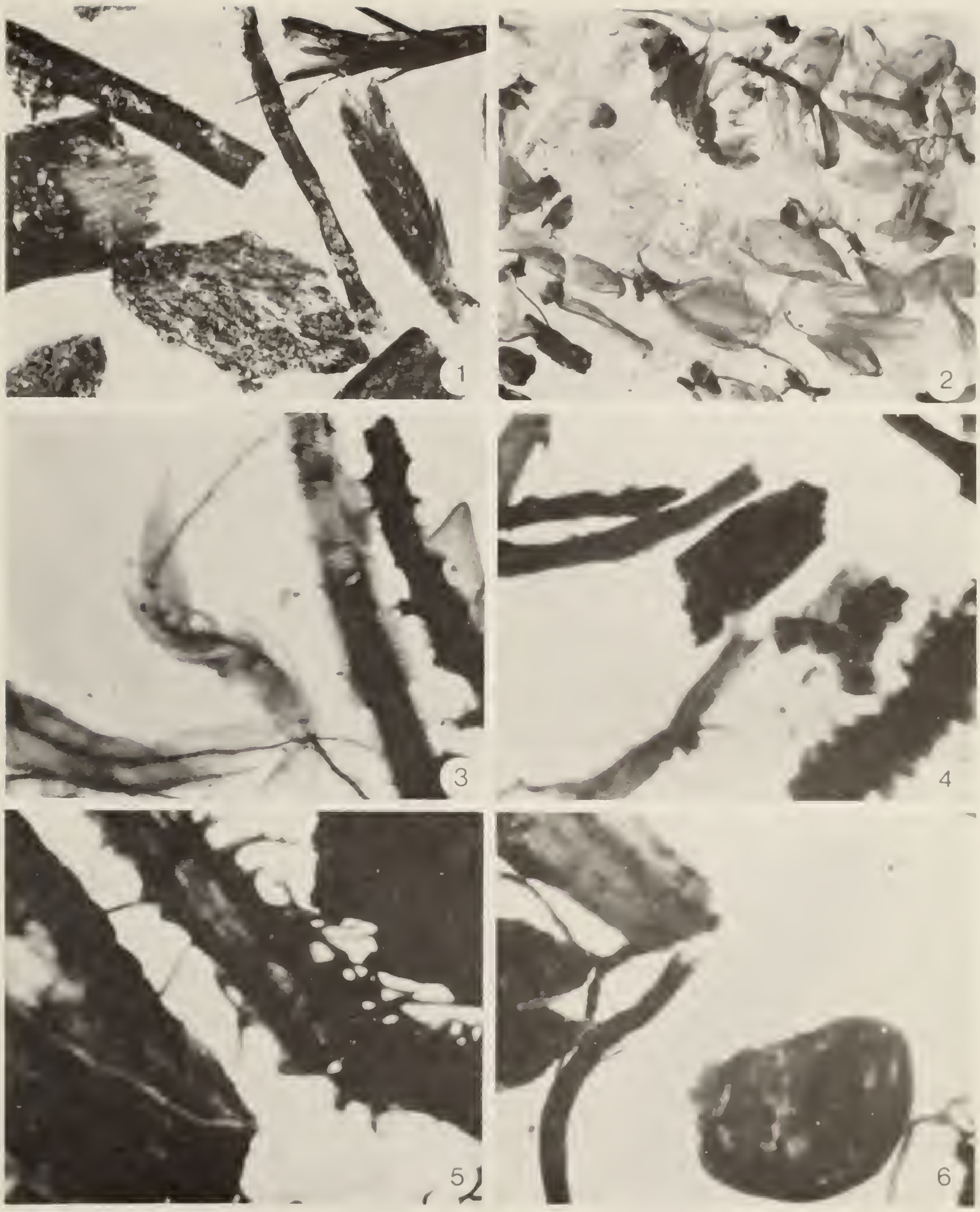

Plate IV

1. Macrofossils of woody fen peat - 1000-2000 μm fraction: ericale stem; fern roots; rhizome of sedge, and leaf fragments (?)
2. Macrofossils of sedge fen peat- 1000-2000 μm fraction: epidermis and selerenchyma of sedges.
3. Epidermis and sclerenchyma of Carex.
4. Sphagnum leaf primordium - X10
5. Sphagnum stem - X2.5
6. Sphagnum stem - X5.0

Plate IV

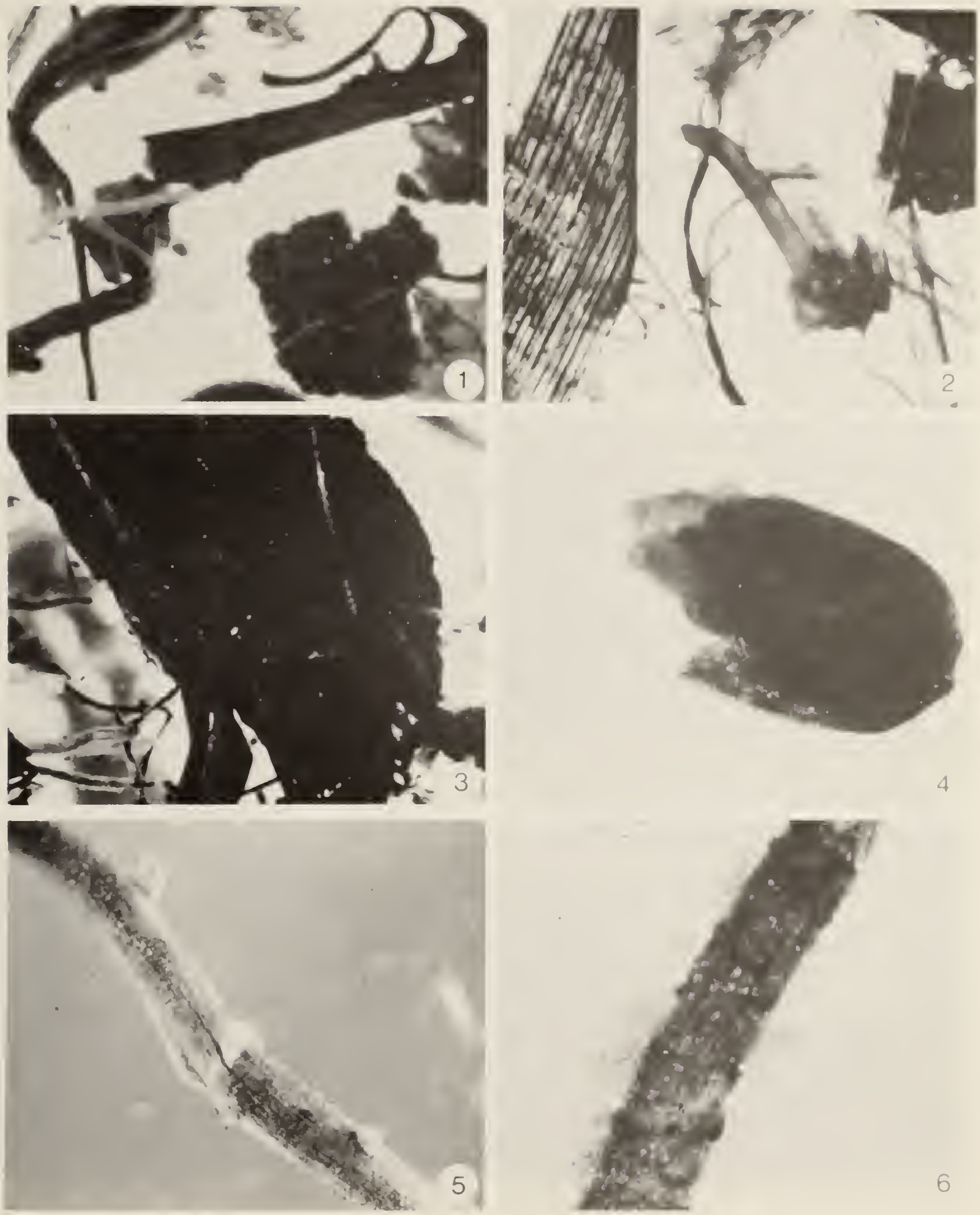

Plate V

1. Stem and leaves of Aulacomnium - X5.0
2. Leaf of Aulacomnium - X10
3. Stem and leaves of Polytrichum - X7.5
4. Stem and leaves of Polytrichum - X2.5
5. Leaves of Polytrichum - X5.0
6. Leaves of Myrica Gale - X2.5

Plate V

Plate VI

1. Leaf of <u>Ledum</u> - X2.5
2. Stem of ericale (<u>Ledum</u>?) X2.5
3. Rhizomes of Carex; vascular bundles -X2.5
4. Stem of grassy plant (node) -X5.0
5. Node of grassy plant -X2.5
6. Shells from sedimentary peat;
   Pulmonate Gastropods -X2.5

Plate VI

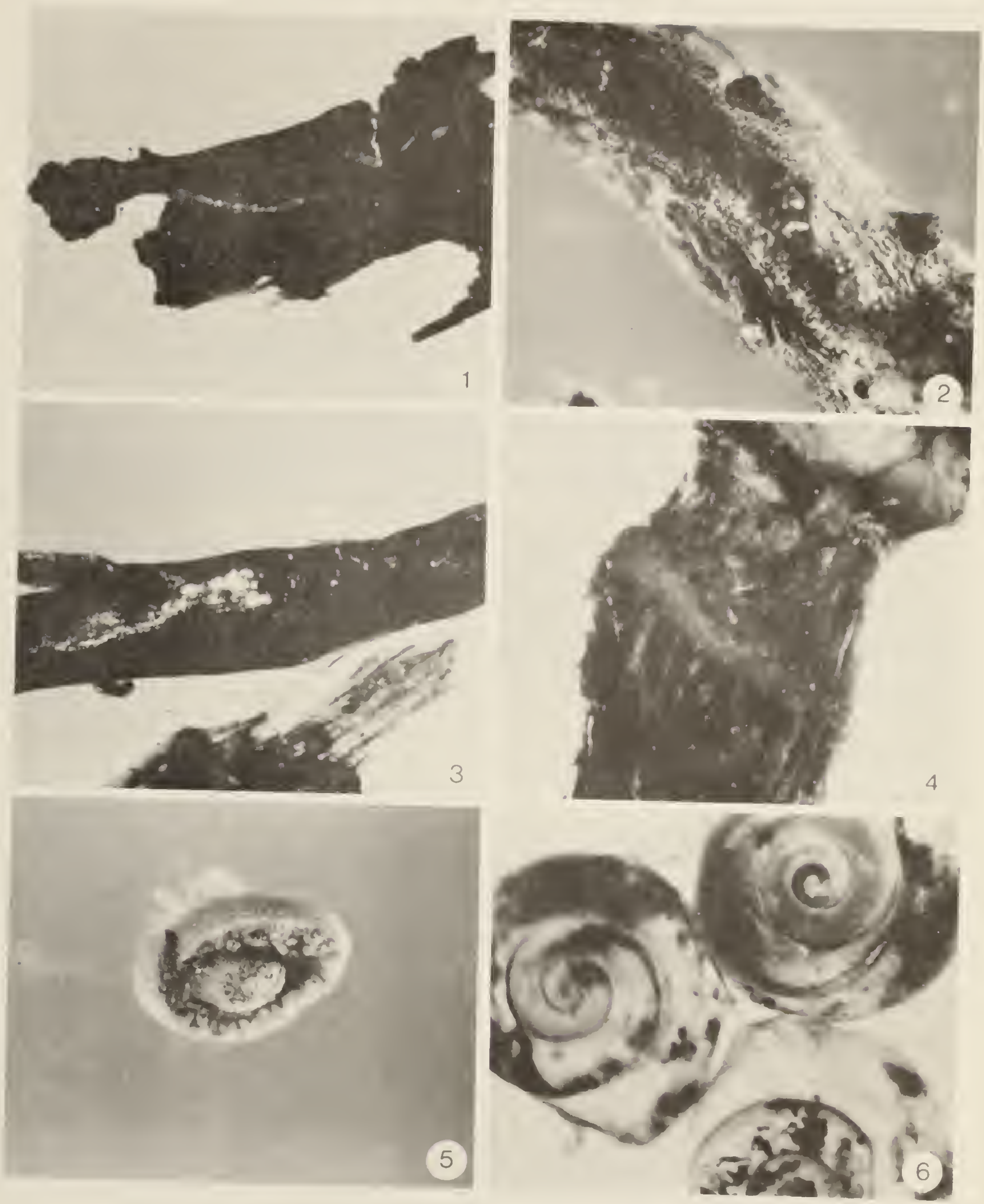

Table 2. Recommended proportions of peat-forming plant remains in the differentiation of eight peat groups (IPS-Largin, 1979)

Peat group	Limits of wood content %	Maximum (minimum) content of plant remains at limiting wood contents	
		mosses, %	herbs, %
1. Wood	> 40	60(0)+0	60(0)+0
2. Wood-herb	15+35	35(0)+15(0)	85(50)+65(50)
3. Wood-moss-herb	15+35	45(40)+45(20)	45(40)+45(20)
4. Wood-moss	15+35	85(50)+65(50)	35(0)+15(0)
5. Herb	0+10	25(0)+15(0)	100(75)+90(75)
6. Moss-herb	0+10	50(30)+45(20)	70(50)+70(45)
7. Herb-moss	0+10	70(50)+70(45)	50(30)+45(20)
8. Moss	0+10	100(75)+90(75)	25(0)+15(0)

The morphological features such as general appearance, size, shape, contour, color, structure, density, capacity, humicity, etc., would help in the identification. In general, it is difficult to make good observation from a mass of heterogeneous peat material. Fractionation according to particle-size is recommended. Of course, fractionation and binocular examinations are done best in the laboratory. However, a certain sorting out of the material can still be achieved in the field, which would make hand-lens examinations more revealing.

It is realized that the series of macrofossils shown above (Plates 1 to 6) is far from being complete, but this knowledge is expanding as more and more sites and different peat materials are being studied. Of course, this will not happen without the need for developing new tools and means for the qualitative and quantitative determinations of indicator macrofossils (Larouche, 1981).

The information pertaining to the botanical characterization of peat materials is obviously needed to set up a base for a classification system applicable to types, groups and kind of peat materials. Such a system based on the proportions of the peat-forming plants in USSR has been proposed by Largin (1979) and is given in Table 2.

3. Chemical and physical properties

The botanical make-up of peat materials is reflected in their chemical and physical properties. The properties of 5 selected and typical peat materials are listed in Table 3. The values are reported according to the kind of peat, and could be characterized by the following:

Peat A - woody fen peat - advanced degree of decomposition, a relatively high calorific value, a high Ca: Mg ratio and a prominent proportion of wood.

Peat B - Sedge fen peat - a high proportion of sedge, a relatively low C:N ratio, and a rather high Ca:Mg ratio.

Peat C - Reed and sedge marsh peat - predominantly of sedge and brown mosses; among the 5 peats, the highest value for pH and ash content and the lowest for C:N ratio.

Peat D - woody forest peat - predominantly made of wood with intermediate values for several properties.

Peat E - Sphagnum peat - predominantly Sphagnum mosses; among the 5 peats, the highest fiber content and the lowest ash content and calorific values.

In a previous study (Lévesque et al.1980) (Table 4), 26 different peat materials were used to asses the most meaningful peat properties. It was concluded that measurements involving rubbed fiber, botanical composition, carbohydrate analysis, bulk

Table 3 Various properties and botanical components of five selected peat materials.[1]

	Peat A (Farnham) Woody fen peat	Peat B (Ormstown) Sedge fen peat	Peat C (Keswick) Reed sedge marsh peat	Peat D (St. Chrys.) Woody forest peat	Peat E (Clair) Sphagnum peat
pH	3.30	3.66	5.09	4.38	3.01
Rubbed Fiber %	8.6	23.3	28.0	34.0	59.3
Ash %	1.9	2.1	7.8	5.4	0.5
Bulk density	.115	.114	.145	.131	0.68
Calorific Value Kcal/Kg	5891	5745	5030	5101	4890
Cation exch. Capacity me/100g	131	122	154	171	144
P_2O_7 Index	35.4	16.7	11.0	10.6	8.0
Carbon %	54.9	53.9	47.2	51.5	50.3
Carbon:Nitrogen	40.7	33.1	16.9	42.9	99.2
Ca: Mg	29.1	10.3	20.3	5.7	2.7
Glucose - % of total sugars	83.3	77.2	39.6	66.1	82.4
Botanical components:					
Wood %	50	15	12	83	15
Sedge %	40	77	62	8	8
Mosses %	10	8	26	9	77

1 Levesque & Dinel, 1982

Table 4. Some peat properties that showed statistically significant correlations. [1]

Peat properties	Rubbed fiber content	Moss content	Total sugars	C:N	Ash content	Bulk density	<75 µm particles	No. of significant correlations
Rubbed fiber content		+	+	+			−	4
Moss content	+		+	+	−	−	−	6
Total sugars	+	+		+	−	−		5
C:N	+	+	+		−	−		5
Ash content		−	−	−		+		4
Bulk density		−	−	+	+			4
<75 µm particles	−	−						2
150 µm particles	+	+		+		−	−	5
Sedge content	−	−	−	−				4
Wood content					+	+		2
P_2O_7	+	+					+	3
Phosphatase activity	+	+						2
No. of significant correlations	8	10	6	7	5	6	4	

+: positive significant (5% level) correlations
−: negative significant (5% level) correlations
[1] Lévesque et al., 1980b.

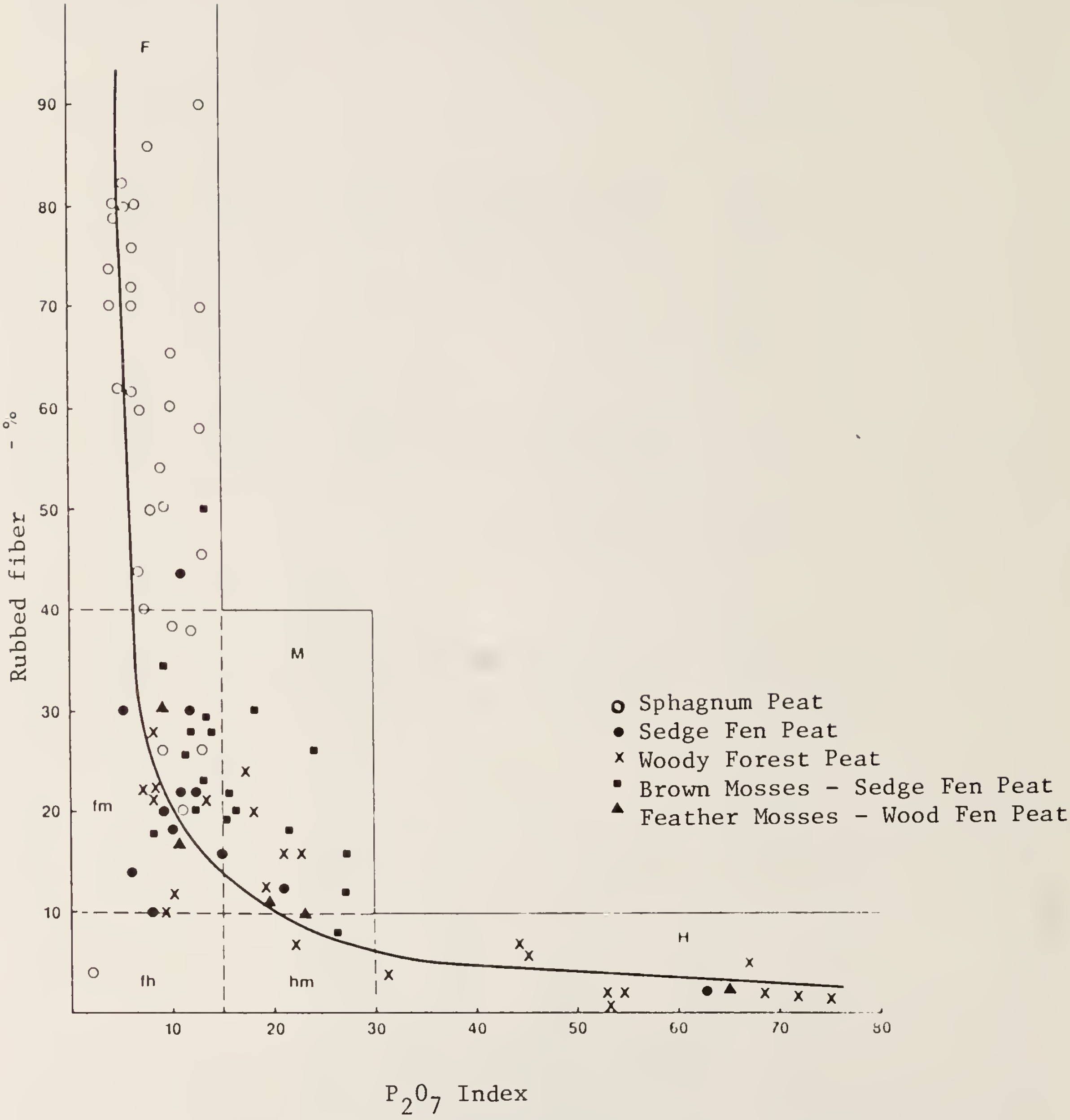

Figure 1. Distribution of 92 peat materials according to rubbed fiber and P_2O_7 index. (Lévesque et al. 1980a)

Table 5. Means of the various properties of 92 peat materials differentiated on the basis of rubbed fiber content.[1]

		Fibrisols	Mesisols	Humisols
Rubbed fiber - %		66.0	22.6	4.8
	cv	21	32	68
P_2O_7 Index		7.9	13.4	44.6
	cv	40	41	46
Bulk density		.065	.121	.151
	cv	8	22	9
Ash - %		2.3	4.9	10.0
	cv	63	7o	71
C.E.C. - me/100g		136	166	181
	cv	14	27	45
Ca/Mg		3.9	9.1	12.3
	cv	105	68	51
Population		26	48	18

cv = coefficient of variation (%)
[1] Lêvesque et al, 1980a

Table 6: Means of the various properties of 92 peat materials differentiated on the basis of botanical composition.[1].

		Peat Materials			
		Sphagnum	Sedge fen	Woody fen	Woody forest
Rubbed fiber - %		58.4	20.0	11.9	23.0
	cv	37	55	73	31
P_2O_7 Index		8.0	15.2	29.0	9.9
	cv	38	102	72	22
Bulk density		.065	.107	.168	.121
	cv	8	7	4	22
Ash - %		3.7	5.0	9.5	6.1
	CV	169	53	68	58
C.E.C. me/100mg		132	153	204	177
	cv	15	31	24	25
Ca/Mg		3.6	10.5	12.0	9.1
	cv	115	66	54	51
Population		31	12	22	37

cv = coefficient of variation (%)
[1] Lêvesque et al, 1980a

density, C:N ratio, ash content, particle-size distribution and pyrophosphate index would be the most useful ones for the differentiation of peats.

It appears, however, that pyrophosphate index, and, to a certain extent, rubbed fiber are of lesser value for mixed peats if no consideration is given to the botanical composition, as this could be seen from Figure 1. A hyperbolic relation was found between rubbed fiber and pyrophosphate index. Thus, for content of 40% and above, rubbed fiber does not reflect the concentration of the decomposition products in peats. Similarly, for values of 30 and above, P_2O_7 index does not reflect the fibrous nature of peats. It so happens that the more fibric peats coincide with sphagnum peats and the more humified ones with the woody forest peats; the intermediate population was made of peats having various proportions of Sphagnum, sedges and wood. Therefore, to be really operative, any peat differentiating system based on chemical and physical criteria should assess the botanical composition in a preliminary step.

The 92 peat materials shown in Figure 1 were differentiated on the basis of rubbed fibre content, and the properties are given in Table 5. The grouping into fibrisols, mesisols and humisols may illustrate the kind of distribution (peat properties) one may expect as the decomposition of the peat materials changes. When these peat materials are grouped according to botanical composition (Table 6) the picture is quite different. Here, all the six properties measured may be used to asses the degree of decomposition. Accordingly, the peat materials could be placed in the following order:

Sphagnum peats $<$ w. forest peats $\leq$ s.fen peats $<$ w.fen peats

increase in decomposition ⟶

The respective position of the extreme groups, that is, woody fen peats and Sphagnum peats is very clear. The indications obtained for the other groups are not so consistent. No doubt, this inconsistency is a reflection of the nature of the materials. However, this may also be related to the difficulties encountered in peat differentiation and identification.

These difficulties could be illustrated through an examination of the data presented in Table 7. These are some of the properties of peat materials obtained from different regions and by different workers. The Sphagnum peats, the peat materials generally identified with the least difficulty, are showing consistent data, when comparing both the various peat properties and the various sources of data. This consistency is

Table 7: Selected chemical and physical characteristics of peat materials from various regions.

	Pop.	Rubbed fiber	C/N	C.E.C.	P_2O_7 Index	Ash	Bulk Density
1. Manitoba (Mills, 1974)							
Sphagnum peat	15	51.3	68	119	7.2	7.3	.07
Sedge fen peat	36	8.0	26	151	22.7	14.5	.13
Woody fen peat	10	8.4	30	155	11.9	15.1	.12
Woody forest peat	22	12.6	35	186	39.5	18.3	.17
2. Que. & Ont. (Tarnocai, 1980)							
Sphagnum peat	9	59				4.0	.09
Sedge fen peat	29	14				8.0	.11
Woody fen peat	10	17				19.0	.11
Woody forest peat	32	13				16.0	.15
Sedimentary peat	9	12				39.0	.13
3. Que. & Ont. (Lévesque, 1980							
Sphagnum peat	31	58	76	132	8.0	3.7	.07
Sedge fen peat	12	20	20	153	15.2	5.0	.11
Woody fen peat	22	12	43	104	29.9	9.5	.17
Woody forest peat	37	23	26	177	9.9	6.1	.12
Sedimentary peat [1]	16	6	16		5.0	66.0	
4. P.E.I. (Lévesque' 81)							
Sphagnum peat	7	63	63	121	9.0	5.0	.10
Sedge peat	3	41	15	98	21.0	14.0	.15
Woody fen peat	3	27	42	128	48.0	3.8	.11
Woody forest peat	3	12	39	131	53.0	2.1	.12

1 British Columbia

particularly apparent if one considers rubber fiber, C:N ratio, P_2O_7 index, ash content and bulk density. However, it is quite obvious that no clear conclusion can be drawn from the other peat materials, except that they were different from Sphagnum peats.

4. Conclusion

In concluding, one can say that a need for a better characterization of peat materials is recognized. An improved characterization, however, can be achieved only through better identification, differentiation and evaluation of peat materials.

Some of the necessary techniques are being worked out, and include the following: means of separation and evaluation of macrofossils in the field; identification keys and macro-photographs of plant macrofossil indicators; repertoire of distinctive morphological elements observable in the field, etc. It is believed that improved techniques for differentiating peat materials coupled with a sound and consistent means of assessing the degree of decomposition (the Van Post test is aceptable) would be the basis for a sound peat classification system.

Acknowledgements

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SOME IDENTIFICATION HINTS FOR THE FIELD CLASSIFICATION OF PEAT

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INTRODUCTION

The lab demonstration and field trips associated with this workshop led to numerous requests for compilation of various identification criteria used by the field crews of the peatland inventory. Many of these differentation criteria are difficult to describe in writing. However, it is hoped that the descriptions which follow, combined with ideas exchanged during the field trips, will be of assistance.

CLASSIFICATION PROCEDURE

The field methods used by the N.B. Peatland Inventory are described in the paper by Keys and Ferguson in this Proceedings. The following is an amplification of the sample recovery and classification procedure:

1) Sample recovered from required depth using Hiller auger, mini-Macauley sampler, or similar equipment. The sampler should be completely emptied to avoid contamination of the next sample;

2) Sample divided (normally to the nearest 10 cm) on the basis of changes in colour, texture (visual and tactile), and botanical composition so that each sample has only one peat type and humification degree. Boundaries are normally fairly distinct. If the boundary is questionable, make the division and complete the rest of the procedure. Should the two samples prove to be the same, they can then be grouped;

3) Place the sample (or a portion of it) in the palm of the hand and compress the sample in such a way as to release water (if present), while leaving the plant structure relatively undisturbed. (This procedure is somewhat similar to squeezing a small egg without breaking the shell.). Note the turbidity and colour of water released;

4) Examine the sample for recognizable plant remains. This is an important aid in the determination of decomposition (see column 3 of Table 1);

5) Determine botanical composition (see Table 2). Steps 4 and 5 are

performed before the final squeezing for von Post determination so that fragile plant structures are not destroyed;

6) Compress out remaining water;

7) Perform the final squeeze for determination of von Post degree (break the egg shell from Step 3), (see Table 1);

8) The peat remaining can be further examined to aid in determination of botanical composition. The "ball" of peat can often be broken to look for the presence of *Carex* rootlets, etc.

DETERMINATION OF DECOMPOSITION

The decomposition of peat can be determined by numerous field and laboratory methods (I.P.S. 1976). The von Post scale of humification (H) has wide international acceptance as a field method and is recommended over other systems used in Canada (Stanek and Silc 1977). The method is designed for field use in undrained peatlands. The determination of the degree of humification is more meaningful if done in conjunction with the identification of the botanical constituents.

The von Post scale has been described in numerous publications (Korpijaakko and Pheeney 1977, Korpijaakko and Woolnough 1977). The scale divides the peat into 10 classes or degrees and can be carried out rapidly in the field. As with most field classifications, there is a certain degree of individual subjectivity, but careful adherence to guidelines presented in Table 1 can enable consistant results between individuals. An investigator with a basic understanding of the system can use the table as a field reference. Experience will allow the determinations to be made at a greater rate. It should be emphasized that the "squeeze test" alone has limitations. Results of the squeeze between individuals will vary according to the number and size of gaps in one's fist as well as the amount of pressure being applied on the sample. Familiarity with one's own results, and consistency during repeated applications allows an individual to standardize himself against any other one or group of investigators. Examination of all factors shown in the table results in more reliable determinations.

Certain materials, such as wood or *Eriophorum* fibres, are resistant to decomposition and are often minor constituents in highly humified peats. In these special cases the amount of material remaining in the hand after squeezing (see column headed "Squeeze test" in Table 1) overrules the indications of the other columns.

DETERMINATION OF BOTANICAL COMPOSITION

In poorly decomposed peats, plant remains can be identified with relative ease with a basic knowledge of the species involved. As decomposition increases, individual structures are less recognizable. Identification must

Degree of Humification	Initial Water	Texture	Plant Remains	Squeeze Test	Remarks
H1	clear	rough	living plants	very spongy	living layer
H2	clear to slightly yellow	rough	entire structure	spongy - will spring back after pressure. Holds no shape	
H3	yellow, slightly turbid	rough	breaking into pieces, but pieces are intact	slightly spongy holds a fairly definite form of handprint	
H4	light brown, turbid	very slightly soapy	pieces breaking up into individual components, *e.g.* leaves, stems, etc.	not spongy - forms a distinct replica of handprint - no peat escapes fingers	"brass knuckles" (H3 is rounded, whereas H4 is sharp)
H5	brown - mixture of plant debris, amorphous material and water	slightly soapy	individual components disintegrating such that some amorphous material is present	a very small amount of peat escapes the fingers	
H6	dark brown solution	soapy	plant structures evident on close examination - nearly half of sample in an amorphous state	one third of sample escapes fingers	
H7	very small amount - very dark brown	somewhat pasty	vague structures	over half of material escapes the hand as a paste	
H8	little or none	pasty	only roots or fibres are distinguishable - homogeneous	over two-thirds escapes the hand	
H9	none	pudding-like	extremely few remains	almost all escapes the hand	
H10	none		no distinguishable remains	all escapes the hand	rare

Initial water - Performed by gently squeezing the sample and catching the water in a cupped hand (step 3 in procedure). This test is limited, in that botanical composition can strongly affect water colour, *e.g.* a small amount of charcoal can turn the water dark. H9 and H10 peats have no free water, not even a glistening between the fingers.
Texture - Performed by visual and tactile (running fingers along core) examination. This test is used primarily as an indicator of where a core sample should be divided.
Plant remains - Performed by visual examination of the sample (step 4 in procedure). The amount of distinguishable plant structure is used in conjunction with the squeeze test for the final determination of degree of decomposition.
Squeeze test - This is the most subjective test of the von Post method, and strict adherence to the following guidelines is required for consistent results:
- Before performing the final squeeze, all the water must be released, otherwise a higher humification value will result. This is done by gently squeezing and turning the sample in the hand until water stops dripping. The final squeeze is performed by taking the sample in one hand, curling the fingers around the sample (such that as few openings as possible are created) and applying firm, even pressure. The squeeze should be performed "soon" after the peat is sampled, because drying can result in a low humification value, whereas too much "kneading" of the sample will give a high humification value.

TABLE 1. Some characteristics of the 10 degrees of humification (decomposition) in the von Post scale.

CONSTITUENT	CHARACTERISTICS	
	H1-H3	H7-H10 (mostly amorphous)
Sphagnum (S)	Entire stems, branches and leaves	Dark to very dark brown, soapy, sticky, leaves hands "dirty"
Brown mosses e.g. *Bryales* (B)	Entire stems, with leaves 2-3 mm long - bright gold (*Bryales*)	Are often resistant to decomposition and are commonly found as unhumified lenses in basal humified layers
Lichen	Entire, broken pieces, or grey-black slime. Rarely identifiable at depths over 10 cm	Rarely, if ever identified
Sedges		
- *Carex* spp. (C)	Entire or broken leaf blades - thin, yellow/bronze with midrib. Roots - very thin (0.2-0.5 mm diameter), white to light yellow, wavy or kinky	Tan to light brown, not soapy, will break up into "chunks" - not sticky, leaves hands "clean". Common to find roots
- *Eriophorum* spp. (Er)	Strands of very fine (0.1 mm) straight fibres, often clotted together like locks of hair	Individual or clotted fibres. Not frequent.
- *Trichophorum caespitosus* (Tr) (*Scirpus*)	White roots, 5-30 cm long, 1-2 mm wide, flattened, with alternate rootlets spaced 1-5 cm along root	Rare
Grasses	Entire or broken leaves	Difficult to distinguish from *Carex* spp.
Scheuchzeria (Sh)	Leaf blades bronze, shiny, hollow (often flattened), 4-8 mm wide, broken at a circumferential ridge. Occasionally coarse straight roots.	Difficult to distinguish from *Carex* spp.
Equisetum (Eq)	Black pieces of stem 0.5-1 cm wide with slight to definite longitudinal ridges, often broken at the node with the typical notched leaf sheath	Same as in less humified peats
Fern	Black pieces of root, 1-2 mm wide, 2-4 cm long, wavy, often bunched	Same as in less humified peats
Shrubs (N)	Pieces of stems or branches, 0.5-5 cm long, 0.2-0.5 cm wide. Leaves (often of *Chamaedaphne calyculata*).	Soft pieces of stems or branches
Shrub roots (N)	Red to yellow red, very fine to coarse, wavy, sometimes matted. The colour is often the only difference between shrub and sedge roots.	Rare
Wood (L)	Irregular pieces or chips	Pieces or chips up to H7. A pronounced soapy or slimy texture indicates presence of completely decomposed wood.
Seeds	Most common - *Carex*, *Menyanthes*, *Nuphar*, *Potamogeton*	Same
Other minor constituents	Spruce or pine needles or cones, charcoal pieces, insect parts, etc.	Same

TABLE 2. Characteristics of some common botanical constituents of peat.

often be made on the basis of characteristics such as texture, colour, small plant fragments or rootlets, and general stratigraphy. Comparison of plant fragments to living plants on the peatland surface can be useful.

Table 2 lists some typical botanical constituents. The characteristics of each constituent are described for poorly humified (H1-H3) and well humified (H7-H10) peats. Peats of medium decomposition (H4-H6) will have characteristics common to both. A sample composed of more than one species will include characteristics of the various constituents.

The basic characteristics of the various species in a living state are described in several publications (see bibliography). The intent of the table is not to reproduce such information but rather to concentrate on techniques of differentation between similar species.

An ability to recognize the various constituents is a prerequisite for estimation of percentage. In the New Brunswick inventory estimation was made to the nearest 10%. Species present in minor amounts were noted in the remarks. Some individuals find estimation of amounts easiest if the amount of minor peat types, such as shrubs, is determined before assigning a value to the dominant species.

In generalized descriptions the various peat types can be combined into 3 main groups based on the dominance of *Sphagnum* (S), sedge (C), or *Bryales* (B). The dominant peat types are given last when identifying a peat sample, with minor constituents treated as a prefix. Thus, a shrubby sedge-sphagnum (NCS) is predominantly composed of *Sphagnum* with lesser amounts of shrubs and *Carex*. A woody sedge peat (LC) is predominantly *Carex* with wood.

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Interpretation of Organic Soil Properties for Agriculture

John L. Nowland

A. Preamble

B. Factors used in evaluating organic soils for agriculture
   1. Climate
   2. Landforms
   3. Hydrology
   4. Soil physical attributes

      (i) Degree of decomposition
      (ii) Presence of woody layers
      (iii) Depth and kind of mineral substratum
      (iv) Density and compaction
      (v) Mineral content
      (vi) Hydraulic conductivity

   5. Soil fertility

      (i) Inherent fertility
      (ii) Soil reaction
      (iii) Toxicity levels

   6. Botanical composition
   7. Surface vegetation
   8. Economic and social factors

C. Incorporating evaluation factors in an interpretation framework
   1. The C.L.I. approach
   2. The Ontario penalty point approach
   3. Soil potenial ratings

References

Appendix 1 The C.L.I. approach

Appendix 2 The Ontario penalty point approach

Editor's Note:
Only an outline of Mr. Nowland's paper has been included. For the complete text, the reader is referred to:
Nowland, J.L. (1981). Interpretation of organic soil properties for agriculture. - p.69-98 in: Tarnocai, C. (ed.). Proceedings of a Workshop on Orgainc Soil Mapping and Interpretation, May 26-29, 1980, St. John's Newfoundland. Land Resource Research Institute, Research Branch, Agriculture Canada, Ottawa, Ontario. K1A 0C6

HYDROLOGIC CHARACTERISTICS OF PEAT MATERIALS OF NEW BRUNSWICK

by

Chow, T.L., H.W. Rees, and R.E. Wells

In general, organic soils develop under conditions of excessive wetness which are unfavourable for the decomposition of plant remains. Unless artifically drained, they are saturated or nearly saturated with water at all times of the year and therefore, removal of excess water is mandatory prior to agricultural, forestry and industrial utilization. Knowledge on the hydrologic characteristics of the individual peat materials that make up the resource is essential for proper management.

Hydrologic characteristics of a peat material are largely governed by its structure and its degree of decomposition. Structure normally refers to the form and natural arrangement of constituent particles. Peat structure, in general, ranges from an open network of living material or well-preserved plant elements to an amorphous mass of highly decomposed organic residues and decomposition products. The quantitative characterization of peat structure requires consideration of the size, shape, and relative proportion of primary and secondary particles, and the distribution and continuity of pore spaces within and between structure units. Peat structure is therefore a complex phenomenon that cannot be determined precisely by any single physical measurement (Puustharvi and Robertson 1975). However, many of the structure related properties, such as the ability to retain and transmit water, are largely determined by the degree of decomposition of the organic material. As decomposition proceeds, large particles gradually break down into smaller particles, resulting in smaller pores and larger mass per unit volume.

Although the degree of decomposition appears to be a key property, it is not clearly defined and is difficult to quantify. A variety of methods have been developed to characterize degree of decomposition.

The von Post scale of decomposition seems to be the best known and most widely used technique universally. In this method, the degree of decomposition is evaluated on a 10-point scale by visual examination of colour, consistency and proportion of expressed water and peat when squeezing a small quantity of fresh peat in the palm of the hand (Scottish Peat Survey, 1968). Other methods for measuring degree of decomposition include: bulk density; rubbed fiber content; and pyrophosphate index. Bulk density refers to the ratio of mass of oven-dry peat per unit wet bulk volume. Fiber content is the amount of fiber greater than a designated size. The pyrophosphate index is based on the color intensity of the extract following suspension of the material in sodium pyrophosphate solution as related to solubility.

The objectives of this study are to determine the hydrologic characteristics and other related physical properties of selected peat soils in New Brunswick and to test the applicability of some easily measurable physical properties for predicting hydrologic characteristics of peat materials.

HYDROLOGICAL TERMINOLOGY

Presented below is a brief description of general terminologies which will be used throughout this report.

1. Field soil moisture regimes

   Field soil moisture regime refers to the temporal and spatial distribution of soil water under natural field conditions. This information is not only essential to the agriculturist for crop production, but is also required for most other utilizations - fuel peat harvesting, horticultural peat harvesting, road construction, etc. The field soil moisture regime of a given area is generally governed by: (1) climatic factors such as precipitation and energy influx; (2) internal soil factors such as pore size distribution, hydrologic characteristics and degree of humification; and (3) external soil factors, namely, the relief and microrelief of the soil surface and existing artifical drainage conditions. While climatic factors are equally important in determining a soil's field moisture condition, this study will only deal with the internal soil factors that are involved.

2. Water retention characteristic

The water retention characteristic of a peat material is a measure of its ability to retain water. It is generally presented as a plot of moisture content vs matric potential. This parameter is important for determining the depth of drains and availability of soil moisture for plant growth.

3. Water content

Water content of a peat material refers to the volume of water per unit wet, bulk volume of peat (volume basis) or the mass of water per unit oven-dry mass of peat (weight basis). To be useful to hydrologists, the soil water content should be expressed on a volumetric basis (Boelter and Blake, 1964). This is especially true for organic soils because they have a wide range of bulk density and there is no basis for comparing water contents on a per unit weight basis.

4. Energy status of soil water

Energy status of soil water refers to the force fields to which the soil water is subjected and is a measure of the availability of that water. Spatial changes in energy per unit quantity of soil water are the driving forces responsible for water movement. Water tends to move from regions of higher specific energy to regions where it is lower.

5. Water yield

Water yield is generally considered to be the difference in water content between saturation and -0.1 bar metric potential (Boelter, 1972). One-tenth bar is chosen as the lower limit because studies indicate that all the gravitation water is removed at this potential. These coefficients represent the maximum water that can be removed from a specific peat material by simply lowering the water table and are values for evaluating the water resources of the peatlands.

6. Water flow characteristic

The water flow characteristic, frequently referred to as hydraulic conductivity, is a measure of the ability of peat materials to transmit water. It is the volume flux of water per unit area resulting from unit gradient. Saturated hydraulic conductivity is strongly dependent on the pore geometry of the peat material as related to porosity, pore size distribution and continuity between pore spaces. In addition to the pore geometry, unsaturated hydraulic conductivity is also dependent upon water content. Water content determines not only the amount of pores available for water movement but also the length of the pathway that the water has to follow. In drainage engineering, both the saturated and unsaturated hydraulic conductivities are key factors for determining the intensity of drainage ditches and therefore, have important hydrological implications in water resource management.

MATERIALS AND METHODS

Site Description

The samples analyzed in this study were collected from seven sites on three peatland deposits - St. Charles, Bull Pasture, and Benton.

The St. Charles deposit, located in the coastal peatland zone of New Brunswick, is a well developed raised or domed bog. Peat stratigraphy consists of layers of dominantly fibric sphagnum peats varying in thickness from 1 to 10 meters, underlain by a thin (usually less than 0.5 meters) to absent layer of mesic and/or humic sedge peat. Surface vegetation is Sphagnum mosses and low Ericaceous shrubs with little or no tree cover except for bog peripheries where dense stands of stunted black spruce and larch are common.

The Bull Pasture deposit, like the St. Charles', is a domed bog, however, it is of reduced aerial extent and total thickness, and is [illegible] central peatland zone. The surface layer of sphagnum [illegible]bric with some mesic, range in thickness from 0.5 to

4.5 meters and is underlain by a thin layer of approximately 0.5 meters of mesic and/or humic sedge peat which is in turn underlain by a thin (less than 0.3 meters) to absent basal layer of sedimentary peat. Tree cover of black spruce and larch, while dense on the margins, is sparse on the dome centre and slopes which are dominated by Sphagnum mosses and low Ericaceous shrubs. A wide lagg area surrounding the dome is without tree cover and sedges are intermixed with the mosses and shrubs.

The Benton deposit, located in the western peatland zone, is a stream fen transitional to Atlantic plateau bog. The fen portion consists of 1 to 2 meters of mesic and humic sedge peats over a relatively thick, 0.5 to 1 meter, sedimentary peat. The bog portion consists of a thin layer approximately 1 meter thick of fibric to humic sphagnum peats over the fen deposits. Surface vegetation reflects the transition in conditions encountered in going from a fen to bog environment. The cover changes from sedges and willows on the fen portion to alders, then to wire birch and larch and finally into the treeless, Sphagnum moss-low Ericaceous shrub complex of the bog portion.

For more detailed peatland and site information the reader is referred to Table 1.

Sample collection

Relatively undisturbed peat profile samples were obtained using columns 15 cm in diameter and 2 m long of plastic PVC pipe. Even though these columns were sharpened around the circumference to provide a cutting edge, it was necessary to remove surface living vegetation and other relatively undecomposed peat materials (von Post class 1) which proved difficult to cut through. After carefully forcing the column into the peat profile to the desired depth, the surrounding peat material was excavated to facilitate in sample retrieval. The columns were then labelled and packaged for shipment back to the laboratory. A total of 9 columns were collected from St. Charle's, Bull Pasture Bog and Benton Fen. In addition to the undisturbed columns, samples were also collected with the Macaulay sampler (9 cm dia. head) for bulk densities and on-site determinations of the von Post Scale of

Table 1. Description of sample sites and peatlands.

Peatland Deposit					Site					
Name	Classification	Location Lat.	Location Long.	Elev. m AMSL	I.D. No.	Position	Micro Topography	Drainage	Classification	Dominant Vegetation
St. Charles	Domed Bog	46°39'	64°56'	17	1	Side of dome	Strongly Mounded	Poor	Typic Fibrisol	Sphagnum mosses, Ericaceous shrubs
Bull Pasture	Domed Bog	46°02'	66°20'	108	2	Lagg	Slightly Mounded	Very Poor	Mesic Fibrisol	Sphagnum mosses, Ericaceous shrubs, sedges
					3	Edge of dome	Strongly Mounded	Poor	Typic Fibrisol	Sphagnum mosses, Ericaceous shrubs
					4	Crest of dome	Strongly Mounded	Poor	Typic Fibrisol	Sphagnum mosses, Ericaceous shrubs
Benton	Stream Fen transitional to Atlantic Plateau bog	46°59'	67°37'	120	500	Fen near stream	Level	Very Poor	Limno Humisol	Sedges, willows
					700	Edge of plateau	Level	Very Poor	Mesic Humisol	Sphagnum mosses, scattered wire birch and larch.
					800	Plateau Center	Strongly Mounded	Poor	Humic Mesisol	Sphagnum mosses, Ericaceous shrubs

decomposition were made. Experience is required for consistently determining von Post classes and so, these parameters were done by the Peat Land Inventory Group of New Brunswick Department of Natural Resoures.

Laboratory determinations

In the laboratory the columns were subsampled. Depending upon the sample profile, four to six 10 cm long sections were removed (the pipe itself was cut) for analyses: saturated hydraulic conductivity, water retention characteristics and bulk density determinations. The remaining portions of the column were cut into 5 or 10 cm sections for bulk density determinations. Saturated hydraulic conductivity was determined by the constant head, steady state method and calculated according to Darcy's equation. Retention characteristics were measured with individual tension plates by means of a hanging water column. Due to the difficulty of achieving complete saturation, saturated moisture content of the peat was taken as its total porosity which was calculated from bulk and particle densities. An average value of 1.5 gm/cm^3 was used for particle density in the calculation. Moisture contents at the various matric potentials were computed from the accumulated outflows collected at that potential. Pore size distributions were calculated from the moisture retention data according to the capillary rise equation and by assuming the pores are cylindrical. Water yield was taken as the difference in moisture content between saturation and -0.1 bar matric potential.

RESULTS AND DISCUSSIONS

Bulk Density: 15 cm PVC cores vs Macaulay sampler

Results of bulk density values determined by the 15 cm PVC column method as compared with bulk density values determined by the Macaulay sampler are shown together with a 1:1 line in Figure 1. In general, very good correlation in bulk density was obtained between the two independent methods of sampling ($R^2 = 0.81$). It is important to note

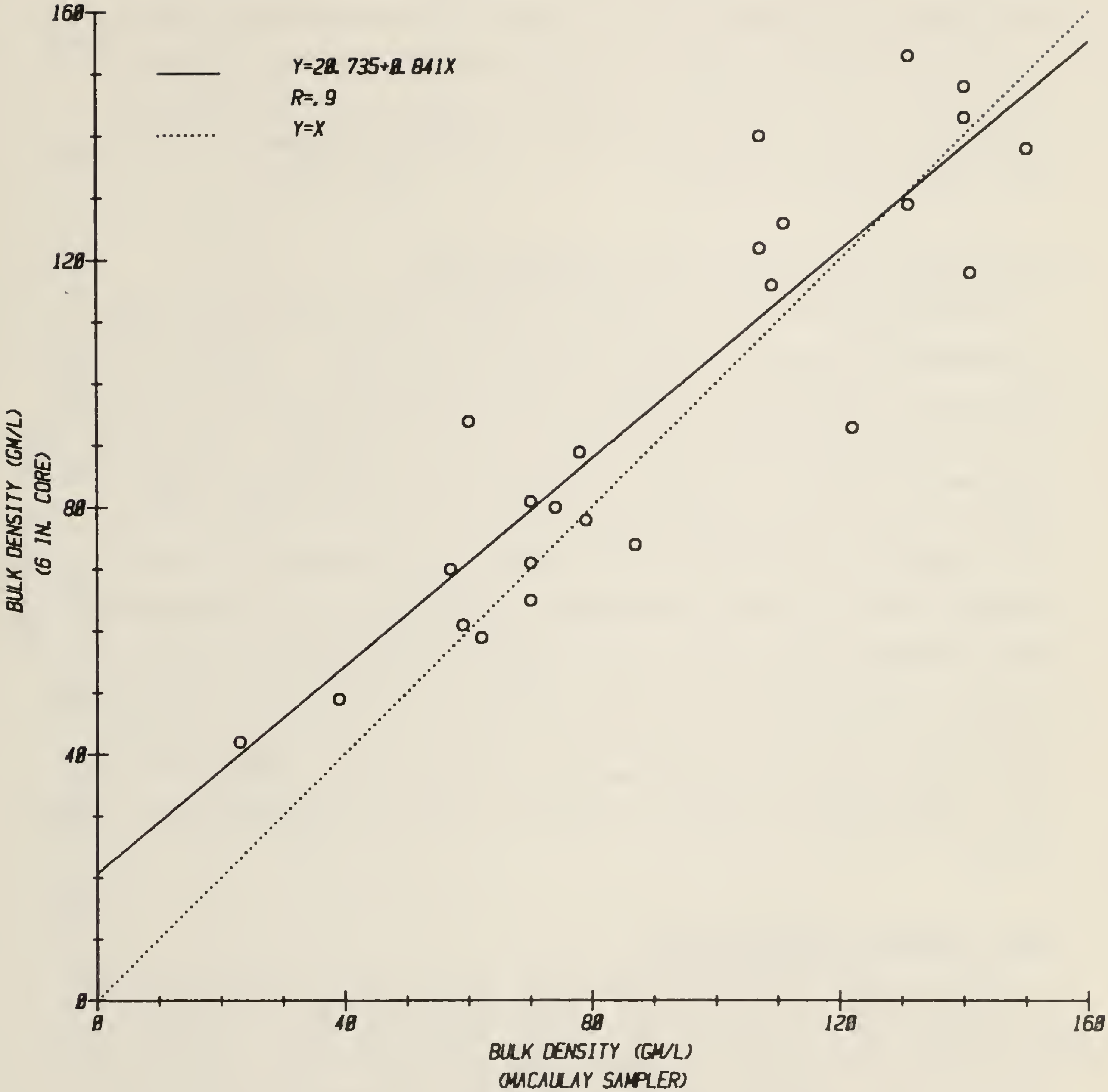

Figure 1 Bulk density: 15cm PVC cores vs Macaulay sampler

that the deviation in bulk density between these methods of sampling decreased with increasing bulk density. Based on the regression equation of Figure 1 the bulk density determined by the 15 cm PVC core was 75% higher than that measured with the Macaulay sampler at 20 gm/l, whereas at 120 gm/l, it was less than 3%. The higher deviation at lower bulk density may be attributed to the presence of less decomposed peat which is difficult to cut by both the Macaulay sampler and the sharpened 15 cm PVC core. While the Macaulay sampler tends to underestimate the bulk density, the 15 cm PVC core has a tendency of compacting the peat resulting in over estimation.

Bulk Density vs von Post Scale of Decomposition

Bulk density and von Post Scale are both used to estimate the degree of decomposition and are closely related to each other. In order to assess this relationship, bulk densitites determined using the 15 cm PVC core were plotted against corresponding von Post classes. These results are shown in Figure 2. Based on linear regression analysis, a good correlation was found between bulk density and von Post Scale ($R^2 = 0.72$). It is important to note that the analysis was performed only on data obtained from virgin peat. When data from samples of a cultivated peat were included in the analysis, the correlation coefficient, R^2 was reduced to approximately 0.36. This indicates that the von Post scale of decomposition should not be applied to cultivated peat. In addition, great caution should be exercised when predicting bulk density from von Post classes because of the wide range of density variations within class limits.

Water Retention Characteristic

Partial water retention curves (from saturation to -150 cm of water matric potential) for site # 800 in Benton Fen and site # 2 in Bull Pasture Bog are shown in Figures 3a and 3b, respectively. The depth intervals, bulk densities and von Post Scale of decomposition of samples corresponding to the curves are also listed. The results show that at water matric potentials lower than -5 cm of water, water

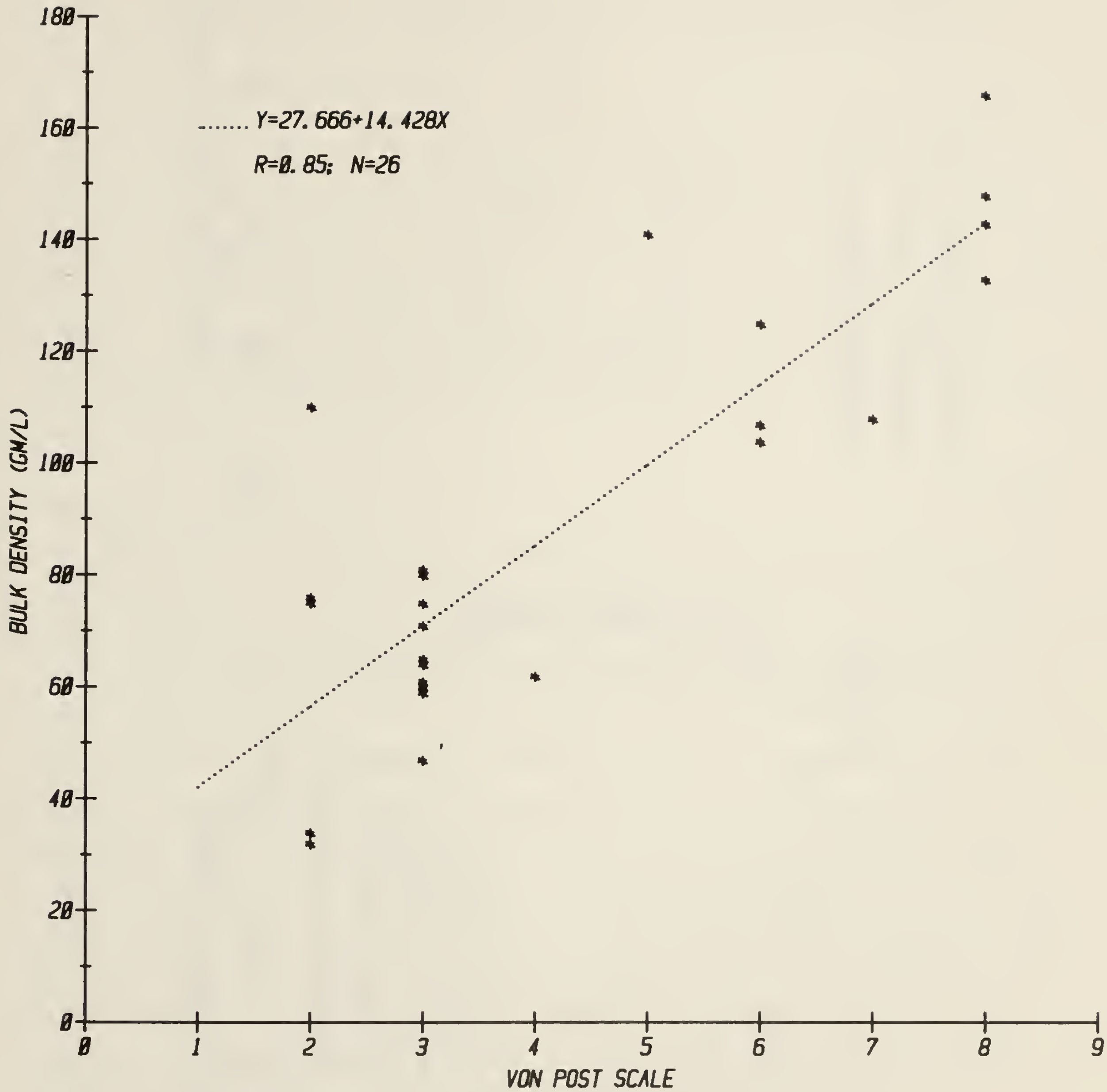

Figure 2 Bulk density vs von Post Scale of decomposition.

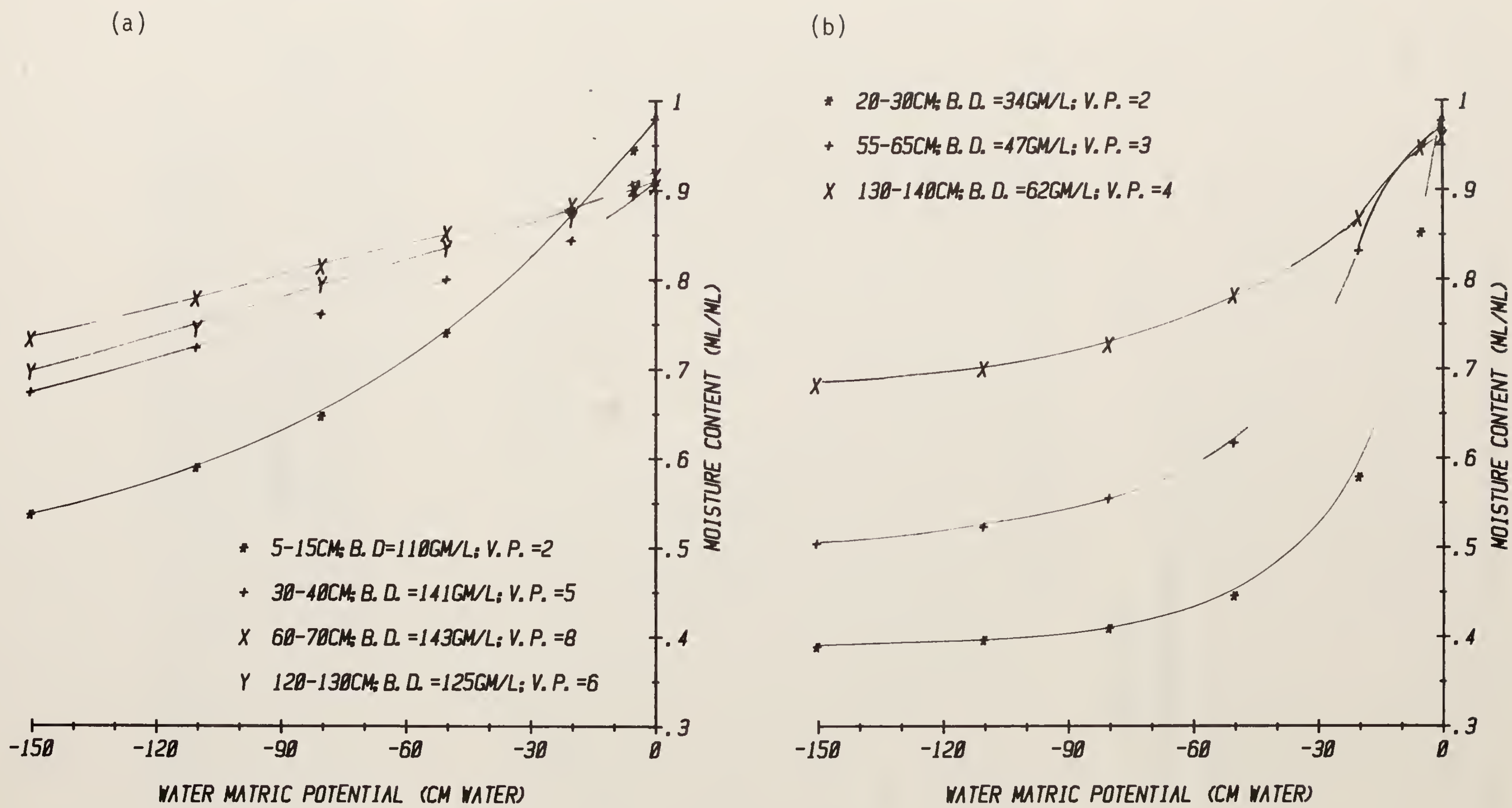

Figure 3 Partial water retention curves: (a)Benton Fen and (b) Bull Pasture Bog.

retention increased with increasing decomposition (von Post), but at a decreasing rate. For example, in Figure 3b, for von Post class 2 (20 - 30 cm) the sample retained less than 40% of its saturated water content at -150 cm of water matric potential, while at von Post 4 (130 - 140 cm) water retention was more than 70%. This difference of over 30% between von Post classes 2 and 4 is much greater than the difference of less than 10% between von Post 5 (30 - 40 cm) and 8 (60 - 70 cm) from Figure 3a.

In addition to the degree of decomposition, it has been recognized that water retention also depends upon botanical composition. This is to some degree evidenced by a comparison of the retention curves from Figure 3a, Benton Fen 5 - 15 cm and Figure 3b, Bull Pasture Bog 20 - 30 cm; both of which are at von Post class 2, but vary somewhat in material content. However, due to the limited results available for analyses a relationship between botanical composition and water retention cannot be established.

Pore Size Distribution

Pore size distributions for samples taken from Bull Pasture Bog and Benton Fen as calculated from water retention data and the capillary rise equation are listed in Table 2. Bulk densities, von Post classes of decomposition and total porosity of the corresponding peat type are also given in Table 2. The results show that peats of lower bulk density contain a much larger percentage of macropores as compared with peats of higher bulk density. Large percentages of macropores for adequate aeration are essential for crop growth and therefore percent macropores should be considered as an important criterion for selecting peat type for agricultural purposes. Table 2 also shows that even within a single von Post class, percent micropores increases with increasing soil depth. The reduction in macropores at the lower horizons may be due to a higher degree of decomposition, as well as the deposition of colloidual particles. The change in pore size distribution of peat materials plays a major role on the drainability and water yield of peat land and is an important parameter in peat resource management.

Table 2: Pore size distribution of peat material at various depths.

Sample No.	Depth Int. (cm)	Bulk Den. (gm/l)	von Post	PORE SIZE DISTRIBUTION (%) Size range (microns) >297	74-297	30-74	19-30	14-19	10-14	<10	Total Porosity (%)
Bull Pasture Site # 2	20-30	34	2	12.8	28.0	13.6	3.7	1.3	.8	39.8	97.7
	55-65	47	3	2.2	11.9	22.2	6.4	3.3	1.9	52.1	96.9
	90-100	59	3	5.5	11.4	23.1	9.1	3.8	3.5	43.2	96.1
	130-140	62	4	9.5	8.9	2.3	3.5	2.8	1.9	72.1	95.9
Bull Pasture Site # 3	15-25	64	3	1.5	5.6	23.6	8.9	6.8	7.8	46.5	95.7
	50-60	61	3	0.6	6.5	17.7	8.1	6.6	8.8	51.7	95.9
	90-100	60	3	0.5	7.2	19.5	9.0	7.3	7.6	48.9	96.0
	140-150	75	5	1.6	5.9	15.4	7.5	4.7	4.8	60.1	95.0
Bull Pasture Site # 4	15-25	71	3	2.3	12.7	15.7	6.8	5.8	6.7	50.0	95.3
	50-60	65	3	0.7	11.0	16.7	7.6	6.3	6.8	50.9	95.6
	90-100	65	3	0.9	7.4	19.0	8.5	6.6	8.3	49.3	95.7
	135-145	80	3	3.6	9.3	14.2	7.2	4.2	4.3	57.2	94.7
Benton Site # 500	20-30	107	6	6.4	7.9	2.8	2.9	2.6	2.1	75.3	92.9
	50-60	140	7	0.7	2.5	3.4	4.9	4.8	4.8	78.9	90.6
	85-95	108	7	0.3	3.1	3.0	4.0	4.1	3.3	82.2	92.8
Benton Site # 700	25-35	148	8	3.2	5.2	6.3	5.0	3.8	4.2	72.3	90.1
	60-70	166	8	2.3	4.6	5.1	5.3	4.6	5.0	73.1	89.0
	90-100	133	8	0.5	1.4	4.3	4.7	4.5	5.8	78.8	91.1
Benton Site # 800	5-15	110	2	3.7	7.3	14.7	10.0	6.3	5.7	52.3	92.7
	30-40	141	5	1.2	5.6	4.8	4.3	4.1	5.5	74.5	90.6
	60-70	143	8	0.3	2.1	3.5	4.1	4.0	5.0	81.0	90.5
	85-95	104	6	0.3	2.0	5.8	6.5	6.2	7.6	71.6	93.0
	120-130	125	6	1.9	3.3	3.6	4.4	5.4	5.2	76.2	91.6
St. Charles #1	5-15	98	2	8.2	15.8	9.9	4.0	3.6	4.7	53.8	93.5
	50-60	76	2	1.2	4.2	7.7	8.3	7.7	7.1	63.8	94.9
	75-85	81	3	0.8	2.8	10.1	10.1	8.1	5.7	62.4	94.6
	95-105	75	2	1.2	3.2	7.2	7.2	7.1	4.6	69.5	95.0

Water Yield vs Bulk Density and Von Post Scale

Water yield is taken as the difference in water content between saturation and -0.1 bar matric potential and represents the maximun amount of water that can be removed by drainage. To examine the relationship between the drainability and the degree of decomposition, water yield was plotted against von Post Scale of decomposition and bulk density, respectively. The results are shown in Figures 4a and 4b. Regression analysis on the results show a curvilinear relationship with correlation coefficients (R^2) of 0.72 and 0.84 for bulk density and von Post Scale, respectively. A correlation coefficient of 0.89 between water yield and bulk density has been reported by Boelter (1969). Although the von Post Scale of decomposition provides better correlation as compared to bulk density, water yield inferred from bulk density at consecutive soil depths may provide a more reliable estimate of total yield for a peatland watershed under conditions induced by lowering water tables. This is due to the fact that even within von Post classes water retention increases with soil depth.

Saturated Hydraulic Conductivity

Saturated hydraulic conductivity as a function of soil depths for Bull Pasture Bog and Benton Fen are shown in Figures 5a and 5b, respectively. The figures plotted beside the conductivity values are von Post classes of decomposition. The results indicate that the saturated flow of water in weakly decomposed peats was as much as 3 orders of magnitude higher than that of more strongly decomposed peats. In general, saturated hydraulic conductivity decreases with increasing soil depth. Figures 5a and 5b also show large variations in saturated hydraulic conductivity within the same von Post class of decomposition. These results again indicate that the von Post Scale of decomposition is not really an adequately sensitive indicator of saturated flow. The high permeability of the surface peat generally results in a substantial amount of subsurface flow if the ground water level is within that layer. However, when the water level is below this layer, water may be unable to percolate downwards through some relatively impermeable horizons. This reduction

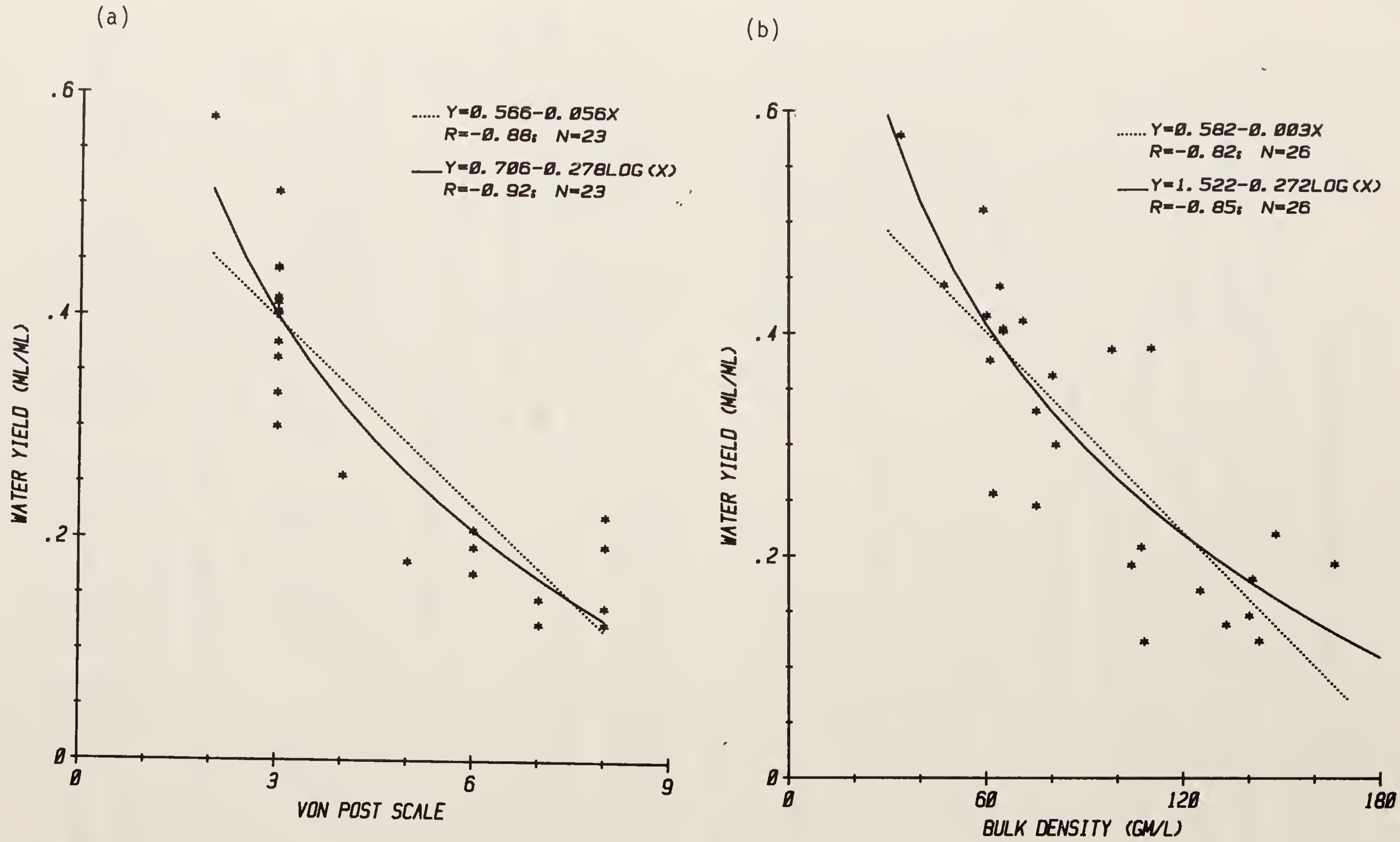

Figure 4. Water yield vs (a) von Post Scale of decomposition and (b) bulk density.

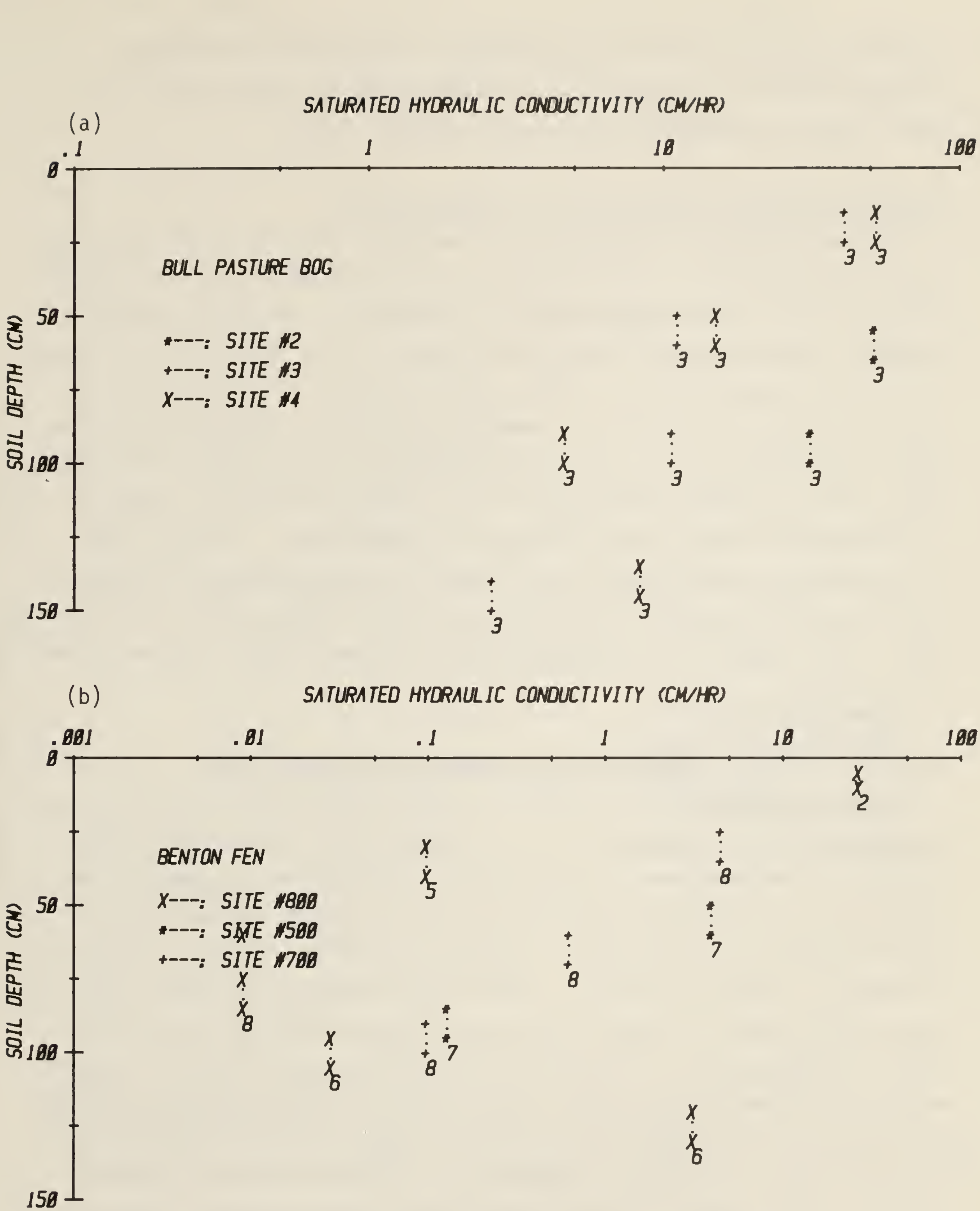

Figure 5. Saturated hydraulic conductivity of (a) Bull Pasture Bog and (b) Benton Fen at various depth intervals.

in flow at lower horizons has significant implication in designing drainage networks. In general, saturated hydraulic conductivity is a major factor of determining the spaces between drains.

Saturated Hydraulic Conductivity vs Percent Pores

Saturated hydraulic conductivity of peat materials is a function of their porosity, pore size distribution and continuity between pore spaces. In order to verify the relationships, logarithms of saturated conductivities were plotted against percentage of pores larger than 30 microns and 10 microns, respectively. A linear regression was also used to test the correlation and the results are shown in Figure 6. Although this figure shows that the data points were fairly scattered, curvilinear relationships with correlation coefficient (r^2) of 0.66 and 0.65 were found for the pores larger than 10 and 30 microns, respectively. The fact that the correlation coefficients are of almost the same magnitude indicates that those pores between 10 and 30 microns have little effect on saturated flow. This suggests that saturated flow is primarily due to pores larger than 30 microns.

Saturated Hydraulic Conductivity vs Degree of Decomposition

Degree of decomposition of peat is a key factor affecting the physical characteristics of the materials. To evaluate the relationship between saturated flow and degree of decomposition, logarithms of hydraulic conductivities were plotted against the von Post Scale of decomposition and bulk density, respectively. The plots, together with the statistics, are shown in Figures 7a and 7b. Statistical analyses show that correlation coefficients (r^2) were 0.40 for bulk density and 0.45 for von Post Scale of decomposition. These lower correlation coefficients as compared with that for percent pore may in part be due to the uncertainty arising from the use of bulk density and von Post Scale to estimate degree of decomposition. Correlation coefficients of 0.45 for hydraulic conductivity vs fiber content and bulk density have been reported by Boelter (1969).

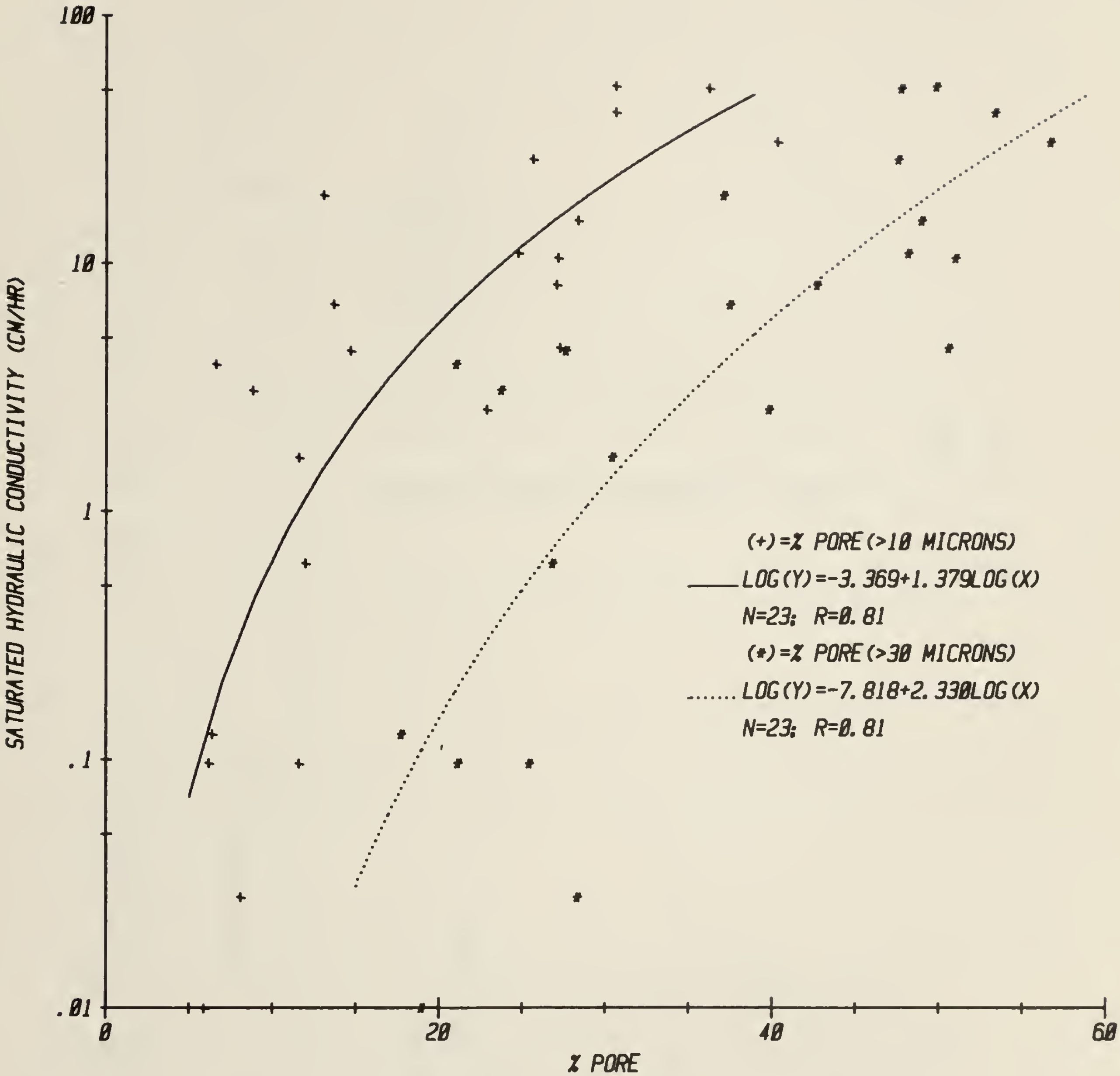

Figure 6. Saturated hydraulic conductivity vs percent pores larger than 10 and 30 microns.

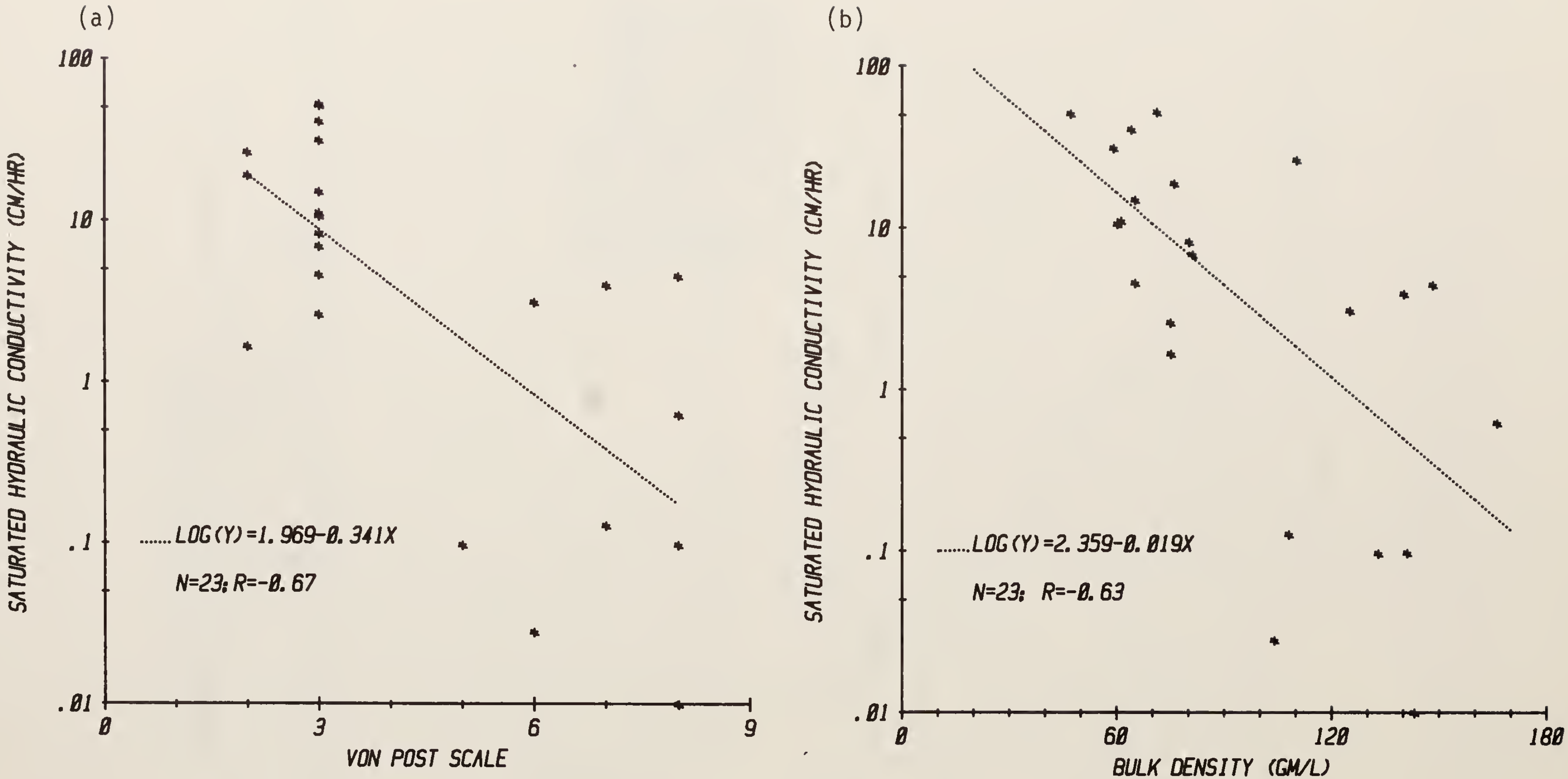

Figure 7. Saturated hydraulic conductivity vs (a) von Post Scale of decomposition and (b) bulk density.

SUMMARY

Hydrologic characteristics and other related physical properties of peat materials at various stages of decomposition (fibric, mesic, and humic) and derived from different botanical origins, were determined in the laboratory. Basic statistical techniques were used to evaluate the correlation between selected hydrological and physical properties. Understanding the limitations of the data base, some tentative conclusions can be drawn:

1. Bulk density measured by the 15 cm PVC core method compared favorably to that of the Macaulay sampler;
2. The significance of the degree of decomposition to hydrologic characteristics is evident. In general, less decomposed peats contain a larger proportion of macropores (>30 microns) that permit rapid movement of water and are easily drained at high matric potential. On the other hand, the low saturated flow in the micropores of the more decomposed peats are difficult to drain and retain much more water at lower matric potential;
3. Linear or curvilinear relationships were found for the regression of water yield to bulk density and von Post Scale of decomposition (r^2= 0.73 and 0.86 respectively).
4. Saturated hydraulic conductivity is highly dependent upon the degree of decomposition and to a lesser extent, it is affected by the botanical composition. Normally, saturated flow decreases markedly with increasing soil depth. A difference as large as 3 orders of magnitude is very common.
5. A significant linear correlation exists between the logarithm of saturated hydraulic conductivity and percent macropores, bulk density and von Post Scale of decomposition. Using these relationships, it is possible to estimate hydrologic characteristics of peat materials. Thus, the classification of organic soils based on the degree of decomposition provides useful information on general peat resource management. However, detailed determination of hydrologic characteristics is required for specific soil and water management, such as determining the depth and spacing of drains.

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SITE SELECTION, PREPARATION AND PEAT MINING TECHNIQUES

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SUMMARY

Site selection for peat mining must consider numerous factors including the quantity and quality of the resource and its drainage characteristics. This paper outlines the techniques used for site preparation and drainage prior to the commencement of mining. The features and advantages of several mining techniques are summarized. Options for the use of the peatland at the conclusion of operations are reviewed.

INTRODUCTION

The major categories of peatland use have varying development requirements. Conservation/recreational uses maintain the peatland in its natural state or, in the case of artificial wildlife habitats, alter the water table by the use of control structures on drainage outlets. Agricultural and forestry uses involve drainage and site preparation. Exploitation of peatlands for horticultural or fuel purposes requires drainage, surface preparation and peat extraction.

The techniques used in forestry and agricultural applications are somewhat specialized and have been reviewed in other publications (Paivanen and Wells 1978; Jasmin *et al.* 1977). This presentation will be restricted to techniques used in the mining of horticultural and fuel peat. The techniques discussed are described in detail or illustrated in many of the bibliography listings and the reader is referred to these for further information.

SITE SELECTION

A detailed resource evaluation such as that carried out by the New Brunswick Department of Natural Resources (see Keys and Ferguson this publication) allows the examination and comparison of various deposits to assess the suitability of the resource for the intended product. The quantity and quality of the peat is one of the most important criteria. For a horticultural development, a suitable deposit would have substantial quantities of poorly decomposed peats (H1-H4) composed primarily of *Sphagnum*. For a fuel peat development, well decomposed peats would be preferrable. A peat thickness of 1 metre is generally considered the minumum for economic mineability. Since most mining methods take only a thin layer of peat in each harvest, the number of years that production can be sustained will increase with peat depth. However, the area of peatland in production limits the amount of peat that can be recovered with one pass. Thus, the deposit must have sufficient size to support the annual production requirements. Drainage requirements and constraints must be carefully assessed. Dense tree cover or stumps within the peat would increase production costs and should be avoided if possible. Climate, especially with regard to the number of days suitable for peat harvesting, must be considered.

If all of these factors are within acceptable limits, cultural parameters such as land purchase or leasing arrangements, road and electricity access, manpower availability, and transportation advantages to the market must be considered. For fuel peat a distance of 100 km is considered the limit for economic transportation. Horticultural peat has a much higher market value and can be transported over longer distances.

When a suitable peatland has been selected a detailed investigation of the deposit should be carried out. The density of field sites in the New Brunswick inventory program is about 1 site per 4 hectares on those peatlands studied with a grid network. In a preproduction inventory the peat quality is often assessed on 100 m centres (*i.e.* 1 site per hectare) while peat depth and elevation only are determined on 50 m centres. This preproduction inventory allows the preparation of a comprehensive drainage layout. As well, the more detailed assessment of peat quality fills "data gaps" in previous work and further assesses the suitability of the deposit for the intended use prior to major investments in site preparation or equipment. If the preproduction inventory indicates previously unforeseen difficulties an alternate deposit can be selected but if all conditions are acceptable site preparation can be undertaken.

SITE PREPARATION

A peatland in its natural state will contain in excess of 90% moisture (wet weight basis), *i.e.* 9 parts water to 1 part peat by weight. The use of a properly designed and maintained drainage system can reduce this to 80-85% moisture (4-6 parts water to 1 part peat).

Using the results of the preproduction inventory, a detailed drainage plan is made. The drainage layout must take into account: the mining method; the slope and shape of the peatland; field length; access and haulage roads; suitable locations for stockpiles, service buildings, and processing plants; peat depths; and drainage outlets.

DRAINAGE

Perimeter ditches are normally the first to be excavated to ensure a good flow away from the peatland. Primary ditches at widely spaced intervals are then excavated to remove open water and increase the bearing capacity of the peatlands. Various types of equipment, with very low ground pressure, are used for this phase. While it is common for the peatland to be left for 3 years or longer at this stage to allow drainage, it is possible to proceed with further development sooner, especially if the peatland has good drainage characteristics.

Secondary or production ditches are placed at closely spaced intervals. Ditch spacing of 30 to 45 m are considered adequate by many horticultural peat producers in New Brunswick but their deposits have poorly decomposed sphagnum peats with good drainage characteristics. A spacing of 20 m is considered preferable but this can be varied somewhat to correspond to equipment size. For example, a 10 m harrow used on a 20 m field requires only 1 pass in each direction. If a 6 m harrow is to be used a 24 m ditch spacing would allow 2 passes to complete the operation.

SURFACE CLEARING

In some cases, surface clearing activities commence prior to the placing of secondary ditches. Large trees can be cut and the stumps removed. In some horticultural operations, on deposits with few trees, brush cutters are used to remove low shrubs and the surface mat is rotovated and allowed to decompose prior to the harvesting phase. In other operations, screw levellers are used to strip the surface mat for removal off the peatland. Screw levellers are also used to profile or "crown" the production fields to aid in surface runoff into the ditches. Specialized equipment can also be used to remove stumps to a depth of about 50 cm.

MINING METHODS

BLOCK CUTTING

The historical method of peat harvesting was by cutting blocks of peat with a spade and stacking the blocks to dry. The block cut method is basically a mechanization of this procedure and has been used extensively in horticultural peat production. Machines are now available for turning the peat to accelerate drying and for loading the stacks for transport. However, these phases were usually completed manually and high labour costs led many companies to convert to other methods. The blocks produced by the mechanical cutters are approximately 40 cm X 10 cm X 10 cm when dry. For horticultural applications, the blocks pass through a shredding mill prior to bagging. This allows some control of the particle size of the horticultural product and minimizes damage to the fibre structure of the peat. These factors result in block cut peat having a slightly higher market value than horticultural peat produced by milled peat methods. While drying time is variable and the stacked blocks can be left over the winter, several weeks of suitable weather will normally reduce the moisture content to as low as 30%. The cutting operation is not dependant on good weather conditions. Three of the twelve companies presently operating in New Brunswick harvest portions of their annual production by this method.

MILLED PEAT

Vacuum (Pneumatic) Method - In this system a thin surface layer of peat is milled or harrowed and allowed to air-dry to about 50% moisture. This drying can be accomplished in one day in optimum weather conditions. The peat is lifted from the bog surface by large vacuum harvesters. The peat passes through a cyclone and settles in a storage tank. The storage tanks are then dumped on stockpiles at the end of the production fields. Only a thin surface layer (about 0.5 cm) is collected by the vacuum. The height of the suction mouth of the vacuum can be varied to ensure only dry peat is collected. The equipment used in this method has generally good maneuverability and is well suited to peatlands where the configuration precludes long production fields. The relatively short drying time is advantageous in areas where several consecutive days of good drying weather are not common. This method is used by all of the horticultural peat operations in New Brunswick and is also common in fuel peat harvesting.

Ridge Method - A peat layer of 1 to 2 cm thickness is milled and the surface allowed to dry. A spoon harrow is then used to turn the milled layer and further drying allowed. The spoon harrowing may have to be repeated several times, particularly if rain interrupts the drying process, before the entire layer reaches 50% or lower moisture. Once this is achieved, the layer is scraped or ploughed into a ridge in the centre of the production field. The ridges from a number of production fields can be combined into a large central stockpile running the length of a production field. The stockpile forms the storage until the peat is transported off the field to the user. This stockpiling system is known as the Peco system. In the Haku system, the ridge on each production field is loaded on a wagon and transported to a large central stockpile located at the edge of the bog. Stockpiles of milled peat, particularly in the Haku method, are often compacted to reduce the possibility of spontaneous combustion. Stockpiles can also be covered with plastic to reduce moisture up-take and wind losses.

Since the ridge method collects a larger amount of peat with each pass than in the vacuum system, fewer passes are required to obtain the annual requirements. In areas of favourable climate, this more than compensates for the longer drying period required. The equipment utilized has a higher efficiency on long production fields where little turning is required. One horticultural peat producer in New Brunswick utilizes the ridge method in their operations, but the method is most common in the recovery of fuel peat.

SOD PEAT

In sod peat harvesting, the peat is "cut" from the bog, macerated, and extruded through nozzles onto the bog surface for drying. There are several types of sod cutters. The "disc" type can be attached to a conventional farm tractor and has a thin circular cutting blade which works to a depth of about 50 cm. The cylindrical sods which are produced are about 8 cm in diameter and 10 to 20 cm long. The "screw" type of cutter has a screw auger which operates to depths approaching 1 metre. A relatively large tractor is required to pull this cutter. The "bagger excavator" type operates at depths up to 4 metres and scrapes the peat from a vertical face or trench. The machine is self-propelled and has a spreading arm for the sods which can be up to 50 cm long. The large size and weight (over 25 tonnes) necessitates long production fields for efficient operation. The sods produced are rectangular with dimensions of about 6 cm X 12 cm X 35 cm.

The sods are left to dry for several days then windrowed with specialized equipment and allowed to dry for several more days. During the drying process, there is substantial shrinkage and hardening of the sods and they become resistant to rewetting. When moisture content is in the order of 35% the sods are collected and transported to stockpiles. Two to three harvesting cycles are normally achieved each season.

The production costs for this method are somewhat higher than for milled peat, so in most cases it is not used for large scale fuel peat harvesting. However, many small scale furnaces are designed to use peat sods and sods are also used in the production of metallurgical coke and related products.

WET MINING

Wet mining methods involve the excavation or dredging of peat from an unprepared site, screening, and pumping of a slurry to a dewatering site. Mechanical presses are used to reduce the moisture content to about 70% and thermal drying can then be used. A wet harvesting system, including mechanical dewatering, is used in British Columbia for horticultural peat. Other horticultural peat or humus operations use drag lines or similar equipment to excavate the peat. Drying is achieved thermally using drum rollers or by spreading the peat over a prepared bed for solar drying and later collection.

Wet mining methods are not weather dependant and have a longer operating season than "dry" methods. Conversion processes such as wet carbonization, wet oxidation, liquifaction, and gasification would be compatible with wet harvesting methods.

POST MINING OPTIONS

The lower horizons of most peat deposits are well decomposed and are not suitable for horticultural peat, but can be used for fuel purposes. Irregularities in the sediment underlying the deposits may limit complete removal of the peat layer with conventional methods. As well, the basal peat layers often have ash contents above acceptable limits for fuel peat use.

The peat layer which remains, combined with an established drainage system, provides a good potential for agricultural or forestry uses of the peatlands on what formerly was unproductive lands. As well, experiments on the use of shallow peatlands for biomass cultivation (willows, alders, cattails) are being carried out (Healy 1980; Pratt and Andrews 1980; Pohjonen 1980). There is some potential for flooding the areas for waterfowl habitat. A scenario with poorly decomposed peat used for horticultural purposes, well decomposed peats used for fuel purposes and the remaining layers reclaimed for agricultural or forestry purposes would be consistent with long term management objectives.

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ORGANIC SOIL SUBSIDENCE: A SCAN OF CONVENTIONAL WISDOM AND CURRENT RESEARCH

BY

Sukhdev P. Mathur

All organic deposits subside upon drainage. Subsidence is a loss in volume which is manifested as a permanent fall in the surface elevation of the organic terrain. This subsidence not only threatens the long-term existence of some highly productive cultivated organic soils, but also necessitates frequent expensive adjustments in the various systems used for draining these soils. And yet, we are not sufficiently certain of the nature, extent and rate of this loss much beyond the conventional wisdom expressed in the adage that "Newly drained peat sinks by the height of a man in the life of a man" (Astbury 1958). In the meanwhile about 10,000 ha of cultivated organic soils in central Canada are disappearing at a rate of about 2.5 cm/yr so that their average thickness now is only 80 cm. The severity of this problem is heightened by the facts that (a) it is costly to open new peatlands; (b) this resource is scarce in the areas suitable for truck farming near urban centers; and (c) the cost of importing the vegetables we grow on these soils is high.

This review is an attempt at summarizing present knowledge of (a) the processes that contribute to subsidence; (b) factors affecting the rate of subsidence; (c) traditional methods of retarding subsidence, and their limitations; and finally (d) current research on an economic and safe method of slowing down subsidence by about 50% through the use of moderate amounts of copper.

A. PROCESSES CONTRIBUTING TO SUBSIDENCE

1. <u>Shrinkage</u>: Peat lands are often more than 90% water by volume. Desiccation by drainage and evapotranspiration therefore cause losses in volume. Only part of this loss is recoverable because only some of the desiccation is reversible. Estimates of shrinkage range widely - e.g., 87% loss in volume of an aquatic peat subsoil (Maas 1972); 50% of the initial loss in elevation (Irwin 1976); 12% shrinkage in the volume of a high-lying peat (Roguski 1973). By its very nature the shrinkage is a short-term surficial phenomenon, becoming less important with time (Schothorst 1977; Maas 1972).

2. <u>Compression</u>: Drainage, cultivation and crop roots create moisture tension which results in capillary forces that cause compression of the soil matrix through reduction in pore volume (Irwin 1976). The effect may be equal to a load of 3 kg/cm^2, and depends upon depth of the water table. Compression contributes to subsidence continuously albeit marginally until the soil is well humified.

3. <u>Settlement</u>: Upon drainage, the buoyant support of water is depleted, leaving the peat material to support more of its own weight resulting in a load of 1 g/cm^2 for each cm fall of water table. This accounts for 25 to 33% of the initial subsidence (Irwin 1976; Schothorst 1977).

4. <u>Consolidation and Compaction</u>: This is similar to settlement except that the weight imposed is that of livestock, machinery and buildings. Temporary loads of the former two have transient effects which are offset by tillage and frost heaving.

5. <u>Erosion and Fire</u>: Losses due to fire, some times intentional (for raising pH and nutrient availability), and by wind or water erosion are obviously important only in specific cases. Stephens and Speir (1970) estimated that about 5% of the long-term subsidence in Florida was due to fires, while erosion contributed negligibly. Please see addendum for discussion of a new paper on "erosion".

6. <u>Biological oxidation</u>: Lack of air, low pH and temperatures retard biological activity, leading to accumulation of organic matter in water-dominated environments. Drainage, liming, fertilization, cultivation and darkening by humification, reverse the preservation-favoring conditions, thus promoting biological oxidation. The oxidation not only dissipates mass through mineralization of organic matter to CO_2 and H_2O, but also promotes humification. Since humus is denser than plant material, (e.g. compare leaves with their compost), the oxidation also results in loss of volume. In a somewhat simplistic manner, it may be stated that 75% of the volume of an organic soil of 0.1 g/cm^3 bulk density may be lost on its humification alone to a soil of 0.4 g/cm^3 bulk density.

Quantitative estimates of the contribution of biological oxidation are made often without considering the aforesaid aspect of humification. These estimats range from 55 to 75% (Stephens and Spier 1970) for the Florida Everglades to 13 to 14% for cultivated organic soils in Belorussia (Skoropanov 1962). For pasture lands, corresponding figures are between 20 and 50%.

The role of biological oxidation in subsidence has been discounted by Skoropanov (1961, 1962) from Minsk, and by Stout (1971) who studied the Wicken Fen in England. The background to the study by Skoropanov (1962), as stated by him, was "the scarcity of nitrogen fertilizers in the USSR, necessitating fuller utilization of native nitrogen in the soil". For peat soils, this required deeper drainage to allow more mineralization of soil-N. The fear that this could lead to much more destruction of the resource, was laid to rest by Skoropanov (1962) by showing that better crop yields are obtained on deeper drainage and that the 1 cm and 2 cm annual decrements in the rather shallow 55 cm and 100 cm deposits respectively were actually due to compaction anyway. Besides, the peat resources of the USSR are vast.

The conclusions of Stout (1971) were based upon a respiration study of 4 hours duration with surface samples reported to be containing upto 43% of their carbon component as charcoal. Elemental carbon is not a suitable source of energy or carbon for micro-organisms. The C/N ratio of these soils, which was 10 to 14, also suggests a high degree of humification and a lack of readily biodegradable material. In such conditions, therefore, biological oxidation may indeed play only a minor role in effecting subsidence.

Many authors make a distinction between oxidataion and biological oxidation, and others quite appropriately use the term biochemical oxidation to include enzymatic and microbial processes. Assessment of purely chemical oxidation is difficult to make because of the drastic nature of the means required to sterilize soils as well as inactivate the accumulated soil enzymes.

B. FACTORS AFFECTING THE RATE OF SUBSIDENCE

It is important to realize that the physical and biochemical processes contributing to subsidence are neither concomitant nor all continuous; nor do they contribute in equal measure. Consequently, when surface elevation is plotted as ordinate against time after drainage, workers around the world obtain a series of slopes of generally decreasing ratios, instead of a smooth curve (Weir 1950; Coulter 1957; Harris et al 1962; Stephens and Spier 1970; Zubtsev and Dubrova 1974; Roguski 1973; Nesterenko 1976; Egglesmann 1976; Kuntze 1976). Therefore average rates of subsidence calculated from empirical data such as surface elevation then and now are not likely to yield accurate information. Same applies to predictions based on such data, or on some parts of a curve. For example, the forecast that the soils of Holland Marsh would lose 3.2 cm of surface elevation (Mirza and Irwin 1964) every year was based on before and after type of data and corroborated by observations pertaining to a part of the aforementioned curve. Irwin (1976) later reported that regular measurements made since 1963 by a permanently installed sensitive instrument show that the rate of subsidence between 1969 and 1975 at this site was only 1.07 cm/yr. The rates reported from different locations range from 1 to 80 mm/yr (Schothorst 1976; Coulter 1956). The important reasons for this wide difference are as follows. Many of these factors are naturally inter-related.

1. Type of material:

It is well known that various plant constituents degrade at different rates in soil and that most plant materials are distinctive in their composition. One should therefore not be surprised that inspite of the hot and humid climate of Indonesia the rate of subsidence of a local lignin-rich oligotrophic woody peat was less than 1 cm per year (Eggelsmann 1976). Eggelsmann (1976) has shown convincingly that because of the associated vegetations, the initial loss due to physical consequences of drainage is greater in high bogs than in low moor or rich fen peats. Conversely, the losses in elevation due to oxidation are more in the low moor than in high bogs. The differences could be more than two fold. Eggelsmann (1976) also mentions that, because of the nature and amount of plant detritus and root residues, forest and pasture peatlands tend not to subside rapidly. However, the degree of decomposition is also important. The rate of decomposition decreases as the extent of decomposition increases (Frercks and Puffe 1959, Roguski 1973; Kowalczyk 1973, Levesque and Mathur 1979). Also, as humification progresses, the proportion of micropores increases at the expense of macropores; and mineral content increases. Micropores tend to be anaerobic and the lack of oxygen slows down decomposition (Okruszko and Szuniewicz 1974). Mineral matter tends to stabilize organic matter against decomposition.

Kuntze (1976) has pointed out that initial bulk density influences the long-term rate of subsidence, so that from this consideration alone, soils with sphagnum origins should subside faster than woody peats under similar agronomic conditions.

2. Climate:

Within a group of low moors, Eggelsmann (1976) found significant correlation between the logarithm of the annual rate of subsidence and the Lang factor (mm annual precipitation divided by mean temperature in degrees Celsius). The differences were five-fold upto a maximum of 70 mm/yr in northern Greece. Among soils reclaimed from high bogs, the rate first increased to a rainfactor of 80 and then decreased from about 12 cm to 0.3 cm/yr.

3. Water table:

Many studies have shown that in cultivated organic soils the most important factor determining the rate of their microbial decomposition is the depth of water table because it controls the moisture/air equilibrium in the top layer (Stepehns and

Spier, 1970; Harris et al 1962; Clayton 1943; Neller 1943; 1944; Roguski 1973). For example, Zubtsev and Dubrova (1974) showed that the mineralization of organic matter when the groundwater level is 70cm., is 2.75 times less than when the level is 120 cm and 7.2 times less intense than when the groundwater is at 150cm depth level. At these three levels, the actual annual weight losses alone in terms of peat layers were about 0.8, 1.6 and 3.6 mm respectively. Harris et al (1962) reported that in Indiana, where due to climatic factors the rate of subsidence is lower than in Florida, subsidence was decreased from 0.79"/yr to 0.36"/yr by raising the water table from the depth of 40" to 16".

4. The nature of plant cover:

Grasses and forests with underbrush cover the soil more intensely than grain crops and more so than intertilled vegetable crops. Greater root density in soil depletes soil oxygen and thus discourages microbial oxidation. It is therefore well recognized and convincingly documented by several European workers that subsidence due to oxidation is about half as much in pasture lands as in cultivated lands (Schothorst 1977; Nesterenko 1976; Skoropanov 1961; Kuntze 1976; Walczyna 1973). It is, of course, also possible to keep the water table closer to the surface in pastures than in cultivated fields. The bearing capacity of pastures is sometimes increased by the expensive step of covering the organic soil with a few inches of mineral soil or sand.

5. Soil reaction (pH)

Oxidation of organic soils being mainly a biological process it is naturally affected by both nutritional and physiological factors. Among the latter, pH is well recognized to be the most important in soil science (Ivarson 1977). Frercks and Puffe (1959) noted that about 50% of the increase in the rate of decomposition with rising pH is between pH 4 and pH 6.0. All steps helpful in maintaining a lower pH, such as (a) mixing of the added lime so as not to allow too much of a gradient between surface and root depth, (b) crop selection, (c) use of fertilizers which retard the rise in pH that follows mineralization, are therefore advisable.

6. Initial thickness of the peat:

It has also been well established that thicker the peat greater is the absolute net subsidence. Zubtsev and Dubrova (1974) report that a 375 cm thick peat subsided by 89 cm while a similar 170 cm peat subsided by 66 cm during simultaneous cultivation of both for 40 years. Skoropanov (1962) reports that in 46 years a 104 cm peat subisded by 56 cm while a 197 cm peat subsided by 100 cm. This, of course, implies that within a single bog, drainage problems arise when thickest parts of the bog, usually in the center, subside the most. Aside from physical factors; in a deeper deposit, there is just that much more which is susceptible to decomposition.

7. The carbon/Nitrogen ratio:

In the light of experience with mineral soils, one would expect that wider the C/N ratio greater the potential for degradation (Mathur 1982c).

8. Time:

As indicated before, subsidence due to shrinkage is confined to a short period immediately following drainage. In contrast, biological oxidation is a continuous process. but one of the inevitable side-effects of this mineralization is humification. Humified materials decompose and subside at a slower rate than fresh plant materials. Consequently, the rate of subsidence decreases with increasing length of cultivation of an organic deposit (Roguski 1973).

C. TRADITIONAL METHODS OF CONTROLLING SUBSIDENCE

1. High Water table.

From a scientific viewpoint, maintaining a high water table is the most logical way of slowing down subsidence, as the water gives buoyant support as well as excludes air that promotes oxidation. From a practical viewpont, however, the promise is nearly offset by the perils such as increased chances of (a) flooding of crops during and following rainstorms, (b) difficulties in tillage, (c) damage to crops by the H_2S produced by anaerobic decomposition, (d) loss in crop growth or quality, particularly for root crops, due to lack of oxygen required for root respiration. It is therefore not surprising that this practice has not been widely adopted even where the costly installations required for maintaining a high water table exist.

2. Low pH

Vegetable crops agronomically and economically suitable for organic soils require a soil pH of about 5.0. The achievement of uniform crop growth and quality within a few years of new cultivation, however, makes it desirable to increase the average pH of a field to higher than 5.0. This value, of course, increases as the organic soils mineralize, in spite of the continual mixing of generally more acidic sublayers as a consequence of subsidence. It therefore appears that there is a lack of significant potential benefit that may be derived by deliberately decreasing the pH periodically, such as by adding S.

3. Admixing with mineral soils.

In the case of pastures, overlaying of sand over the organic soils is widely practiced in Europe where these bogs are underlined usually by marine sand. The water table can then be maintained safely at the mineral-organic interface without harmful loss in bearing capacities of the pastures.

In certain fen peats cultivated for growing cereals, the fields are periodically inundated in fall to allow sedimentation of mineral material in the river water, again in Europe.

The cultivated organic soils in central Canada generally lack in underlying mineral matter that can be slurried easily and pumped to the top; while those in Florida are underlain by rock.

D. MITIGATION OF THE EXCESSIVE DEGRADATION AND SUBSIDENCE BY MODERATE APPLICATIONS OF COPPER

The Rationale:

Partly decomposed plant materials making up the bulk of organic soils and forest litter are primarily composed of water-insoluble organic polymers of large molecular size which do not permeate microbial cell walls. Their decomposition therefore is dependent upon the catalytic activities of several extracellular, degradative enzymes added to soils mostly by decomposer microbes. Most of these enzymes are ephemeral. The survival of some enzymes, however, is prolonged by their immobilization on humus and clay colloids. Such accumulated, abiontic enzymes stabilized in soils function in time and space far removed from their parent cells. These are called soil enzymes by biochemists (Mathur 1982a, b). In mineral soils the effect of the soil enzymes is restricted severely by the lack of organic substrate compounds on which they act. However, in environments where concentrations of the organic substrates for enzymes tend not to be limiting, such as in forest litters and organic soils, the activities of the soil enzymes are found to be correlated with the rate of decomposition of their surrounding organic milieu (Tyler 1976; Spalding 1977; Ross and Speir 1979; Mathur and Levesque 1980; Freedman and Hutchinson 1980; Mathur and Sanderson 1978, 1980a, b).

The effect of Cu on soil enzymes

Enzymes, being proteins, contain $-NH_2$, -COOH, and -SH groups which chelate easily with metals. Enzymes are therefore inactivated by metals such as Pb, Hg, Ag, and Cu. Of all the feed and fertilizer elements essential to life, Cu is most effective in inactivating enzymes. Consequently, it was found that the level of residual fertilizer Cu, in each of four different areas of organic soils, was negatively correlatd with their enzyme activities, and their rates of decomposition, both in vitro and in situ (Mathur and Rayment 1977; Mathur and Sanderson 1978, 1980a, 1980b, Mathur et al 1979a). Most noticeably, the rate of decomposition declined by 70% as the concentration of total Cu in the soils increased from 100 to 300 ppm. The reason for such variation in Cu in cultivated organic soils is that although Cu is recognized as essential to farming on organic soils, the recommended rates of application vary widely from 0.5 kg/ha periodically to 58 kg Cu/ha initially, followed by about 14 kg Cu/ha/yr (see Mathur 1982b) due to ambiguities in our knowledge of the residual effect of fertilizer Cu.

The above noted effect of Cu on organic soil degradation is in agreement with the suppression of decomposition noted in forest litters contaminated with Zn, Ni or Cu (Tyler 1976; Feeedman and Hutchinson 1980) where the Cu is more effective than the Zn or Ni.

Persistence of the Cu effect

The fact that the effect of Cu and other metals function even in forest litters which have been receiving the metals for a few centuries (Tyler 1976) suggests that their inhibitory effect on decomposition is not transient. Microbes that resist toxication by Cu do exist. But free enzymes, by their very nature can not be immune to inactivation by Cu. Mathur et al (1980), therefore found that enzyme activities and decomposition continue to be influenced negatively even where the Cu has existed for a few centuries, as in the Cu bogs near Sackville, N.B. This is understandable because (a) a large part of the soil-Cu remains in the relatively biodynamic hydrolysable fraction of organic matter, and (b) the ability of proteins to chelate Cu is stronger than that of soil humus (Preston et al 1981, Levesque and Mathur 1982).

Practical use of the Cu effect

Since, in quantitative terms, the concentration of enzymes in soils is low the level of Cu needed to curtail decomposition by 70%, and thus subsidence, by about 50%, is also low. It is anticipated that additions of 15 kg Cu/ha for each of the first 3 or 4 years, followed by 5 kg Cu/ha every second year to attain and maintain total soil-Cu levels at 100, 200, 300 and 400 ppm in soils of bulk densities 0.1, 0.2, 0.3 and 0.4 g/cm^3 would slow down subsidence by 50% safely and economically. It is apparent that as the soils humify, and increase in bulk density, the W/W concentration of Cu in the soils would decrease, not increase. It should also be noted that the above mentioned regime of Cu fertilization is close to that recommended in Ontario where in the Holland marsh the annual subsidence rate, according to Irwin (1976) is about 1 cm, and the average level of Cu in soils about 250 ppm (Mathur and Sanderson 1980b). Apparently, the practice in Southwestern Quebec is different. According to Millette (1976) the subsidence rate there is about 2.1 cm/yr, and the average Cu content about 100 ppm (Mathur and Sanderson 1978).

The Cu would be applied and mixed into the surficial 0-20 cm and would have little influence on the biochemical activities below that layer. Recent studies have confirmed that biochemical oxidation, the major cause of subsidence in the long term, is almost confined to the surface 0-20 cm layer (Mathur et al 1982, Levesque et al 1982).

Preliminary results of field microplot experiments at three sites indicate that all levels of Cu above 150 ppm do slow down subsidence by inactivating the extracellular, degradative soil enzymes (Preston et al 1980, Mathur 1982b).

Effect of Cu on humus and N

Studies by Preston et al (1981) have shown that the distribution of humus-C and N compounds are affected by the Cu, only quantitatively, not qualitatively. For this reason, and because the ammonification and nitrification processes involved in mineralizing the soil-N to plant available forms occurs mostly inside microbial cells, where the organic, macromolecular chelates of Cu do not permeate, the Cu does not significantly influence a soil's ability to supply N to the crops, at the relevant Cu concentrations (Mathur and Preston 1981).

Effect on crop yields and nutrition

Results of the microplot and some greenhouse studies, also indicate that at concentrations even 2 to 3 times of the 400 ppm, the Cu would not be phytotoxic, nor adversely interfere with plant absorption of other element (Mathur et al 1979b, Preston et al 1979, 1980; Levesque and Mathur 1982). Other studies have shown that the antagonisms between absorptions and translocations of Cu and Fe, Mn or Zn are mostly offset due to displacement by Cu of the other metals from stronger to weaker ligands more accessible to plants (Mathur and Levesque 1982). Our data are consistent with the observation of Reuther and Smith (see ibid) that soil-Cu begins to be phytotoxic only when total Cu in soil is equivalent to more than 5% of the soils cation exchange capacity (CEC). Since the CEC of organic soils usually lies between 100 and 150 meq/100 g soil, this threshold of phytotoxicity should be between 1600 and 2400 ppm of total Cu in soil.

Cu in organic-mineral soil mixtures

Copper is not held as tightly in mineral as in organic soils. It is a common practice to mix shallow organic soils with mineral sublayers, which have much lower CEC than organic soils. However, as the mineral sublayers have higher bulk density than organic soils, the Cu concentration in such mixtures would be lower than in the organic soils. Greenhouse studies have indeed shown that no phytotoxicity would result when an organic soil containing the recommended level of Cu would be mixed with sand, gyttja, shell-rich or clay sublayers, even if upto 98% of the organic matter thus added is dissipated which, of course, is unlikely to occur (Levesque and Mathur 1982, Mathur and Levesque 1982). The Cu contents of crops grown would be much below maximum safe levels of Cu in food.

Impact on groundwater quality

As is well known humus can hold up to 50,000 ppm Cu by chelation and adsorption. Indeed some Cu bogs contain up to 100,000 ppm Cu. It is therefore not surprising that the Cu applied to organic soils surficially has been found not to move down into deeper layers (Mathur et al 1979c, and unpublished data). The Cu therefore is unlikely to be lost through groundwater.

A discussion of some more recent studies has been appended to the references.

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ADDENDUM TO THE REVIEW ON SUBSIDENCE

Impact on groundwater:

MATHUR, S.P., SANDERSON, R.B., BELANGER, A., VALK, M., KNIBBE, E.N., and PRESTON, C.M. 1982. The effect of using copper for mitigating Histosol subsidence on the movement of copper and other elements in soil sublayers in the context of groundwater pollution. Can. J. Soil Science (submitted).

Microplots on a peat and a muck were amended with 0, 150, 500 and 1500 ppm of Cu (0-15 cm layers) at Ste. Clothilde in 1978, and with 0, 100, 300 and 800 ppm Cu at a site in Holland Marsh in 1979. Downward movement of Cu was detected only where 1500 ppm Cu had been applied in one dose to a peat at Ste. Clothilde. The general lack of movement is in agreement with earlier studies in Sweden and Norway.

Effect on crop yields and nutrition:

MATHUR, S.P., BELANGER, A., VALK, M., PRESTON, C.M., KNIBBE, E.N., and SANDERSON, R.B. 1982. A study of onions grown in microplots of three organic soils each containing four levels of copper in the context of retardation of the soils' degradation and subsidence by copper. Can. J. Soil Sci. (submitted).

In the same microplots as above, neither the yields nor Cu contents in bulbs or leaves revealed any phytotoxicity. However, the Fe:Cu and Zn:Cu ratios were lowest on the peat at Ste. Clothilde with the 1500 ppm Cu addition.

The following two papers report that application of 14 kg Cu/ha for the first three years of new cultivation, (as recommended in Ontario) of even peats, poor in Cu-chelating humus, pose no threat of photoxicity even at pH 4.0 where the Cu is more available than at higher pH values.

LEVESQUE, M.P., and MATHUR, S.P. 1982. Effect of liming and pH on the yields, nutrition and copper status of potatoes, carrots and onions grown in two peat soils. Can. J. Soil Sci. (submitted).

Lack of bactericial effect of Cu in organic soils:

Determination of the survival or growth rates of a Cu-sensitive bacterium in the soils in the above mentioned microplots has shown that the Cu held in organic soils is not bactericidal. Both sterile (methyl bromide treatment that spares soil enzymes but not microbes) and nonsterile soils were used in the study. A report is under preparation.

Soil-Cu, humus and N

Two recent studies in Austria (Plant and soil 57: 85-93; 257-270) have shown that Cu applied with peat to a sandy soil slowed down decomposition, suppressed soil enzymes; and increased plant-available N, partly due to lack of immobilization of N in soil microbes short of energy sources (consequence of less C mineralization).

Soil-Cu and Organophosphorus pesticides

Inorganic Cu hydrolyses O-P pesticides. However, when 100 to 1000 ppm of Cu where added as $CuSO_4$ on top of a soil just treated with Fensulfothion, only the highest rate had an effect, and that too a temporary delay in metabolism of the pesticide (R. Greenhalgh, M. Ihnat and S.P. Mathur: 1980 O.V.R.C. Ann. Rept. 9, p. 78).

In the above mentioned microplots at Ste. Clothilde the soil-Cu had no effect on the rate of disappearance of Dyfonate (Belanger and Mathur - paper under preparation) because the soil-Cu is in tightly chelated form, and metabolism of pesticides by soil microbes generally involves induction of enzymes and population by the pesticide itself. Where co-metabolism is involved even the reduced total microbial activity in a muck would be much higher than in a mineral soil.

Erosion and Subsidence

PARENT, L.E., MILLETTE, J.A., and MEHUYS, G.R. 1982. Subsidence and erosion of a Histosol. Soil Sci. Soc. Amer. J. 46: 404-408.

Parent et al (1982) concluded that "subsidence and erosion should be estimated separately for modelling adequately the subsidence process as a whole". Indeed, as indicated in the preceding review, long-term subsidence rate is nearly unpredictable because it is influenced by so many factors in varying intensity with time. It may also be inter-related with episodal or general erosion in specific areas to an extent more than the negligible observed in Florida (Stephens and Spier 1970).

Parent et al (1980) measured the subsidence of four areas within the Ste. Clothilde Experimental Farm in Quebec during 1974 to 1978. Experimental area I (northern parts of fields 1 and 5) was considered to be protected by a woodlot south-west of field 5, and area II (rest of fields 1 and 5) by a windbreak. Some of the areas within I and II at times sustained a cover crop of oats which was probably ploughed in. Areas III (fields 6 and 7) and IV (fields 2 and 3) were deemed to be "relatively unprotected" from wind erosion. Mean annual subsidence was measured to be 0.31, 1.26, 3.52 and 5.23 cm for areas I, II, III and IV respectively. The difference between the mean rates for protected areas I and II (0.99 $\pm$ 1.59) and for unprotected III and IV (4.53 $\pm$ 2.29) was deduced to "show" that wind and water erosion made an important contribution to subsidence.

This study merits extension to determine whether surface velocity of wind from the relevant direction varies significantly between these areas so that field 1 of area I is protected by the woodlot (about 150 m away) more than area III by the elevated wooded region (not shown in map by Parent et al) about 100 m south-east of the same. This unreported wooded region extended south-east for about 300 m starting about 150 m south-west of the woodland area adjoining field 5. It would perhaps be even more interesting to determine how well were the rates of overall subsidence affected by the facts that (a) areas I and II are richer in Cu (ca. 250 ppm) than areas III and IV (ca. 125 ppm) (see Mathur and Sanderson 1978), (b) the depth of organic layer is less in area I than in II, (c) the degree of decomposition, as indicated by pyrophosphate index, is about 50% more in surface layers of areas I and II than the same of areas III and IV (ibid). As stated in the preceding review, rate of decomposition and subsidence decline as (i) degree of decomposition advances, (ii) soil copper content increases, and (iii) depth of organic layer diminishes. It would therefore seem that, irrespective of erosion, the rates of subsidence observed by Parent et al (1982) are in agreement with the literature although soil pH, only one of the factors that influence decomposition, did not vary. The fields at Ste. Clothilde are known to vary in Cu content from about 20 to 300 ppm which is negatively correlated with their rates of soil decomposition (Mathur and Sanderson 1978).

Nonetheless, the need for precise measurements of actual erosion under fully defined and controlled conditions is worth recognizing because some areas may gain while others lose soil by erosion. For example, the cultivated and sometimes bare fallow area (the Dennigan field) immediately to the south-east may have contributed wind-blown soil to area III. This field was also not shown in illustration of the area by Parent et al (1982).

NONPARAMETRIC STATISTICAL APPROACH TO CORRELATION STUDIES IN PEAT

J.A. Millette and L.E. Parent

SUMMARY

The Pearson product-moment correlation coefficient r can be used to correlate peat decomposition assessments with other peat properties if the scores are all measured on at least an interval scale and are assumed to derive from a bivariate normal distribution. An interval scale is defined by a common and constant unit of measurement. The von Post scale and the peat fiber content do not achieve this condition. Those scales are ordinal. In such cases, the nonparametric Spearman or Kendall rank correlation coefficients could be used. A nonparametric simple linear regression is possible using such a weak scale as the von Post values. A case study is presented only to illustrate the techniques and not necessarily to test the validity of hypotheses.

INTRODUCTION

For correlation studies in peat many investigators have used the Pearson product-moment correlation coefficient r (D.H. Boelter 1974, M.P. Levesque and S.P. Mathur 1979, M. Levesque et J.A. Millette 1977, G. Ye Pyatetskiy 1976, T. Silc and T. Stanek 1976, J. Päivänen 1973, J. Päivänen 1969, V.H. Kuntze 1965, L. Heikurainen, J. Päivänen and J. Sarasto 1964, A. Kaila 1956). Unfortunately not all investigators have paid enough attention to the assumptions associated with the Pearson product-moment correlation coefficient. The Pearson r correlation requires (1) that the data be measured on at least an interval scale and (2) that the two variables have a bivariate normal distribution. If these conditions are not met, one should use other methods.

This paper is intended to define the scale measurements made on peat, to present rank correlation coefficients, to fit a simple linear regression equation and to perform a regression analysis.

SCALE DEFINITION

Siegel (1956) distinguishes four scales of measurement: nominal, ordinal, interval, and ratio scales. Symbols that are used to classify objects form a nominal scale. When objects can be ranked the scale is ordinal. If in addition to ranking, a common and constant unit of measurement with an arbitrary zero point is assigned to objects, a stronger scale arises: the interval scale. For this scale, the ratio of any two intervals is independent of the unit of measurement (eg. temperature scales). The ratio scale is similar to the interval scale, except that it has a true zero point, and thus the ratio of any two points is independent of the unit of measurement.

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Parametric tests should not be applied to data measured on a nominal or an ordinal scale. Instead, nonparametric tests can be used. Usually these tests assume only that the observations are independent, however, some may also assume continuity and/or symmetry of the underlying distribution of the variables.

SCALE OF MEASUREMENT

The methods most widely used to assess peat decomposition are the von Post scale, the rubbed and unrubbed fiber content, the percentage of nonhydrolysable residues (r-value), the pyrophosphate index, and several physical characteristics such as bulk density, ash and water content and hydraulic conductivity.

The von Post scale for wet peat generally has ten classes of decomposition; these are sometimes reduced to five. The assessment of peat decomposition is made by squeezing the peat into the hand. Three units of measurement, each unequally spaced, constitute the criteria of the test: water turbidity, volume of extracted mud, and plant residues. The von Post scale states simply that H-1 is less decomposed than H-2, and so on up to H-10. Consequently, the von Post scale is ordinal. In order to correlate it with other peat properties, one can use a nonparametric test such as the Spearman or Kendall rank correlation coefficients (Daniel 1978). Pearson r, as well as a regression equation estimated by the least squares method, may give misleading results in this case because the ordinal scale is too weak.

Farnham and Finney (1965) developped a new method to reduce the subjectivity of the von Post scale and thus increase the reproductibility of the results among countries. They based their classification on three criteria measured concomitantly: color, fiber content, and pyrophosphate index (Lynn et al. 1974).

Unrubbed and rubbed fiber contents are frequently correlated with peat physical and chemical properties by a parametric correlation (Boelter 1974, Levesque and Mathur 1979). Although a common unit of measurement is conferred to any peat, the assumption of a constant unit is not rigidly applied. Errors due to human manipulations are unavoidable during the preparation of the peat material and the determination of the rubbed fiber content and result, not only in lack of precision, but also in inconsistency between operators, survey units and establishments (Levesque and Dinel 1977). In order to meet the requirements of the interval scale, many investigators have assumed, incorrectly, that giving the right value to any one item implies, in terms of skill and ability, that the correct value will be assigned consistently to any other item. Consequently, the computed Pearson r is doubtful, since the interval scale is not achieved. Nonparametric rank correlation coefficients such as the Spearman and Kendall rank correlation coefficients (Siegel 1956 and Daniel 1978) are thus more appropriate than Pearson r to correlate the fiber content with other peat characteristics, unless technical improvements add consistency to measurement units, such as the method proposed by Dinel and Levesque (1976).

The chemical methods permit objects to be measured on an interval or a ratio scale. However, implicit in the pyrophosphate index and the r-value is the restriction that they relate to specific peat types or peat-forming ecosystems for the decomposition state to be assessed adequately (Grosse-Brauckmann 1976). Physical properties measured with well calibrated instruments generally satisfy the requirements of the interval or the ratio scale. Thus, chemical properties, bulk density, water content, ash content, hydraulic conductivity and other similar characteristics can be correlated one with another by the Pearson r, if the scores are assumed to derive from a bivariate normal distribution. For such data, the non-parametric correlation coefficients yield only 91% of power efficiency as compared to the Pearson r (Siegel 1956).

CASE STUDY

The following case study illustrates the usefulness of the Spearman rank correlation coefficient and of a nonparametric simple linear regression. Although other rank correlation coefficients can be determined for the same data, the purpose of the case study is only to demonstrate the technique involved. The conclusions based on the hypotheses tested could be different if a larger sample size was used.

Actual data obtained from a summer student project were compiled to perform the necessary nonparametric statistical tests. Table 1 shows the data composed of the von Post humification scale, rubbed and unrubbed fibers taken at 10 different sites on the Farnham Bog in Quebec.

Table 1. Von Post values, unrubbed and rubbed fiber content for ten sites on the Farnham Bog, Quebec

Site	Von Post scale	Unrubbed fiber %	Rubbed fiber %
1	7	44	16
2	5	57	27
3	8	63	16
4	6	74	28
5	4	74	28
6	7	67	21
7	6	64	25
8	5	64	25
9	4	67	52
10	5	67	52

To measure the degree of association between any two variables the Spearman rank correlation coefficient (r_S) will be calculated. The test statistic r_s is calculated using the following equations:

$$r_s = 1 - \frac{6 \sum_{i=1}^{N} d_i^2}{N^3 - N} \quad \text{for no ties and...} \qquad (1)$$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d_i^2}{2\sqrt{\Sigma x^2 \quad \Sigma y^2}} \quad \text{if ties exist where...} \qquad (2)$$

d_i = difference between two ranks

N = number of values in sample

$$\Sigma x^2 = \frac{N^3 - N}{12} - \Sigma Tx$$

$$\Sigma y^2 = \frac{N^3 - N}{12} - \Sigma Ty$$

where ΣTx and ΣTy are correction factors. The correction factor T is computed as follows for both x and y:

$T = \frac{t^3 - t}{12}$ where t = number of observation tied at a given rank.

For this example, r_s will be determined for the von Post values and the unrubbed fiber percentages. A table of ranks is necessary (Table 2).

Table 2. Ranks on von Post scale and unrubbed fiber content

Site	Rank		d_i	d_i^2
	Von Post scale (x)	Unrubbed fiber % (y)	(x-y)	
1	8.5	1	7.5	56.25
2	4	2	2	4
3	10	3	7	49
4	6.5	9.5	-3	9
5	1.5	9.5	-8	64
6	8.5	7	1.5	2.25
7	6.5	4.5	2	4
8	4	4.5	- .5	.25
9	1.5	7	-5.5	30.25
10	4	7	-3	9
				Σd_i^2 = 228.00

$$\Sigma x^2 = \frac{N^3 - N}{12} - \Sigma Tx$$

$$= \frac{(10)^3 - 10}{12} - \left(\frac{2^3 - 2}{12} + \frac{3^3 - 3}{12} + \frac{2^3 - 2}{12} + \frac{2^3 - 2}{12}\right)$$

$$= 82.5 - 3.75$$

$$= 78.75$$

Similarly $\Sigma y^2 = 79.25$

Substituting all of the values in equation (2)

$$r_s = \frac{78.75 + 79.25 - 228.00}{2\sqrt{78.75 \times 79.25}}$$

$r_{s\ calc.} = -.443$

The hypotheses that are being tested:

H_0 : The von Post scale and the unrubbed fiber content are linearly independent ($\rho s = 0$)

versus

H_A : There is a linear relationship between the two variables ($\rho s \neq 0$)

The decision in this case, where $r_{s\ tab.} = .6364$ for N = 10 and .05 probability level (Daniel 1978), is not to reject H_0 since $|r_{s\ calc.}| \not> |r_{s\ tab.}|$ at the .05 level. The von Post scale and the unrubbed fiber content are most likely linearly independent.

Another correlation was done between the von Post scale and the rubbed fiber content. The procedure is exactly the same as described previously. Here, the hypotheses are:

H_0 : The von Post scale and the rubbed fiber content are linearly independent ($\rho s = 0$)

H_A : There is a linear relationship between the two variables ($\rho s \neq 0$)

$r_{s\ calc.} = -.8274$

and $r_{s\ tab.} = .7818$ at .01 level (see Daniel 1978) for N = 10

Therefore the decision here is to reject H_0 in favour of H_A since $|r_{s\ calc.}| > |r_{s\ tab.}|$ at the .01 level for N = 10.

This result indicates a negative correlation between the von Post scale and rubbed fiber content.

The analysis can proceed further to fit a regression line to the data to predict the von Post value from the rubbed fiber content. Other regressions are also possible such as between von Post values from different soil survey teams and another parameter, bulk density or ash content to determine the consistency and validity of the von Post method. The Brown-Mood method is described in Daniel (1978). The regression line to fit the data is of the form:

$Y = a + b X$ where
a = Y intercept
b = slope of the line obtained
Y = rubbed fiber content
X = von Post value

The scatter diagram of the sample data is shown in fig. 1 with a 1st approximation and a final approximation of the regression line. Thus the equation for the line is $Y = 39.5 - 3 X$.

Once the regression line is obtained hypotheses about one or both parameters α (a) and β (b) can be tested using the Brown-Mood method.

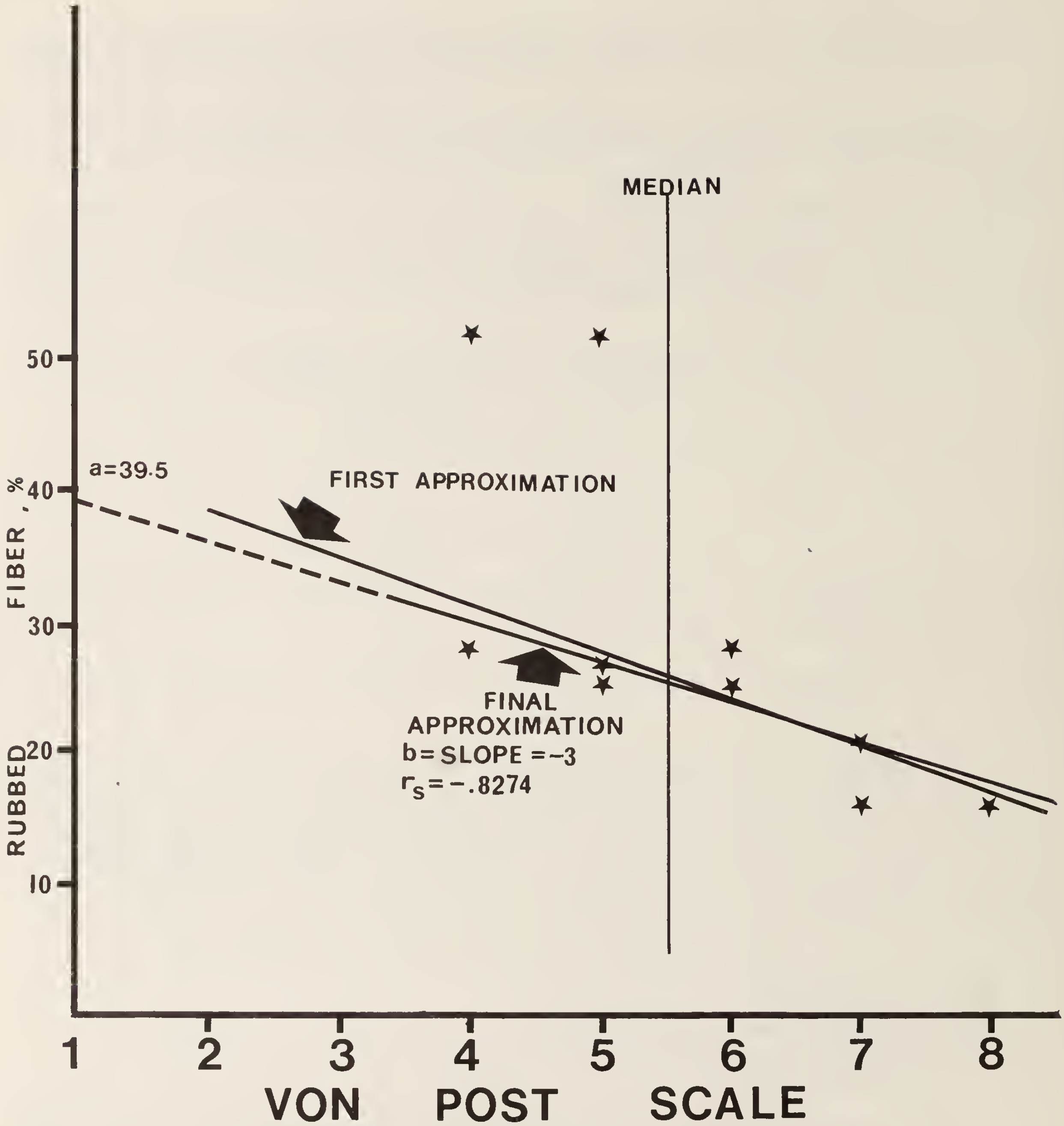

Figure 1. The relationship between rubbed fiber content and the von Post scale for organic soil.

For this example the hypotheses are:

$H_0 : \alpha = 39.5, \beta = 3$ vs $H_A : \alpha \neq 39.5, \beta \neq 3$

Substituting values in the test statistic:

$$\chi^2 = \frac{8}{n}\left[(n_1 - \frac{n}{4})^2 + (n_2 - \frac{n}{4})^2\right] \ldots \qquad (3)$$

where n = sample number

n_1 = the number of data points above the hypothesized regression line and to the left of the line drawn through the median of the X values (von Post values)

n_2 = the number of data points above the hypothesized regression line and to the right of the vertical line drawn through the median of the X values (von Post values)

$$\chi^2 = \frac{8}{10} (2 - \frac{10}{4})^2 + (2 - \frac{10}{4})^2$$

$$= .4$$

The test statistic is distributed approximately as chi-square with two degrees of freedom when H_0 is true and n is about 10 or more. The $\chi^2_{tab.}$ = 4.605 at .1 probability level and two degrees of freedom. Therefore H_0 is not rejected since $\chi^2_{calc.} \ngtr \chi^2_{tab.}$ at the .1 level and two degrees of freedom. The decision is that the sample may have come from a population in which the regression line has a slope of 3 and a y-intercept of 39.5. The equation can be used to predict von Post values (X) from the rubbed fiber content (Y). However, the important feature of this method is that even with a weak scale such as the von Post scale, a regression equation was determined.

CONCLUSION

1. The common practice of using the Pearson product-moment correlation coefficient to correlate the von Post scale, or the unrubbed or rubbed fiber content, with bulk density, hydraulic conductivity, or any other property of peat, should be discouraged, since not all of the data meet the requirement of at least an interval scale to compute the Pearson r.

2. Peat decomposition assessments made on an ordinal scale, such as the von Post scale and the peat fiber content, can be correlated with other physical or chemical properties by the nonparametric Spearman rank correlation coefficient.

3. Simple linear regression analysis can be done on data collected on a weak scale such as was done with the von Post scale and rubbed fiber content.

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MINOR ELEMENT FERTILIZATION OF ORGANIC SOILS

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As you are aware, organic soils are generally poor in plant nutrients, except nitrogen. Even the nitrogen released on decomposition of organic matter may not be available to plants if the C:N ratio in the organic matter is greater than 30, due to immobilization in soil microbial biomass. Newly opened sphagnum peats, therefore generally require more nitrogen fertilization than well decomposed older organic soils.

Lacking in minerals, there are virtually no insoluble reserves of P in most peat soils. However, this fraction appears with cultivation and older soils require less P unless the pH is high and the soil rich in sesquioxides and Ca.

As K does not occur in organic forms, and can be easily leached under acidic conditins, newly opened soils need K fertilization even more than older soils where the turnover of K in the crop residues can meet some of the requirement.

The need for Ca, Mg, and liming with dolomitic limestone are well known. Magnesium deficiencies may appear on older soils heavily fertilized with KNO_3 or $(NH_4)_2SO_4$. Crops are sprayed with Mg compounds to resolve this problem.

Organic soils vary widely in their sulphur contentd (0.1 to 1.0%), sphagnum peats being poorer than fen peats. Sulphur application may therefore be needed on sphagnum peats. Sulfur may also be applied to some calcareous peats to reduce their pH and thus increase availability of Mn.

Virgin organic soils are generally deficient in Fe, Mn, Zn, Cu, B and Mo due to lack of clay minerals, and the leaching of these elements under wet acidic conditions. A well humified cultivated soil of near neutral pH on the other hand, may be poor in plant-available Cu and Zn due to tight chelation on humus, and in Mn due to oxidation to insoluble forms. It should also be realized that minor element nutrition of crops can be imbalanced due to antagonisms between the various metals during absorption and translocation. At the same time high P fertilization and nitrogen status of crops grown on organic soils may increase crop requirements for Cu. The situation is further complicated by the fact that high plant contents of Mn, Cu and Zn can be phytotoxic.

Copper:

Except for liming, the most dramatic increases in crop yields from organic soils are obtained by fertilization with Cu which is usually present in virgin organic soils at a low 2 to 15 ppm level. The nature of organic soil, pH and the type of crops grown, all contribute to determining the level of Cu that is optimum for crop growth. It is obvious that poorly humified soils would contain greater proportion of their Cu content in plant-available forms. For example, 25 ppm Cu in a fibric sphagnum peat pasture in Newfoundland was apparently enough for optimum yields of a grass and legume forage mixture, while even 136 ppm Cu in a moderately humified cultivated organic soil in Ste. Clothilde, P.Q., was insufficient for oats and lettuce when grown either in the greenhouse or in the field.

At a pH of less than 4.8, Cu can be leached from an organic soil, while at pH above 6.5 availability is decreased, due to insolubility of mixed oxides of Cu and Fe, unless carbonates of Cu are present.

Crops vary in their requirements for Cu. Also, for cereals a level of Cu may be sufficient for vegetative growth but deficient for grain-setting. Copper also influences crop marketability of onions and carrots which are richer in color when the soil has Cu in excess of minimum crop requirements for growth. Cu also improves keeping quality of onions.

The rate of application of Cu fertilizer varies widely from about 0.5 kg/ha/yr in some areas to 55 kg/ha for the first year and 14 kg/ha in every subsequent year in coastal plains of the eastern U.S.A. In Michigan, the recommendation is 15 to 35 kg per ha in the 1st three years. In Ontario and Quebec, the suggested rates are 15 kg/ha in each of 1st three years and 5 kg/ha every time onions are grown which is about once in 2 or 3 years.

The reason for these wide variations may be that Cu fertilizer trials are complicated by (a) the spraying of Cu-containing fungicides which can be nutritional; (b) the response to Cu being subject to deficiencies or excesses of Fe, Mn and Zn; and (c) because Cu that was added years ago in much less available than that added recently.

Iron:

Well humified soils are relatively rich in Fe, as also in organic molecules which retain and transport plant-available Fe. Fe deficiencies are therefore observed mostly in fibric sphagnum type peats. In situations where pH rises above 7.5, as in calcium - rich peats, Fe can also become limiting due to formation of insoluble oxides and hydroxides. Most cultivated organic soils, however, do not need Fe fertilization.

Manganese

The availability of manganese is influenced by soil processes more than that of any other element. The fact therefore that raised peats contain about 10 ppm of Mn while minerotrophic peats contain nearly 200 ppm is less important than the pH of the soils. Like in mineral soils, Mn availability at pH below 5 in organic soils also can be high enough to be phytotoxic, while Mn tends to be present in insoluble MnO_2 above pH 6.0. Manganese is applied to organic soils at rates of about 5-10 kg/ha or sprayed on plants at rates of 0.5 to 1 kg/ha.

Zinc:

As in the case of Mn, ombrogenous peats are poorer in Zn than minerotrophic peats. The former, therefore need to be fertilized with Zn at a rate of 10 kg/ha. Deficiency of Zn can also develop at high pH in minerotrophic peats. Fields that have been under cultivation for a number of years generally contain sufficient to excess levels of Zn due to repeated applications of Zn-based fungicides.

Molybdenum:

Unlike Zn and Mn, Mo is less mobile and available at pH below 5.2. Excess Fe also reduces the availability of Mo. Requirements for Mo are rather low so that application of 2 kg/ha to soil or 0.5 kg as spray to leaves are sufficient.

Boron:

Ombrogenous bogs are generally poorer in B than minerotrohpic bogs, because borates are leached easily at low pH. However, a high Ca content in neutral or calcareous organic soils may also necessitate B fertilization to ensure an optimal Ca: B ratio.

As you are well aware, availability of minor elements is affected not only by total soil contents of the elements but perhaps more so by other soil properties, particularly pH, in both mineral and organic soils.

Prof. Lucas of Michigan concluded, as a result of numerous studies, that the ideal pH falls in the range of 5.5 to 5.8 for wood-sedge organic soils and pH 5.0 for sphagnum peats. The ideal pH for mineral soils, in this context, on the other hand, is closer to neutrality. Due to the high exchange capacity of organic soils, and the presence of a large proportion of total soil Ca on the exchange complex, Ca is available in sufficient amounts in organic soils at the slightly acidic pH. Liming of organic soils above pH 5.8 is likely to reduce availabilities of P, Mn, B and Zn.

It should be emphasized that the requirement of minor elements by various crops differ widely. For example, onions have high requirements for Cu, Mn, Mo and Zn but need little B, while celery requires B more than the other minor elements. Table 1, therefore, indicates that minor element fertilization practices have to be finely tuned to the crop grown.

From the viewpoint of evaluating virgin organic soils for the need for minor element fertilization one may rate them in the following order acidic minerotrophic > ombrogenous > calcareous minerotrophic.

Table 1

Response of different vegetable crops grown on organic soils to fertilization with micronutrients when soil or environmental conditions favor a deficiency.

	Boron	Copper	Iron	Man-ganese	Molyb-denum	Zinc
Asparagus	Low	Low	Medium	Low	Low	Low
Beans	Low	Low	High	High	Low	High
Broccoli	Medium	Medium	High	Medium	Medium	--
Cabbage	Medium	Medium	Medium	Medium	Medium	--
Carrots	Medium	High	--	Medium	Low	Low
Cauliflower	High	Medium	High	Medium	High	--
Celery	High	Medium	--	Medium	Low	--
Cucumbers	Low	Medium	Medium	High	--	--
Lettuce	Medium	High	--	High	High	--
Onions	Low	High	--	High	High	High
Peas	Low	Low	--	High	Medium	Low
Potato	Low	Low	--	Medium	Low	Medium
Radish	Medium	Medium	--	High	Medium	--
Spinach	High	High	High	High	High	--
Sweet Corn	Low	Medium	Medium	Medium	Low	High
Tomato	Medium	Medium	High	Medium	Medium	Medium

MAPPING OF PEATLANDS AND ORGANIC SOILS ON DIFFERENT SCALES OF PHOTOS

C. Tarnocai

INTRODUCTION

It has been suggested that, in a number of cases, a large scale organic soil map could be quickly generated by adding additional soil boundaries to an organic soil area mapped previously on a smaller scale. It has also been suggested that maps of different scales be fitted together by reducing or enlarging them to a common scale. In both cases it is found that some soil boundaries on maps with different scales do not match.

This paper discusses the photo scale as it affects the photo pattern and the process of interpretation.

MATERIALS AND METHODS

A portion of the Cranberry peatland was mapped at six different scales (between 1:250,000 and 1:800) in 1974 as a study to show organic soil mapping at different scales and the type of information that can be projected at these scales (Tarnocai 1974). This study focussed on the results of the mapping and no effort was made to explain the manner in which these maps were obtained. Recently, Valentine (1981) in a study to show how map units and delineations change with survey intensity and map scale used three of these Cranberry maps to show the lack of coincident boundaries at different scales. The effect of photo scale on formation of map units and map unit boundaries was not studied.

DESCRIPTION OF THE AREA

The Cranberry peatland (Figure 1) is located approximately 9 km south of Cranberry Portage, Manitoba (approximately 54°28'N lat. and 101°22'W long.). The peatland is situated in a basin underlain by lacustrine clay. On the south it is bordered by a low dolomitic plateau, on the north and east by low ridges of calcareous till and on the west by a lacustrine plain. Provincial Highway No. 10 crosses the peatland in a north-south direction. This highway, fortunately, has not blocked the drainage; culverts allow free drainage westward.

The peatland is a large, approximately 25 km^2, bog and fen complex. The most common peatland types are: flat bogs, peat plateau bogs, palsa bogs, horizontal fens, patterned fens, spring fens and collapse scars. Permafrost approximately 5 m deep is associated with the palsas and peat plateaus (Zoltai and Tarnocai 1971).

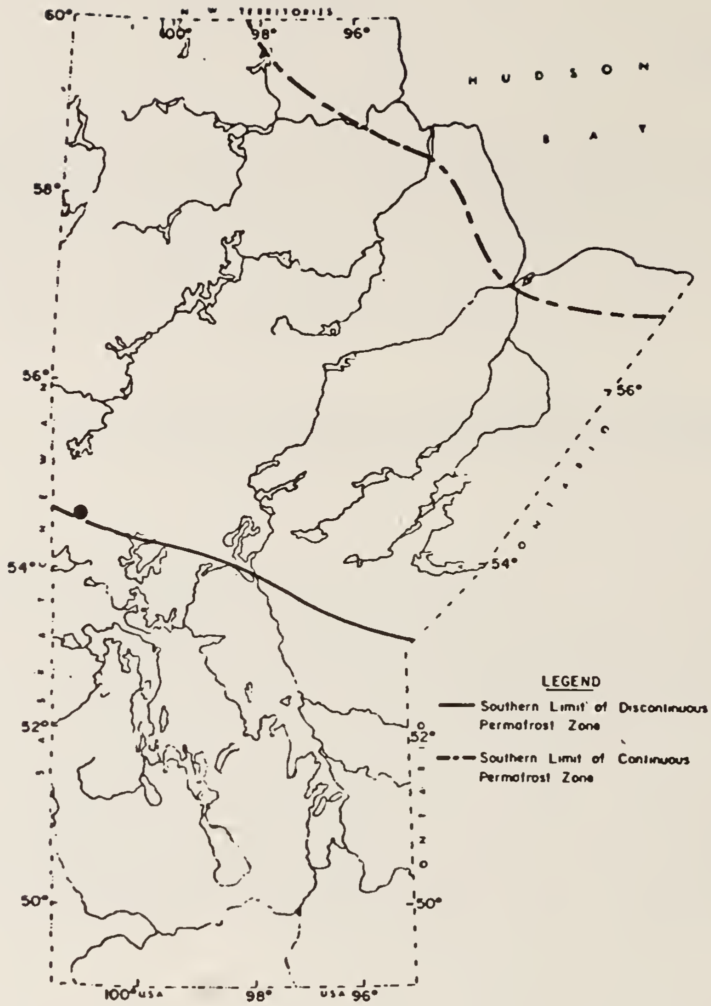

Figure 1 Location of Cranberry peatland (●) at approximately 54°28'N lat. and 101°22'W long.

The bogs are generally treed with dense black spruce (Picea mariana); in some cases, however, they are treeless and covered with a dense carpet of Sphagnum fuscum. The dominant vegetation on the fens are sedges (Carex spp.) with or without a light cover of tamarack (Larix laricina). On patterned fens the ridges are generally treed with black spruce and tamarack.

METHOD OF PHOTO INTERPRETATION

Stereopairs of black and white panchromatic photographs at different scales were interpreted (Figures 2-6). Peatland types, peat material, drainage, soil taxonomy, vegetation and occurrence of permafrost were the main criteria used to form map units at all scales.

The interpretation was carried out on the three-dimensional image created from these photographs by use of the stereoscope. Elevated and patterned peatlands (e.g., palsas, peat plateaus and patterned fens) could be identified on this three-dimensional image but other peatlands were identified by the photopattern created by the vegetation and the vigor of this vegetation (e.g., height of the trees and the crown cover). Lines were drawn around the units and, based on the ground truth, map unit descriptions were given. The results of this photo interpretation are shown in Figures 2-6.

RESULTS AND DISCUSSION

In almost all cases soil maps are generated by use of aerial photographs. The formation of a map unit is based on both the photo patterns and the surveyors' interpretation of these patterns. The map unit so formulated is a somewhat homogeneous unit which may or may not recur elsewhere on the landscape.

At a scale of 1:250,000 (Figure 2) the Cranberry peatland was mapped as a single map unit, a bog-fen complex. At this scale both bogs and fens can be recognized but since the fens cover only small areas they are too small to warrant a separate map unit. In general, units greater than 1 cm^2 were recognized as map units. Soils associated with these peatlands were mapped on the great group level.

At a scale of 1:125,000 (Figure 3) bog and fen peat landforms and vegetation types were recognizable under the stereoscope. Map units generated on this scale were complex units.

At a scale of 1:60,000 (Figure 4) individual peatland forms were easily recognized on the photographs. Although the southeastern part of the map area was identified as a patterned fen at the scale of 1:125,000, at a scale of 1:60,000 the discharge areas were visible and thus it was mapped as a spring fen. Map unit at this scale were single and complex peat landforms, subgroups of soils and vegetation types.

At a scale of 1:60,000 (Figure 5), although individual peat landforms were easily recognizable on the photograph, the map units generated were dominantly complex units. This is partly because, at this scale, large amounts of detail were visible (e.g. treed islands on fens indicating bogs and fen areas within bog units) and thus complexing was necessary.

At a scale of 1:7,000 (Figure 6) the photographs were easily interpreted. Most of the map units were single units.

At a scale of 1:800 (Figure 7) the map was based solely on ground surveys (Zoltai and Tarnocai 1971). A base line bisecting the area was surveyed and the survey lines were run normal to this base line at 15.25 m intervals. Peat landforms, drainage, vegetation and permafrost were recorded along these survey lines and map unit boundaries were located. At this scale all map units are of the single unit type.

Comparison of the maps generated from these different scales of photos revealed that almost none of the boundaries coincided. The boundaries between peatland and mineral terrain were unchanged at the 1:250,000 and 1:125,000 scales. Some map unit boundaries between contrasting peatland types (e.g. the palsa-flat bog unit at scales of 1:60,000, 1:16,000 and 1:7,000) were also unchanged.

REASON FOR THE CHANGE OF MAP UNIT BOUNDARIES AND DESCRIPTIONS

As mentioned in the previous section, the delineation of map unit boundaries and the descriptions of these units are based on both the photo pattern (which is the signature of the surface cover, mainly the vegetation) and the manner in which this pattern is interpreted by the photo interpreter. The photo interpreter draws a line around a unit containing a homogeneous photo pattern and, based on the ground truth, assigns a symbol which characterizes this unit. The unit may be only a single peat landform and soil or a complex of two or more peat landform and soils. The general photo pattern and, more importantly, the combination of photo patterns, changes with scale. Thus, the photo interpreter is faced with the task of interpreting this ever changing photo pattern mosaic for each scale. The result, as shown in Figures 2-6, is partially or completely different map unit boundaries and new sets of map unit descriptions for each of these scales.

The controlling factors influencing the interpreter when map unit boundaries are drawn and map unit descriptions are formulated are mainly environmental factors, the level of generalization and the process of complexing.

Environmental Factors: The photo patterns which are mainly controlled by environmental factors, are generally the signature of the vegetation. Damman (1979) examined the relationships between environmental factors and map scale. He found that, at large scales, soil moisture, parent material, soil fertility, and microclimate are the major factors determining the composition and productivity of the vegetation. At smaller scales, however, climatic variables (temperature and precipitation) and their seasonal changes are the controling factors. Thus, the factors controlling the photo pattern which the photo interpreter analyzes depend on the photo scale.

For example, at a scale of 1:250,000 (Figure 2) photo patterns are controlled mainly by the climate. Although the effect of parent material is also somewhat noticeable at this scale, the units are too small to be recognized as separate map units. At scales of 1:125,000 and 1:60,000 parent materials (peat materials) and soil moisture are the most important controlling factors. At large scales (1:16,000, 1:7,000 and 1:800) soil moisture, parent materials, soil fertility (chemistry of the surface peat) and microclimate are the controlling factors determining the composition of the vegetation and thus the photo pattern.

Level of Generalization: Depending on the map scale and the amount of ground truth available, the photo interpreter has to make generalizations when formulating map unit boundaries and describing these units. This has been done, for example, for the two smallest scale maps (Figures 2 and 3). At the 1:250,000 scale the entire Cranberry peatland forms one map unit with only two different peatland classes being identifiable (bogs and fens). Thus, the description of the map unit is very general and is based on the class level of the peatland classification and on the great group level of the soil classification. At the 1:125,000 scale the peat landforms (plateau bog and flat bogs) are recognizable and thus the description of the map units are less generalized and indicate peatland forms and subgroups of the associated organic soils. Generalization was also necessary at these two scales since the amount of ground truth available was considerably less for the western side of the peatland (west of Highway 10) than for the eastern side.

Complexing: Complex map units occurred at all scales except 1:800. Complex map units are formulated in part because, although peat landforms are recognizable, they are too small to form a map unit at small scales. Some other peatlands are composed of three-unit complexes (e.g. peat plateau - palsa areas interpersed by collapse scars). This highly complex peatland is naturally suited to the formation of a complex map unit.

Complex map units also occur at large scales. At a scale of 1:16,000 complex units were identified because minor peat landforms, which covered less than 10% of the map unit at a scale of 1:60,000, became significant on the map units at the 1:16,000 scale.

Complexing is also a commonly occurring practice when the interpretation is carried out on photographs having a larger scale than the map scale. In this case, complexing is carried out to combine several map units into a larger one.

It is important that the photo interpretation be carried out on photographs whose scale is the same as, or similar to that of the mapping scale. This is necessary in order to avoid over-mapping (photo interpretation carried out on a much larger scale than the map scale) or to avoid generating a map unit which is too broad (photo interpretation carried out on a smaller scale than the map scale).

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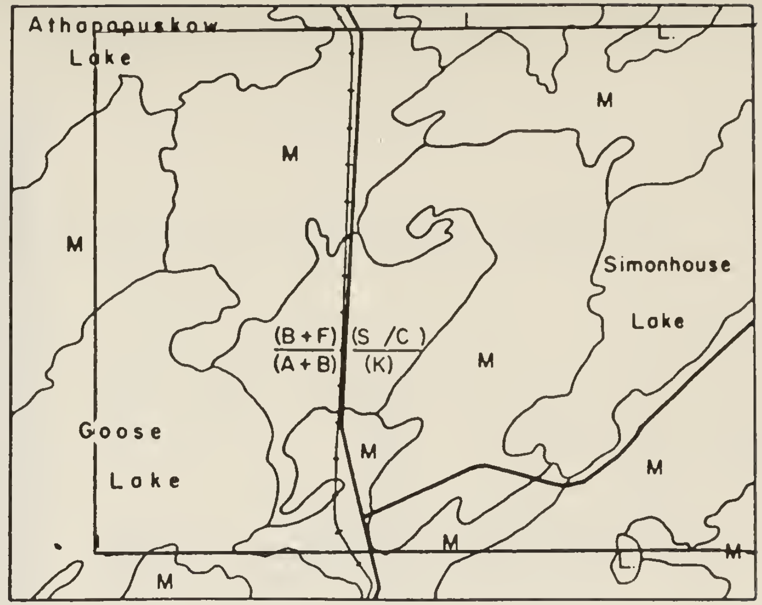


LEGEND

Landform: Map Symbol	Landform: Name	Parent Material	Ecoregion	Drainage (deciles)	Dominant Soil: Classification	Dominant Soil: Map Symbol Association	Dominant Vegetation: Vegetation Group	Dominant Vegetation: Map Symbol
B	Bog	Dominantly forest and/ or sphagnum peat underlain by fen peat.	IV	Well to Imperfect (3)	Organo Cryosol (Mesic Organo Cryosol)	A	Black spruce forest	S
				Poor (7)	Mesisol (Terric Fibric Mesisol and Typic Mesisol)			
F	Fen	Dominantly fen peat.	IV	Poor to Very Poor	Mesisol (Typic Mesisol)	B	Carex Tamarack forest	C

Note: + Second named unit is 10-20% of total unit area
/ Second or third unit is 20-50% of total unit area
K Presence of permafrost
M Mineral soils

INTERPRETATION OF MAP SYMBOLS

The map symbol is interpreted as follows:

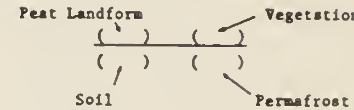


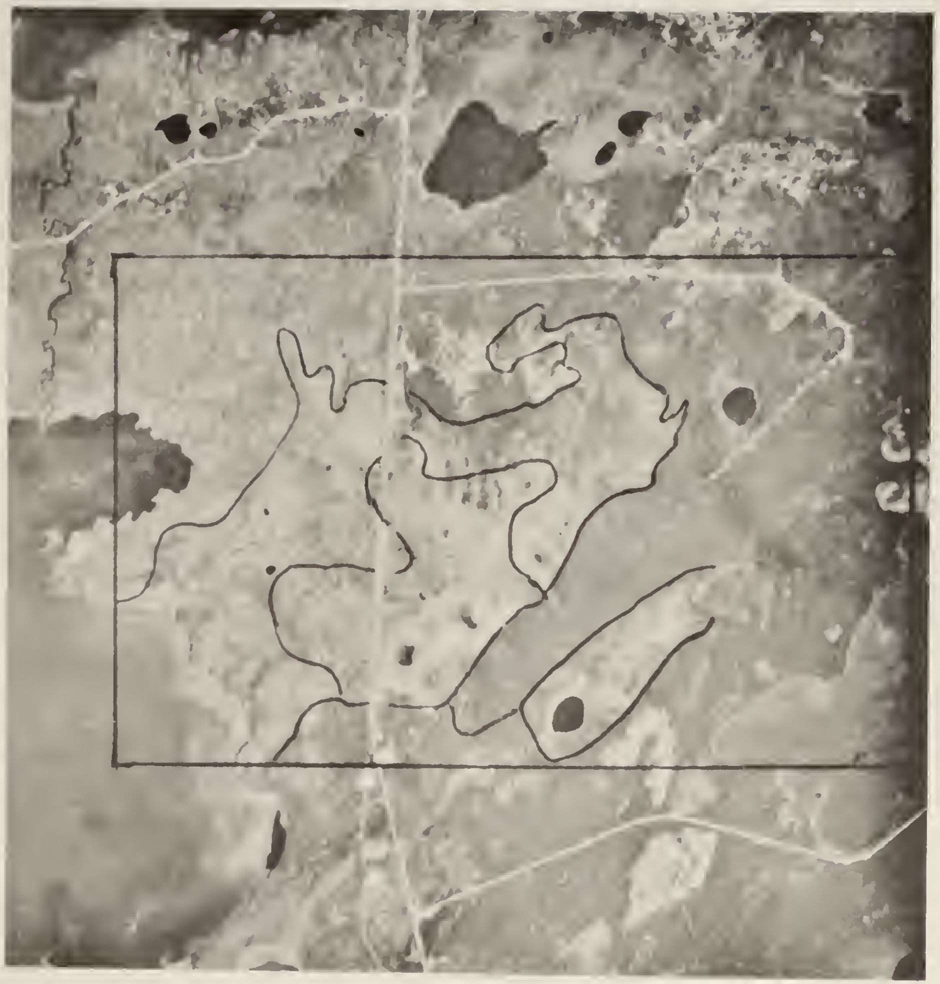
Figure 2 1:250,000 scale map of the Cranberry peatland.

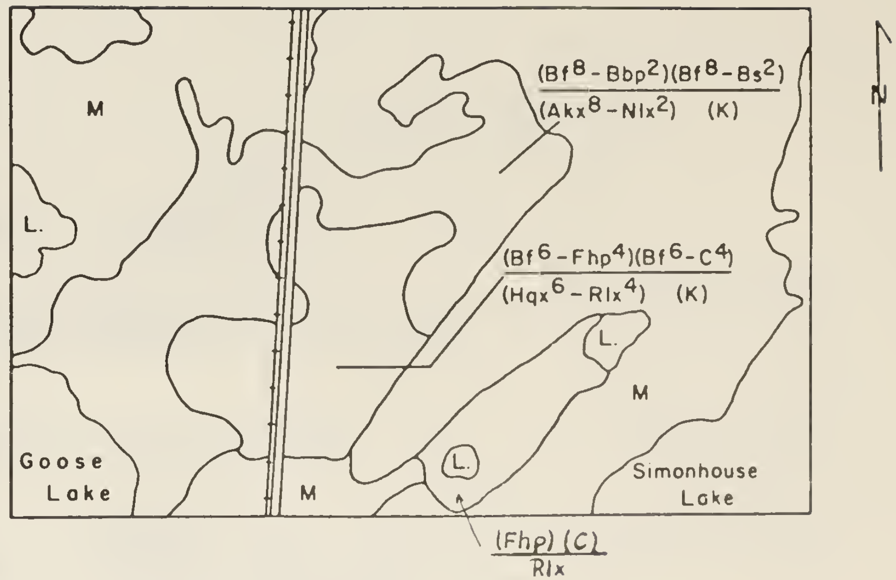
LEGEND

Landform: Map Symbol	Landform: Name	Parent Material	Ecoregion	Drainage	Dominant Soil: Soil Complex	Dominant Soil: Classification	Dominant Soil: Map Symbol	Dominant Vegetation: Vegetation Complex	Dominant Vegetation: Map Symbol
Bbp	Domed and Plateau Bog	Deep to very deep perennially frozen forest peat or thin sphagnum peat overlying forest peat	IV	Well to Imp.	Nekik Lake Complex	Mesic Organo Cryosol	Nlx	Black spruce-Feather moss, Black spruce-Cladonia Complex	Bs
Bf	Flat Bog	16 to 52 inches of mesic forest peat or thin (<24") of sphagnum peat overlying forest peat	IV	Poor	Atik Complex	Terric Fibric Mesisol* Terric Mesic Fibrisol Terric Mesisol	Akx	Black spruce-Feather moss, Black spruce-Feather moss-Ledum, Treeless sphagnum complex	Bf
		Mesic forest peat greater than 52" or thin (<24") sphagnum peat overlying forest peat	IV	Poor	Hargrave Complex	Typic Mesisol* Mesic Fibrisol	Hgx	Same as above	Bf
Fhp	Horizontal Fen Patterned Fen Spring Fen Complex	Greater than 52" of mesic fen peat with little (<6") or no sphagnum peat	IV	Very Poor	Rock Island Complex	Typic Mesisol* Fibric Mesisol	Rlx	Carex, Tamarack-Carex Complex	C

Note: K Presence of permafrost
M Mineral soils
* Dominant soil

Figure 3 1:125,000 scale map of the Cranberry peatland.

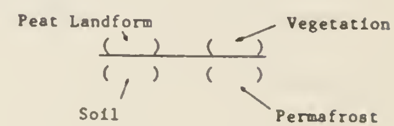




Scale 1:125 000

INTERPRETATION OF MAP SYMBOLS

The map symbol is interpreted as follows:

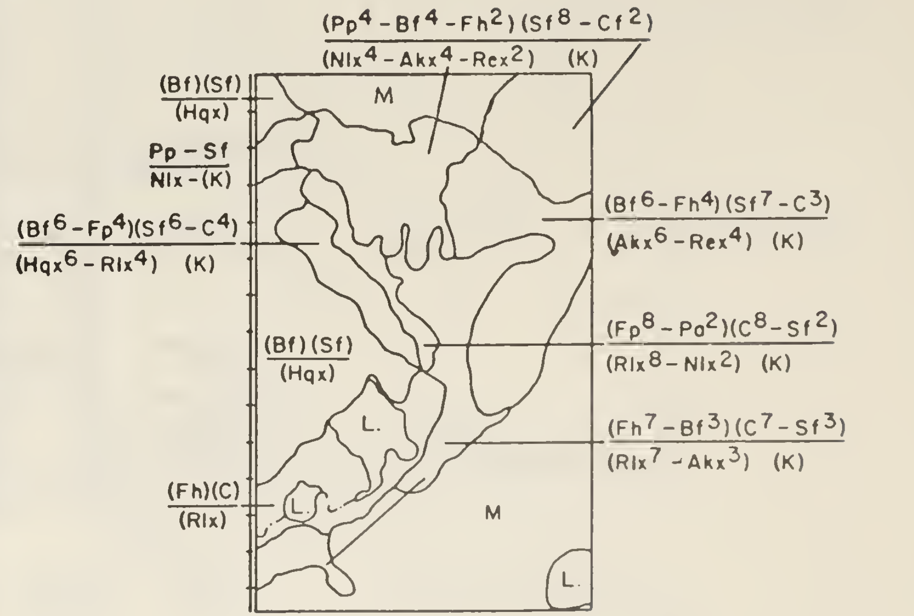


LEGEND

Landform: Map Symbol	Landform: Name	Parent Material	Drainage	Soil: Soil Complex	Soil: Classification	Soil: Map Symbol	Vegetation: Vegetation Type	Vegetation: Map Symbol
Pp Pa	Peat Plateau Palsa	Deep to very deep perennially frozen forest peat or thin (<24") sphagnum peat overlying forest peat	Well to Imp.	Nekik Lake Complex	Mesic Organo Cryosol	Nlx	Black spruce-Feather moss Black spruce-Cladonia	Sf Sc
Bf	Flat Bog	16 to 52 inches of mesic forest peat or thin (<24") of sphagnum peat overlying forest peat	Poor	Atik Complex	Terric Fibric Mesisol* Terric Mesic Fibrisol Terric Mesisol	Akx	Black spruce-Feather moss	Sf
		Mesic forest peat greater than 52" or thin (<24") sphagnum peat overlying forest peat	Poor	Hargrave Complex	Typic Mesisol* Mesic Fibrisol	Hgx		
Fh Fp	Horizontal Fen Patterned Fen	12 to 52 inches of fen peat with little (<6") or no sphagnum peat	Very Poor	Reed Lake Complex	Terric Mesisol* Terric Fibric Mesisol	Rex	Carex Tamarack-Carex	C Cf
		Greater than 52" of fen peat with little (<6") or no sphagnum peat	Very Poor	Rock Island Complex	Typic Mesisol* Fibric Mesisol	Rlx		

Note: K Presence of permafrost
M Mineral soils
* Dominant soil

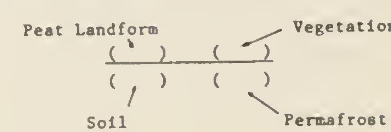
Figure 4 1:60,000 scale map showing a portion of the Cranberry peatland.



Scale 1:60 000

INTERPRETATION OF MAP SYMBOLS

The map symbol is interpreted as follows:

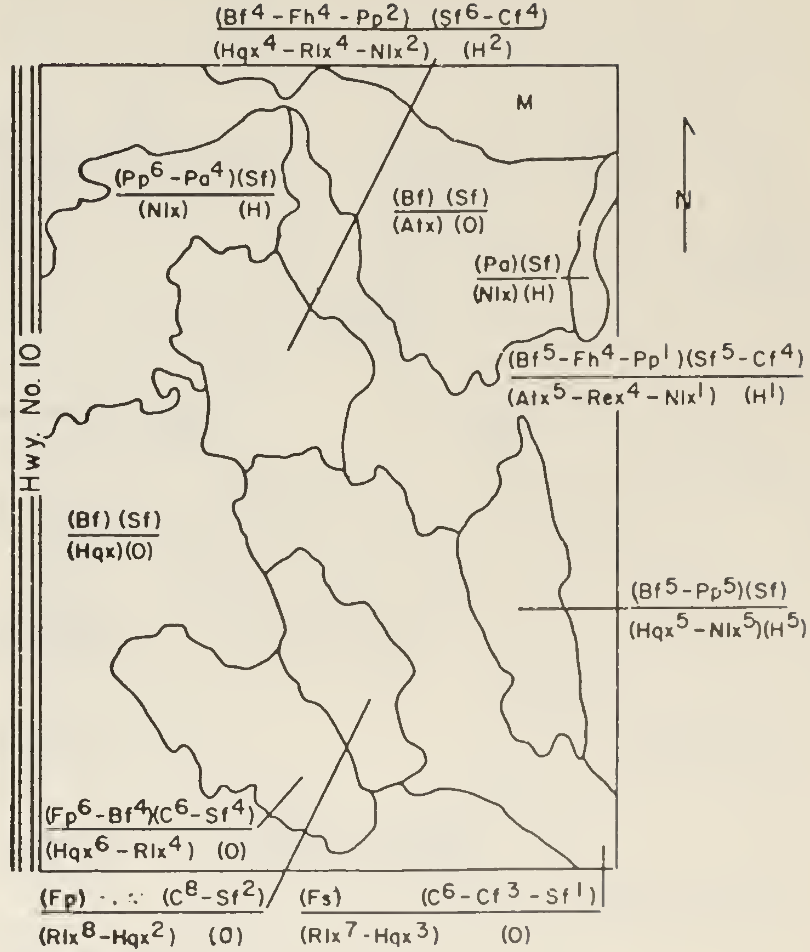


LEGEND

Landform		Parent Material	Drainage	Soil			Vegetation	
Map Symbol	Name			Soil Complex	Classification	Map Symbol	Vegetation Type	Map Symbol
Pp	Peat Plateau	Deep to very deep perennially frozen forest peat or thin (<24") sphagnum peat overlying forest peat	Well to Imp.	Nekik Lake Complex	Mesic Organo Cryosol	Nlx	Black spruce-Feather moss	Sf
Pa	Palsa						Black spruce-Cladonia	Sc
Bf	Flat Bog	16 to 52 inches of mesic forest peat or thin (<24") of sphagnum peat overlying forest peat	Poor	Atik Complex	Terric Fibric Mesisol* Terric Mesic Fibrisol Terric Mesisol	Akx	Black spruce-Feathermoss	Sf
							Black spruce-Feathermoss-Ledum	Sl
		Mesic forest peat greater than 52" or thin (<24") sphagnum peat overlying forest peat	Poor	Hargrave Complex	Typic Mesisol* Mesic Fibrisol	Hgx		
Fh	Horizontal Fen	12 to 52 inches of fen peat with little (<6") or no sphagnum peat	Very Poor	Reed Lake Complex	Terric Mesisol* Terric Fibric Mesisol	Rex	Carex	C
Fp	Patterned Fen						Tamarack-Carex	Cf
Fs	Spring Fen	Greater than 52" of fen peat with little (<6") or no sphagnum peat	Very Poor	Rock Island Complex	Typic Mesisol* Fibric Mesisol	Rlx		

Note: O Indicating no permafrost
H Indicating high ice content permafrost
M Mineral soils
* Dominant soil

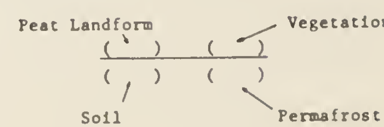
Figure 5 1:16,000 scale map showing a portion of the Cranberry peatland.



Scale 1:16 000

INTERPRETATION OF MAP SYMBOLS

The map symbol is interpreted as follows:



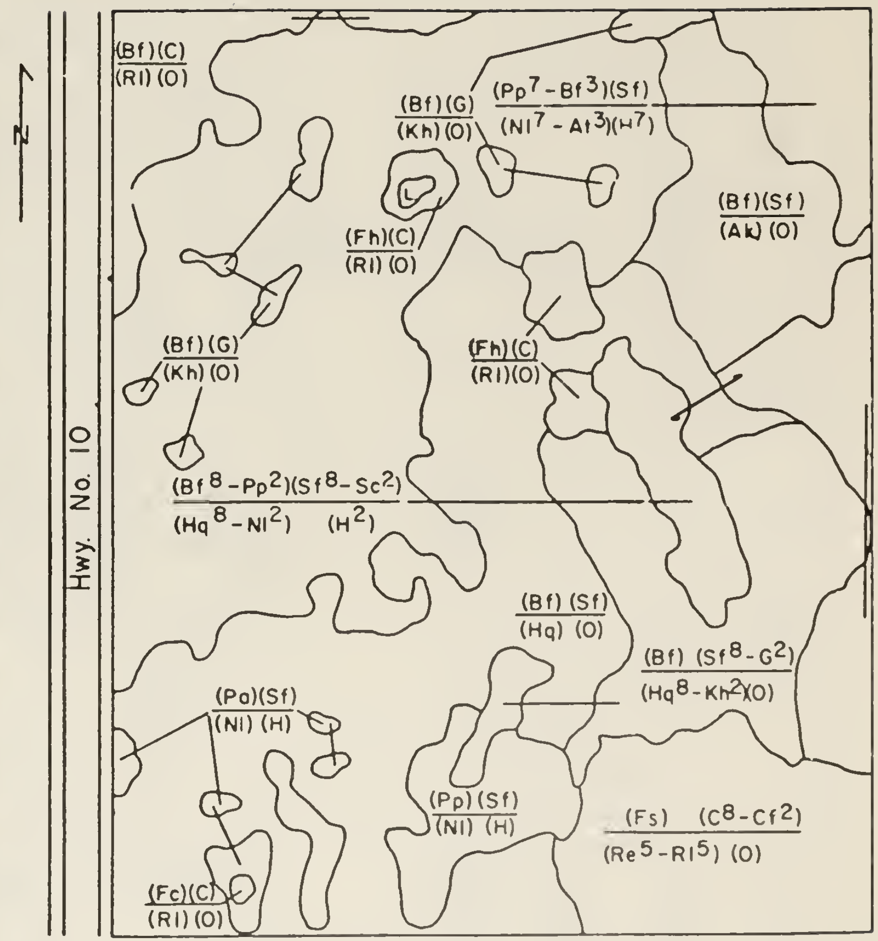
LEGEND

Landform		Parent Material	Drainage	Soil			Vegetation	
Map Symbol	Name			Soil Series	Classification	Map Symbol	Vegetation Type	Map Symbol
Pp Pa	Peat Plateau Palsa	Deep to very deep perennially frozen forest peat or thin (<24") sphagnum peat overlying forest peat	Well to Imp.	Nekik Lake Series	Mesic Organo Cryosol	Nl	Black apruce-Feathermosa Black apruce-Cladonia	Sf Sc
Bf	Flat Bog	16 to 52 inches of mesic peat or thin (<24") of sphagnum peat overlying forest peat	Poor	Atik Series	Terric Fibric Mesisol	Ak	Black spruce-Feathermoss Black spruce-Feathermoss-Ledum	Sf Sl
		Mesic forest peat greater than 52" or thin (<24") sphagnum peat overlying forest peat	Poor	Hargrave Series	Terric Mesisol	Hg		
		Greater than 36 inches of fibric sphagnum peat, underlain by significant layer or layers of forest and fen peat	Poor	Kiskitto Series	Mesic Fibrisol	Kk	Treeless-sphagnum	G
Fh Fp	Horizontal Fen Patterned Fen	12 to 52 inches of fen peat with little (<6") or no sphagnum peat	Very Poor	Reed Lake Series	Terric Mesisol	Re	Carex Tamarack-Carex	C Cf
Fs Fc	Spring Fen Collapse Scar	Greater than 52" of fen or mixed peat with little (<6") or no sphagnum peat	Very Poor	Rock Island Series	Typic Mesisol	Rl		

Note: O Indicating no permafrost
H Indicating high ice content permafrost
M Mineral soils

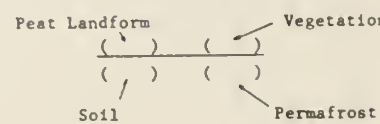
Figure 6 1:7,000 scale map showing a portion of the Cranberry peatland.

Scale 1:7000



INTERPRETATION OF MAP SYMBOLS

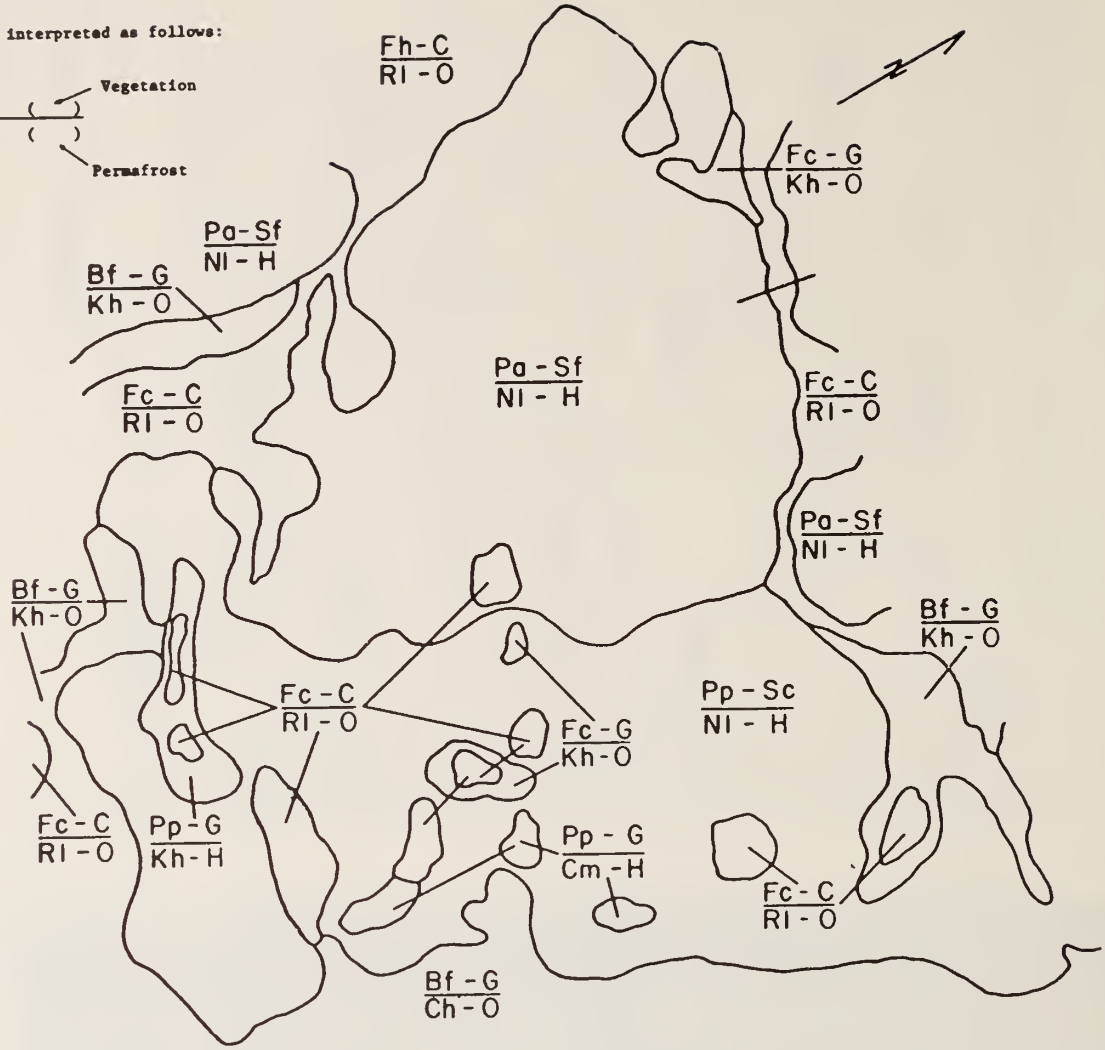
The map symbol is interpreted as follows:



INTERPRETATION OF MAP SYMBOLS

The map symbol is interpreted as follows:

Peat Landform ( ) — ( ) Vegetation
Soil ( ) ( ) Permafrost



LEGEND

Landform Map Symbol	Landform Name	Parent Material	Drainage	Soil Series	Soil Classification	Soil Map Symbol	Vegetation Type	Vegetation Map Symbol
Pp	Wooded Peat Plateau	Deep to very deep perennially frozen forest peat or thin (<24") sphagnum peat overlying forest peat	Well to Imp.	Nekik Lake Series	Mesic Organo Cryosol	Nl	Black spruce-Feathermoss Black spruce-Cladonia	Sf Sc
				Nekik Lake Series sphagnic phase	Mesic Organo Cryosol	Nls		
	Sphagnum Peat Plateau	Deep to very deep perennially frozen sphagnum peat overlying forest and/or fen peat	Imp.	Cormorant Lake Series	Fibric Organo Cryosol	Cm	Treeless Sphagnum	G
Pa	Wooded Palsa	Deep to very deep perennially frozen forest peat	Well to Imp.	Nekik Lake Series	Mesic Organo Cryosol	Nl	Black spruce-Feathermoss	Sf
Bf	Flat Bog	Greater than 36" of sphagnum peat, underlain by a significant layer or layers of forest and fen peat	Poor	Kiskitto Series	Mesic Fibrisol	Kh	Treeless Sphagnum	G
Bf	Flat Bog	24 to 64 inches of fibric sphagnum peat, which may be underlain by significant amounts of forest or fen peat	Poor	Chocolate Series	Terric Mesic Fibrisol	Ch	Treeless Sphagnum	G
Fh	Horizontal Fen	Greater than 52" of fen or mixed peat with little or no sphagnum peat	Very Poor	Rock Island Series	Typic Mesisol	Rl	Carex	C
Fc	Collapse Scar							

Note: O Indicating no permafrost
H Indicating high ice content permafrost

Figure 7 1:800 scale map showing a peat plateau - palsa area of the Cranberry peatland.

FIELD TRIP AND PHOTO INTERPRETATION EXERCISE

C. Tarnocai and H. Rees

Two peatlands were visited during the field trips. The first, Bull Pasture, is located in New Brunswick's central peatland zone and is a domed bog characteristic of this area. The second, Benton, is a stream fen transitional to Atlantic plateau bog, typical of New Brunswick's western peatland zone. See Figure 1. Prior to the workshop each peatland was traversed and sites selected along representative transects were described and sampled for analyses. Figure 2 and 3 are aerial photo stereopairs and triplets showing the peatlands, and Tables 1 to 11, site morphological descriptions and physical and chemical analytical results.

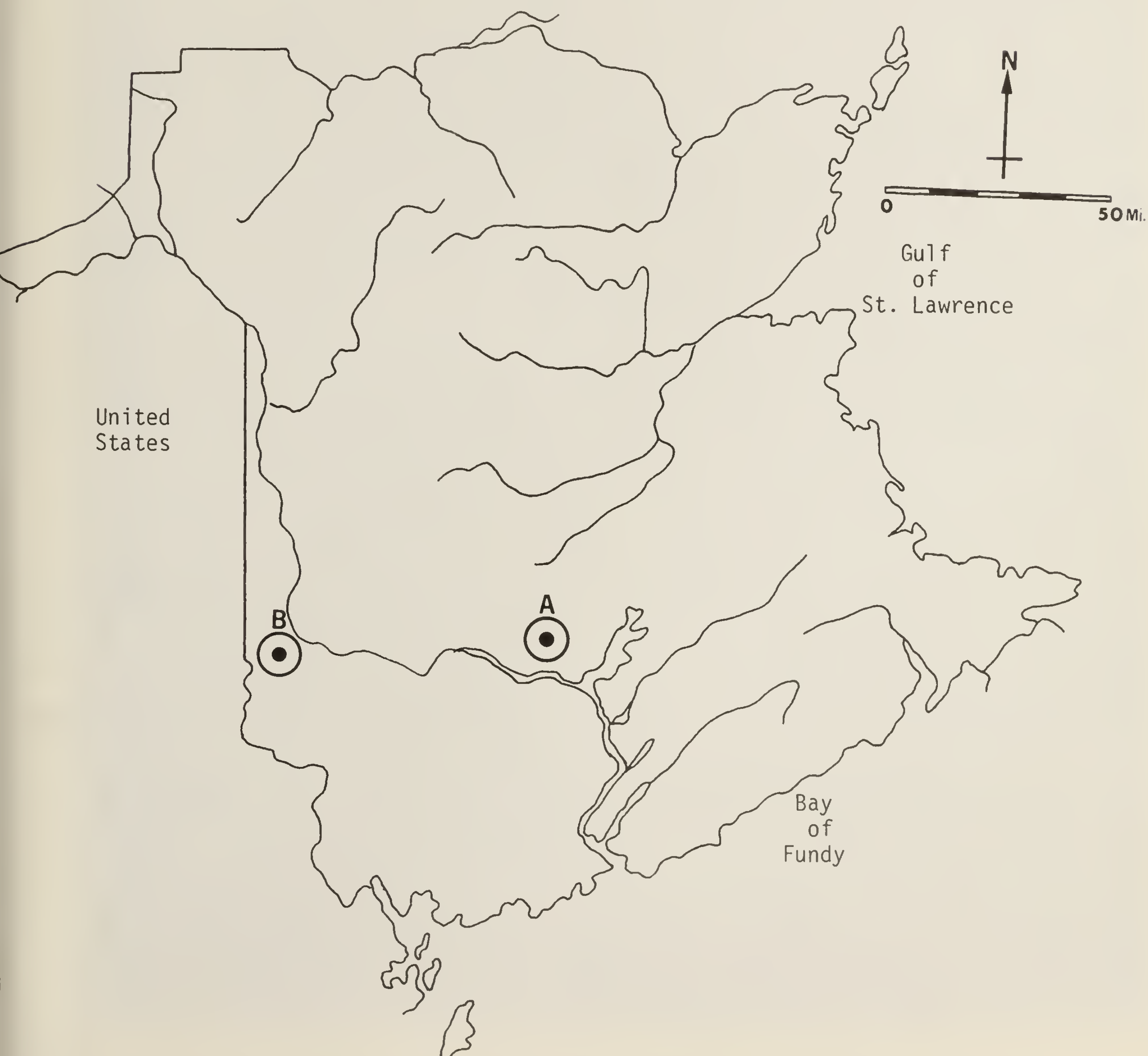


Figure 1. Map of New Brunswick showing locations of: A) Bull Pasture Bog, and B) Benton Fen

Figure 2. Bull Pasture, shown on the aerial photo stereotriplet below, consists of a raised or domed bog (site 3-edge of dome; site 4-crest of dome) with a relatively wide peripheral lagg area (sites 1,2,5). Hypothesis are that the gently undulating topography resulted in peatland development around shallow post-glacial lakes with subsequent paludification of surrounding areas leading to lateral expansion. Peat stratigraphy consists of surface layers 0.5 to 4.5 meters thick of mostly fibric and mesic sphagnum peats over a thin layer of approximately 0.5 meters of mesic and humic sedge peats. This inturn is underlain by a broken basal layer of sedimentary peat. Tree cover, while sparse on the dome centre and slopes, consists of dense stands of black spruce and larch on the margins- a result of the influence of nutrient enriched seepage from the surrounding mineral soils. Ground vegetation consists of Sphagnum mosses and low Ericaceous shrubs with sedges on the lagg.

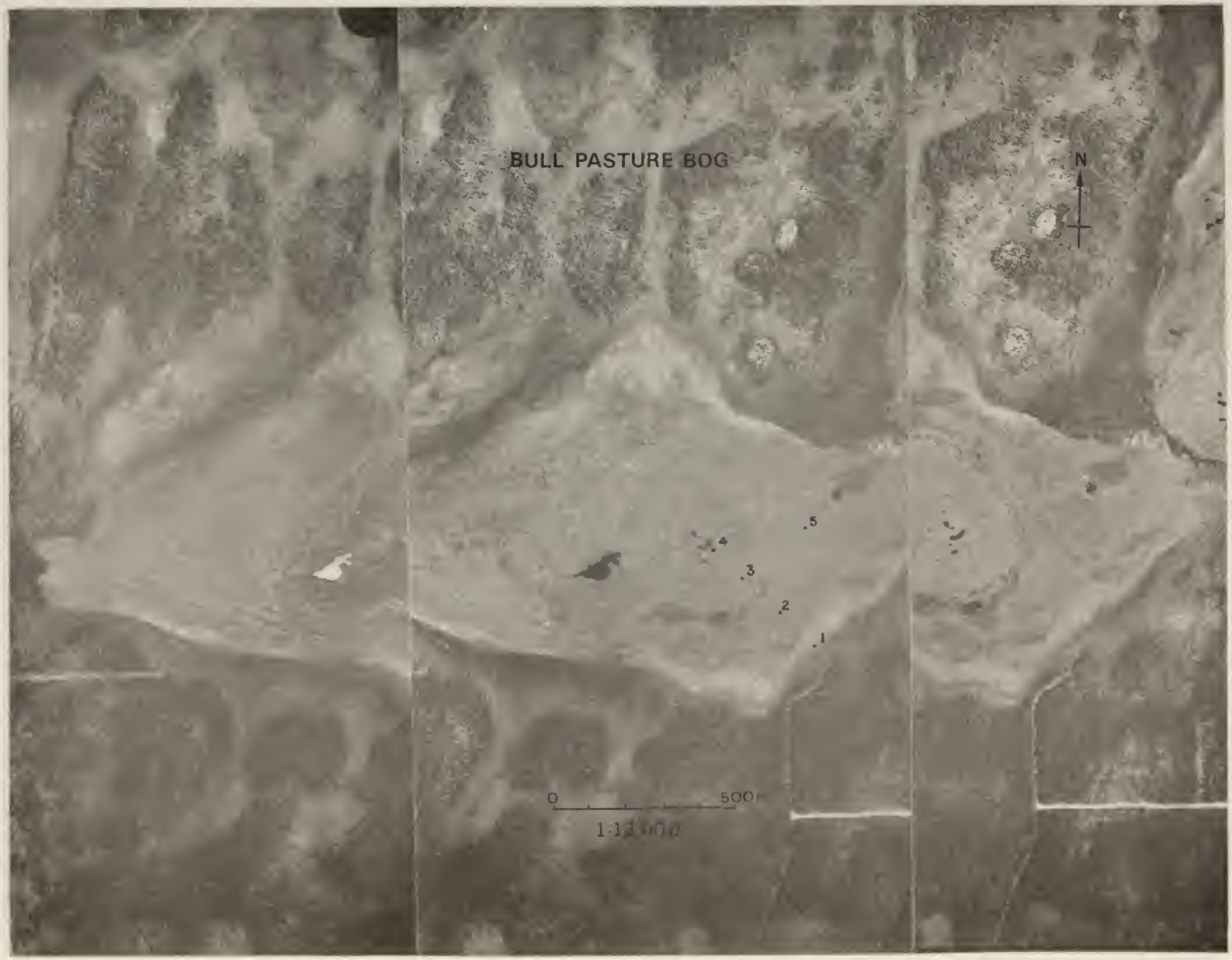

BULL PASTURE BOG
N
5
4
3
2
1
0
500

Figure 3. Benton, shown on the aerial photo stereopair below, is a stream fen transitional to Atlantic plateau bog. It is associated with the fluvial flood plains along the Pocowagamis Brook, situated in the rolling landscapes of western New Brunswick. Peatland development has progressed beyond the fen stage in that part of the deposit is no longer influenced by mineral-rich waters as is evidenced by the formation of the bog component of the peatland. The fen portion, now restricted to areas adjacent to the stream, (sites 400 and 500), consists of 1 to 2 meters of mesic and humic sedge peats over a relatively thick, approximately 1 meter, basal layer of sedimentary peat. Sites 800 and 900 are typical of the area classed as bog-here, a surficial layer or capping of sphagnum peat overlies the fen profile. Surface vegetation reflects the change in trophy level. Sedges and willows on the fen grade into alders, then wire birch and larch, and finally into the treeless sphagnum moss-low Ericaceous shrub complex of the plateau bog.

BENTON FEN (trans.)
N
•900
•800
•700
•600
•500
•400

Workshop participants received two sets of aerial photographs-one for each peatland. The set for Bull Pasture provided aerial coverage at scales of 1:12,000, 1:35,000, and 1:63,360. Aerial coverage for Benton was provided at scales of 1:15,840 and 1:35,000. Site positions were indicated on the largest scale photography.

During the photo interpretation exercise the peatlands were examined stereoscopically and the peat landforms, soil, vegetation and drainage were identified. Different scales of aerial photography were used to demonstrate that the level of interpretive information generated from photo-patterns on aerial photography is heavily dependent upon scale. The peatlands were also examined along the selected transects. Cross-sections were drawn and landforms, peat materials, and vegetation interpreted.

The mapping and legend construction exercise consisted of mapping the organic soils at two different scales. Soil legends were constructed for each scale indicating peat landforms, peat materials, soils and vegetation. (Reference: The technique of mapping organic soils, pages 57-68 of : Proceedings of a Workshop on Organic Soil Mapping and Interpretation in Newfoundland).

During the field trips each peatland was visited and the results of the photo interpretation exercises were verified with ground truthing.

The first day afield was spent at Bull Pasture. Organic soil sampling techniques and different site description formats were demonstrated, followed by a discussion on organic soil water sampling procedures. Workshop participants then formed six to seven member groups to carry out exercises along the transect. The following peatland components were investigated.

1. peat landforms and associated photo-patterns
2. identification of vegetation and associated photo-patterns
3. identification of peat materials and plant remains at various stages of decomposition
4. determination of fiber content and von Post
5. description of organic soil profile

Each group was given the morphological description and physical and chemical analyses for one site and required to collect field descriptions and data for the remaining sites. Interpretations for agriculture, fuel peat, and horticultural peat were considered and utilization-management plans were proposed and discussed.

On the second day similar transect exercises were performed at the Benton sites.

A special note of appreciation is extended to the N.B. Department of Natural Resources' Peatland Inventory Section for their assistance with field exercises and aid in pre-workshop site sampling.

TABLE 1. Bull Pasture Site No. 1: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 46° 02' 12"; long. 66° 19' 28"

ELEVATION: 108m AMSL

SLOPE: 0%

MICRO TOPOGRAPHY: Level

DRAINAGE: Very Poor

CSS CLASSIFICATION: Terric Mesic Fibrisol

VEGETATION:[a] Sphagnum, leatherleaf, kalmia, sedges, few scattered dwarf larch and black spruce

Morphological Description

Horizon	Depth (CM)	Color - Matrix: Natural Wet	Color - Matrix: Pressed Mst	Peat Type %[b]: S	C	N	L	Er	SH	von Post	Horizon Boundary	Remarks
Of1	0-20	7.5 YR 5.5/8	7.5 YR 7/5	0						2	clear	
Of2	20-30	10 YR 5.5/6	10 YR 6/5	0					*	2	clear	
Of3	30-50	10 YR 4.5/6	10 YR 6/6	0		*		*	*	3	clear	
Om1	50-70	7.5 YR 4/4	10 YR 3/4	3	6	1			*	3	gradual	
Om2	70-80	7.5 YR 3/3	7.5 YR 4/3	3	6	1			*	4	abrupt	
C	80+	Fine loamy glacial till										

Physical and Chemical Analyses[c]

Horizon	Depth	PH: H20	PH: CaCl2	%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content: Unrbd	% Fiber Content: Rbd	Exchangeable Cations: Ca	Mg	K	Al	CEC ME/100g
Of1	0-20	3.76	3.06	29.38	0.61	2.7	1.28	0.019	96+	96	7.29	4.17	2.36		124
Of2	20-30	3.75	2.93	35.33	0.59	4.1	1.42	0.019	94	90	5.27	3.63	0.96	5.30	102
Of3	30-50	3.82	3.06	36.48	1.28	14.6	3.47	0.034	88	52	4.10	2.37	0.46	9.66	114
Om1	50-70	3.95	3.21	38.02	1.49	26.0	3.70	0.047	70	32	2.51	1.70	0.72	15.67	130
Om2	70-80	4.10	3.32	37.25	1.63	45.6	7.18	0.039	36	16	2.51	1.73	0.38	16.99	134
C	80+	4.19	3.53	14.59	0.46	34.7	70.60		44	16	2.24	1.36	0.40	19.99	

Footnotes on page following Table 11.

TABLE 2. Bull Pasture Site No. 2: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 46° 02' 15"; long. 66° 19' 34"

DRAINAGE: Very Poor

ELEVATION: 108m AMSL

CSS CLASSIFICATION: Mesic Fibrisol

SLOPE: 0%

VEGETATION:[a] Sphagnum, leatherleaf, sedges

MICRO TOPOGRAPHY: Slightly mounded

Morphological Description

Horizon	Depth (CM)	Color - Matrix: Natural Wet	Color - Matrix: Pressed Mst	Peat Type %[b]: S	C	N	L	Er	SH	von Post	Horizon Boundary	Remarks
Of1	0-50	5 YR 4/4	7.5 YR 6/6	0						2	gradual	
Of2	50-130	7.5 YR 4/4	7.5 YR 4.5/6	0		*				3	gradual	
Om1	130-180	7.5 YR 3/3	7.5 YR 3.5/3	9		1				4	gradual	
Om2	180-240	7.5 YR 3/3	7.5 YR 3/3	4	2			4	*	3-4	clear	
Oco	240-250	2.5 Y 3/2	2.5 Y 3/2								clear	
C	250+	Fine loamy glacial till										

Physical and Chemical Analyses[c)]

Horizon	Depth	PH: H20	PH: CaCl2	%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content: Unrbd	% Fiber Content: Rbd	Exchangeable Cations: Ca	Mg	K	Al	CEC ME/100g
Of1	0-50	3.57	2.80	28.80	0.58	4.9	1.2	0.023	96+	96+	4.94	3.16	0.50	4.67	114
Of2	50-130	3.94	2.95	38.59	0.80	6.8	0.7	0.039	76	64	6.30	3.92	0.43	3.67	130
Om1	130-180	3.91	3.20	42.24	1.34	11.9	1.1	0.038	68	36	6.15	3.85	0.42	3.67	126
Om2	180-240	4.16	3.36	38.78	1.28	25.6	3.3	0.050	52	28	6.21	1.48	0.38	13.99	122
Oco	240-250	4.54	3.78	18.05	0.54	58.5	57.8	0.197	34	8	6.30	1.46	0.42	17.66	106

Footnotes on page following Table 11.

TABLE 3. Bull Pasture Site No. 3: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 46° 02' 18"; long. 66° 19' 38"

DRAINAGE: Poor

ELEVATION: 108m AMSL

CSS CLASSIFICATION: Typic Fibrisol

SLOPE: 2%

VEGETATION:[a] Sphagnum, leatherleaf, labrador tea, dwarf black spruce, reindeer moss, very few scattered stunted white pine.

MICRO TOPOGRAPHY: Strongly mounded

Morphological Description

Horizon	Depth (CM)	Color - Matrix Natural Wet	Pressed Mst	Peat Type %[b] S	C	N	L	Er	SH	von Post	Horizon Boundary	Remarks
Of1	0-140	5 YR 3.5/4	7.5 YR 5/6	0						3	abrupt	charcoal
Of2	140-180	5 YR 3/3	5 YR 3/2	0		*		*		5	gradual	layer
Om1	180-200	5 YR 3/3	5 YR3/2	0		*				4	clear	at 75 cm
Of3	200-255	5 YR 3/4	7.5 YR 4/4	0		*				3	clear	
Of4	255-270	7.5 YR 3/4	7.5YR 3/2	7				3		6	gradual	Lense
Om2	270-290	7.5 YR 3/4	7.5 YR 3/2	7		1		2		6	clear	of Er
Om3	290-300	7.5 YR 4/4	10 YR 3/4	6	3			1		6	clear	at 120
Om4	300-310	10 YR 2/1.5	10 YR 2/2	9	1					6	gradual	cm
Oh1	310-350	10 YR 2.5/1	10 YR 2/2								abrupt	
C	350+	fine loamy glacial till										

Physical and Chemical Analyses[c]

Horizon	Depth	PH H20	PH CaCl2	%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content Unrbd	% Fiber Content Rbd	Exchangeable Cations Ca	Mg	K	Al	CEC ME/100g
Of1	0-140	3.76	2.83	38.4	0.58	7.4	0.8	0.062	82	64	5.97	4.19	0.57		150
Of2	140-180	3.88	2.96	43.0	0.98	11.9	1.0	0.087	70	48	8.90	4.19	0.48		147
Om1	180-200	3.94	3.05	43.78	0.80	10.2	2.2	0.078	68	34	13.58	4.66	0.48		160
Of3	200-255	3.84	3.07	40.11	0.61	7.6	2.0	0.070	74	58	13.89	3.95	0.51		152
Of4	255-270	4.10	3.15	39.73	0.86	14.0	1.2	0.095	80	48	13.89	2.71	0.45		136
Om2	270-290	4.10	3.23	38.58	0.96	16.1	1.4	0.092	68	34	14.27	2.17	0.38		110
Om3	290-300	4.20	3.37	42.62	1.34	16.1	1.3	0.103	72	36	13.31	2.46	0.38		100
Om4	300-310	4.25	3.50	44.54	1.28	38.7	3.4	0.138	36	10	13.92	1.60	0.42		128
Oh1	310-350	4.63	3.75	46.03	1.23	170.0	6.5	0.191	30	LT6	11.21	1.48	0.36		138

Footnotes on page following Table 11.

TABLE 4. Bull Pasture Site No. 4: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 46° 02' 21"; long. 66° 19' 44"

DRAINAGE: Poor

ELEVATION: 109m AMSL

CSS CLASSIFICATION: Typic Fibrisol

SLOPE: 0.5%

VEGETATION:[a] Sphagnum, leatherleaf, dwarf black spruce, kalmia, reindeer moss, very few scattered stunted white pine

MICRO TOPOGRAPHY: Strongly mounded

Morphological Description

Horizon	Depth (CM)	Color - Matrix		Peat Type %[b]						von Post	Horizon Boundary	Remarks
		Natural Wet	Pressed Mst	S	C	N	L	Er	SH			
Of1	0-70	7.5 YR 3/4	10 YR 3.5/4	0						3	gradual	charcoal
Of2	70-110	5 YR 3.5/4	7.5 YR 4.5/4	0						3	abrupt	Layers
Of3	110-140	5 YR 3.5/2.5	7.5 YR 4/4	0						3	gradual	at:
Om1	140-150	10 YR 2.5/2	10 YR 3/4	0		*				3	abrupt	230,
Om2	150-160	5 YR 3/4	7.5 YR 4/4	0		*				4	abrupt	240,
Of4	160-210	7.5 YR 3/4	7.5 YR 4/4	0		*				3	abrupt	260,
Of5	210-220	5 YR 3/3	7.5 YR 3/4	9		1				4	abrupt	300
Of6	220-320	5 YR 3/4	5 YR 3/5	0						3-4	clear	cm
Om3	320-350	7.5 YR4/6	10 YR 3/6	8		1		1		4	gradual	
Om4	350-370	10 YR 3/4	10 YR 3/3	8		1		1		4-5	clear	
Om5	370-420	10 YR 2/2	10 YR 2.5/2	0			*			6	gradual	
Om6	420-430	10 YR 2/2	10 YR 2/1.5	8	2					6	clear	
Om7	430-440	10 YR 2/3	10 YR 2/2	7	3					6	gradual	
Om8	440-470	7.5 YR 3/4	10 YR 3/4	4	5	1				5	gradual	
Of7	470-490	5 YR 3/4	5 YR 3/3	1	7	2				4	clear	
Oco	490-510	10 YR 3/2.5	10 YR 3/2								abrupt	
C	510+	fine loamy glacial till										

Physical and Chemical Analyses[c)]

Horizon	Depth	PH H2O	PH CaCl2	%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content Unrbd	% Fiber Content Rbd	Exchangeable Cations Ca	Mg	K	Al	CEC ME/100g
Of1	0-70	3.79	2.62	38.01	0.64	7.6	0.4	0.070	86	72	3.47	4.19	0.68		138
Of2	70-110	3.75	2.72	38.20	0.45	6.3	0.3	0.059	86	70	4.11	3.73	0.45		144
Of3	110-140	3.85	2.80	33.81	0.46	4.9	0.3	0.057	72	62	4.95	3.68	0.47		136
Om1	140-150	3.88	2.80	38.20	0.70	6.0	0.5	0.073	68	30	4.41	4.19	0.48		134
Om2	150-160	3.82	2.71	45.08	0.77	9.2	0.5	0.073	66	38	3.98	4.19	0.50		130
Of4	160-210	3.75	2.86	43.93	0.51	5.8	0.4	0.060	88	74	4.32	4.44	0.46		134
Of5	210-220	3.90	2.80	47.18	0.74	10.8	0.5	0.076	66	47	5.87	4.44	0.48		134
Of6	220-320	4.01	2.95	38.20	0.58	9.2	0.8	0.064	78	60	8.16	4.44	0.44		134
Om3	320-350	4.18	3.33	42.98	0.80	12.8	1.6	0.059	68	38	14.24	2.46	0.38		128
Om4	350-370	4.21	3.36	44.31	1.30	29.2	1.9	0.056	64	30	16.77	2.46	0.39		126
Om5	370-420	4.33	3.43	49.04	1.25	74.5	2.7	0.108	54	18	14.73	1.78	0.39		140
Om6	420-430	4.40	3.56	49.61	1.28	71.0	4.1	0.127	54	16	17.73	1.78	0.38	7.99	153
Om7	430-440	4.50	3.67	42.93	1.44	47.5	4.2	0.132	62	22	19.20	1.83	0.40	5.67	142
Om8	440-470	4.50	3.70	43.50	1.41	29.2	3.4	0.104	62	18	21.47	1.95	0.38	4.67	134
Of7	470-490	4.50	3.72	42.74	1.28	19.7	2.8	0.089	70	46	19.11	2.02	0.42	3.99	122
Oco	490-510	4.52	3.92	31.48	1.62	6.0	29.9	0.095	58	24	14.63	1.78	0.42	4.67	102

Footnotes on page following Table 11.

TABLE 5. Bull Pasture Site No. 5: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 46° 02' 22"; long. 66° 19' 30"

DRAINAGE: Very Poor

ELEVATION: 108m AMSL

CSS CLASSIFICATION: Typic Fibrisol

SLOPE: 0.5%

VEGETATION:[a] Sphagnum, leatherleaf, sedges

MICRO TOPOGRAPHY: Slightly mounded

Morphological Description

Horizon	Depth (CM)	Color - Matrix Natural Wet	Pressed Mst	Peat Type %[b] S	C	N	L	Er	SH	von Post	Horizon Boundary	Remarks
Of1	0-50	7.5 YR 4/5	10 YR 6/5	0						2	clear	charcoal
Of2	50-170	7.5 YR 3/4	10 YR 3.5/4	0						3	clear	Layer
Of3	170-180	5 YR 3/4	7.5 YR 3/4	2	8				*	3	clear	at
Om1	180-220			3	7				*	3	abrupt	245 cm
Oh1	220-230	2.5 Y 3.5/2	2.5 Y 3/2	7	3					7	clear	
Om2	230-250	10 YR 3/2.5	10 YR 3/2	9	1					5	abrupt	
Oh2	250-280	2.5 Y 2.5/2	2.5 Y 3/2								abrupt	
C	280+	fine loamy glacial till										

Physical and Chemical Analyses[c]

Horizon	Depth	PH H2O	PH CaCl2	%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content Unrbd	Rbd	Exchangeable Cations Ca	Mg	K	Al	CEC ME/100g
Of1	0-50	3.60	2.86	30.72	0.07	8.1	2.4	0.040	90	80	6.06	3.45	0.59		110
Of2	50-170	3.98	3.03	29.96	0.93	13.1	1.1	0.036	70	50	7.83	4.05	0.59		98
Of3	170-180	4.13	3.16	43.31	1.10	13.8	1.3	0.051	76	46	11.81	2.64	0.46		104
Om1	180-220	4.23	3.29	37.20	1.50	39.8	1.8	0.051	62	36	9.94	2.10	0.36		94
Oh1	220-230	4.34	3.50	42.36	1.41	35.7	3.7	0.090	30	LT6	13.71	1.85	0.35	4.99	124
Om2	230-250	4.51	3.68	30.91	1.18	100.0	3.2	0.096	66	30	14.28	1.73	0.33	3.67	95
Oh2	250-280	4.98	4.15	36.06	0.93	116.0	7.5	0.132	40	8	21.83	2.34	0.38		102

Footnotes on page following Table 11.

TABLE 6. Benton Site No. 400: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 45° 59' 00"; long. 67° 37' 10"

DRAINAGE: Very Poor

ELEVATION: 119.6m AMSL

CSS CLASSIFICATION: Cumulo Mesisol

SLOPE: 0%

VEGETATION:[a] Sedges, willows

MICRO TOPOGRAPHY: Level

Morphological Description

Horizon	Depth (CM)	Color - Matrix: Natural Wet	Color - Matrix: Pressed Mst	Peat Type %[b]: S	C	N	L	Er	SH	von Post	Horizon Boundary	Remarks
Of1	0-30	10 YR 3/3	10 YR 3.5/4		0					2	clear	
Om1	30-40	10 YR 3/2	10 YR 2.5/2		9	1				7	abrupt	
C	40-60	2.5 Y 5/2									abrupt	SiCL
Om2	60-80	10 YR 2/1.5	10 YR 2/1.5	2	7	1				7	gradual	
Om3	80-170	7.5 YR 2/2	7.5 YR 2/1		9	1				6	gradual	
Oco1	170-180	10 YR 3/2	10 YR 2.5/2								clear	
Oco2	180-240	2.5 Y 3/2	2.5 Y 3/2								gradual	
C	240+	fine loamy alluvium										

Physical and Chemical Analyses[c]

Horizon	Depth	PH: H2O	PH: CaCl2	%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content: Unrbd	Rbd	Exchangeable Cations: Ca	Mg	K	Al	CEC ME/100g
Of1	0-30	5.14	4.66	34.06	1.66	9.5	20.9		84	54	26.67	4.07	1.12		92
Om1	30-40	5.32	4.80	20.04	1.42	24.8	58.6		48	22	29.45	3.21	0.47		96
C	40-60	5.55	4.90	7.20	0.47	14.3	83.2				14.67	2.10	0.44		
Om2	60-80	5.50	5.04	41.26	1.95	66.8	17.3		58	14	66.08	5.67	0.38		156
Om3	80-170	5.57	5.16	38.92	1.78	27.6	13.3		64	24	59.78	5.30	0.38		140
Oco1	170-180	5.51	5.33	21.21	1.73	10.6	35.1		68	16	37.73	3.95	0.44		87
Oco2	180-240	4.96		22.65	1.87	4.1	37.9			LT6	35.93	4.07	0.49		81

Footnotes on page following Table 11.

TABLE 7. Benton Site No. 500: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 45° 59' 04"; long. 67° 37' 10"

DRAINAGE: Very Poor

ELEVATION: 119.6m AMSL

CSS CLASSIFICATION: Limno Humisol

SLOPE: 0%

VEGETATION:[a] Sedges, willows

MICRO TOPOGRAPHY: Level

Morphological Description

Horizon	Depth (CM)	Color - Matrix: Natural Wet	Color - Matrix: Pressed Mst	Peat Type %[b]: S	C	N	L	Er	SH	von Post	Horizon Boundary	Remarks
Om1	0-20	10 YR 3/4	10 YR 4/4		0					2	gradual	
Om2	20-50	10 YR 2/2	10 YR 2/2		0					6	gradual	
Oh1	50-140	10 YR 2.5/2	10 YR 2.5/2		9	1				7	gradual	
Oco	140-200	2.5 Y 3/2	2.5 Y 3/2								gradual	
C	200+	fine loamy alluvium										

Physical and Chemical Analyses[c]

Horizon	Depth	PH: H20	PH: CaCl2	%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content: Unrbd	% Fiber Content: Rbd	Exchangeable Cations: Ca	Mg	K	Al	CEC ME/ 100g
Om1	0-20	4.96	4.48	35.82	1.84	9.5	14.4	0.037	70	36	26.63	4.69	1.36		89
Om2	20-50	5.60	5.09	38.14	1.98	67.8	23.4	0.150	48	14	58.13	6.02	0.42		139
Oh1	50-140	5.64	5.22	33.69	1.95	36.7	17.2	0.141	62	6	67.42	4.81	0.40		144
Oco	140-200	5.25	5.10	25.56	1.87	4.1	44.4	0.097			35.92	3.75	0.45		80

Footnotes on page following Table 11.

TABLE 8. Benton Site No. 600: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 45° 59' 07"; long. 67° 37' 10"

ELEVATION: 120.1m AMSL

SLOPE: 0.5%

MICRO TOPOGRAPHY: Level

DRAINAGE: Very Poor

CSS CLASSIFICATION: Typic Mesisol

VEGETATION:[a] Sphagnum, myrica gale, sedges, speckled alders

Morphological Description

Horizon	Depth (CM)	Color - Matrix		Peat Type %[b]						von Post	Horizon Boundary	Remarks
		Natural Wet	Pressed Mst	S	C	N	L	Er	SH			
Of1	0-10	10 YR 4.5/4	10 YR 6/4	9		1				2	clear	
Om1	10-70	7.5 YR 2/2	7.5 YR 2/2	8			2			6	gradual	
Om2	70-100	10 YR 2.5/2	10 YR 2.5/2		9	1				8	gradual	
Om3	100-180	10 YR 2/2	10 YR 2/2		8	2				6	gradual	
Oco	180-230	2.5 Y 3/2	2.5 Y 3/2								gradual	
C	230+	fine loamy alluvium										

Physical and Chemical Analyses[c]

Horizon	Depth	PH		%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content		Exchangeable Cations				CEC ME/100g
		H2O	CaCl2						Unrbd	Rbd	Ca	Mg	K	Al	
Of1	0-10	5.31	4.65	35.82	1.96	7.9	6.9	0.034	78	54	47.18	8.83	2.15		120
Om1	10-70	4.88	4.13	48.40	1.38	71.0	6.3	0.174	44	12	57.00	6.91	0.44		186
Om2	70-100	5.28	4.85	49.37	2.40	35.1	10.1	0.134	60	14	52.50	5.28	0.38		140
Om3	100-180	5.86	5.31	34.85	1.87	24.8	37.9	0.102	68	32	60.38	4.59	0.38		130
Oco	180-230	4.72	4.61	26.52	1.92	4.6		0.105		18	39.98	3.70	0.45		79

Footnotes on page following Table 11.

TABLE 9. Benton Site No. 700: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 45° 59' 10"; long. 67° 37' 10"

DRAINAGE: Very Poor

ELEVATION: 120.4m AMSL

CSS CLASSIFICATION: Mesic Humisol

SLOPE: 0.5%

VEGETATION:[a] Sphagnum, myrica gale, scattered stunted wire birch and larch

MICRO TOPOGRAPHY: Level

Morphological Description

Horizon	Depth (CM)	Color - Matrix: Natural Wet	Color - Matrix: Pressed Mst	Peat Type %[b]: S	C	N	L	Er	SH	von Post	Horizon Boundary	Remarks
Of1	0-20	10 YR 4/4	10 YR 5.5/4	0						2	gradual	
Om1	20-40	10 YR 2/1.5	10 YR 2/1.5	9		1				8	gradual	
Oh1	40-110	7.5 YR 2/2	10 YR 2/2	8			2			8	gradual	
Om2	110-180	10 YR 2.5/2.5	10 YR 2/2		9	1				6	gradual	
Oco	180-250	2.5 Y 3/2	2.5 Y 3/2									
C	250+	fine loamy alluvium										

Physical and Chemical Analyses[c]

Horizon	Depth	PH: H20	PH: CaCl2	%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content: Unrbd	% Fiber Content: Rbd	Exchangeable Cations: Ca	Mg	K	Al	CEC ME/100g
Of1	0-20	4.44	3.58	38.33	1.44	5.3	4.9	0.025	82	70	31.88	6.00	1.14		130
Om1	20-40	4.30	3.65	45.69	1.41	87.0	5.8	0.140	56	20	41.85	4.74	0.48		178
Oh1	40-110	4.38	3.72	39.88	1.25	72.1	4.0	0.131	48	6	37.73	4.81	0.35		162
Om2	110-180	5.52	4.96	40.66	2.02	24.8	8.4	0.111	44	16	52.05	3.45	0.40		140
Oco	180-250	5.10	4.93	25.36	2.00	8.6	37.7	0.084	78	22	41.18	3.45	0.45		86

Footnotes on page following Table 11.

TABLE 10. Benton Site No. 800: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 45° 59' 14"; long. 67° 37' 10"

ELEVATION: 120.8m AMSL

SLOPE: 0.5%

MICRO TOPOGRAPHY: Strongly mounded

DRAINAGE: Poor

CSS CLASSIFICATION: Humic Mesisol

VEGETATION:[a] Sphagnum, leatherleaf, bog rosemary, kalmia, rhodora, some scattered dwarf wire birch and larch

Morphological Description

Horizon	Depth (CM)	Color - Matrix		Peat Type %[b]						von Post	Horizon Boundary	Remarks
		Natural Wet	Pressed Mst	S	C	N	L	Er	SH			
Of1	0-20	5 YR 3/4	7.5 YR 4/4	9		1				2	gradual	
Om1	20-50	7.5 YR 2/2	10 YR 2/1.5	8	1	1				5	gradual	
Oh1	50-80	7.5 YR 2/2	7.5 YR 2/2	9		1				8	gradual	
Om2	80-100	7.5 YR 2/2	7.5 YR 2/2	8		2				6	clear	
Om3	100-210	10 YR 3/2.5	10 YR 2/2.5		9	1				6	gradual	
Oco1	210-240	10 YR 3/2	10 YR 2.5/2								clear	
Oco2	240-270	2.5 Y 3/2	2.5 Y 3/2								clear	
C	270+	fine loamy alluvium										

Physical and Chemical Analyses[c]

Horizon	Depth	PH		%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content		Exchangeable Cations				CEC ME/ 100g
		H2O	CaCl2						Unrbd	Rbd	Ca	Mg	K	Al	
Of1	0-20	4.08	3.38	36.98	0.88	5.6	2.52	0.032	94	88	21.71	4.59	1.78		119
Om1	20-50	4.32	3.71	44.30	1.22	77.0	3.81	0.140	62	24	43.50	5.67	0.36		177
Oh1	50-80	4.25	3.63	57.97	1.22	130.0	3.64	0.131	48	8	37.73	5.43	0.42		186
Om2	80-100	4.20	3.60	50.65	1.31	45.6	2.73	0.131	60	14	34.80	4.56	0.42		170
Om3	100-210	5.27	4.75	36.59	2.11	25.2	15.0	0.107	66	18	49.50	3.23	0.45		138
Oco1	210-240	5.24		33.71	2.16	12.5	30.1	0.092	66	16	45.90	2.84	0.42		104
Oco2	240-270	4.86		29.28	2.15	4.6	38.3	0.099	86	12	36.95	3.33	0.45		80

Footnotes on page following Table 11.

TABLE 11. Benton Site No. 900: Morphological Description and Physical and Chemical Analyses

LOCATION: Lat. 45° 59' 17"; long. 67° 37' 10"

DRAINAGE: Poor

ELEVATION: 120.9m AMSL

CSS CLASSIFICATION: Humic Mesisol

SLOPE: 0.5%

VEGETATION:[a] Sphagnum, leatherleaf, sedges, kalmia, rhodora, very few scattered dwarf wire birch

MICRO TOPOGRAPHY: Severely mounded

Morphological Description

Horizon	Depth (CM)	Color - Matrix: Natural Wet	Color - Matrix: Pressed Mst	Peat Type %[b]: S	C	N	L	Er	SH	von Post	Horizon Boundary	Remarks
Of1	0-10	7.5 YR 3/3	10 YR 3/2.5	9		1				3	gradual	
Om1	10-70	10 YR 2/2	10 YR 2/1.5	8	1	1				7	gradual	
Oh1	70-100	7.5 YR 2/2	10 YR 2/1.5	3	6	1	1			6	gradual	
Om2	100-180	10 YR 3/3.5	10 YR 3/2.5	*	8	2				4	gradual	
Oco1	180-220	10 YR 3/4	10 YR 3/3								gradual	
Oco2	220-260	10 YR 3/2.5	10 YR 3/2								gradual	
Oco3	260-290	2.5 Y 3/2	2.5 Y 3/2								gradual	
C	290-300+	fine loamy alluvium										

Physical and Chemical Analyses[c]

Horizon	Depth	PH: H2O	PH: CaCl2	%C	%N	% Pyrophosphate sol.	% Ash	Bulk Density G/CM3	% Fiber Content: Unrbd	% Fiber Content: Rbd	Exchangeable Cations: Ca	Mg	K	Al	CEC ME/100g
Of1	0-10	4.11	3.25	36.98	0.88	3.9	3.14	0.075	96+	96+	20.04	5.21	1.61		142
Om1	10-70	4.23	3.58	50.08	1.22	52.3	3.11	0.113	40	12	35.25	5.50	0.42		170
Oh1	70-100	4.11	3.35	45.65	1.02	53.8	3.14	0.149	50	8	35.55	4.40	0.40		192
Om2	100-180	4.78	4.12	40.83	1.73	15.5	3.51	0.092	72	36	36.60	2.24	0.38		130
Oco1	180-220	5.56	5.02	33.71	1.90	21.5	30.9	0.105	58	22	46.80	2.34	0.42		122
Oco2	220-260	5.02		25.73	2.06	8.6	32.0	0.070	66	28	38.25	2.71	0.46		96
Oco3	260-290	5.30		31.30	2.17	10.0	36.0	0.094	80	12	43.58	2.59	0.61		98

Footnotes on page following Table 11.

Footnotes for Tables 1 - 11

a) Common and Scientific Names of the Flora

Common Name	Scientific Name
Black spruce	Picea mariana (Mill.) BSP.
Bog rosemary	Andromeda glaucophylla Link.
Kalmia	Kalmia spp.
Labrador tea	Ledum groenlandicum Oeder
Larch	Larix laricina (DuRoi) K.Koch
Leatherleaf	Chamaedaphne calyculata (L.) Moench
Myrica gale (sweet gale)	Myrica gale L.
Reindeer moss	Cladonia spp.
Rhodora	Rhododendron canadense (L.) Torr.
Sedges	Carex spp.
Speckled alder	Alnus rugosa (DuRoi) Spreng. var. americana (Regel) Fern.
Sphagnum	Sphagnum spp.
White pine	Pinus strobus L.
Willows	Salix spp.
Wire birch	Betula populifolia Marsh.

b) Peat Type %

Symbols	% Composition
S = Sphagnum	0 = 100%
C = Carex	9 = 90%
N = Nanolignidi = Shrubs	8 = 80%
L = Lignidi = Wood	etc.
Er = Eriophorum	* - indicates presence of species but in minor amounts
SH = Scheuchzeria	

Footnotes for Tables 1 - 11 cont'd

c) Methods of Physical and Chemical Analyses from The Manual on soil sampling and methods of analysis, Second Edition 1978.

ANALYSIS	PROCEDURE CODE
pH in water	3.13
pH in 0.01 M $CaCl_2$	3.11
Total carbon	3.611
Total nitrogen	3.622
Pyrophosphate - soluble O.M. index	3.615
% Ash	3.81
Bulk density	2.242
Unrubbed fiber content	2.81
Rubbed fiber content	2.82
Exchangeable cations	3.31
Cation exchange capacity	3.36

BULL PASTURE BOG
IMPACT STUDY - WATER QUALITY EFFECTS OF BOG DRAINAGE
INTERIM REPORT - BACKGROUND MONITORING

by
Environmental Services Branch, N. B. Department of the Environment

1.0 Background

Environment New Brunswick has had an interest in the management of all wetland resources for some time. It is generally felt that wetlands play a very important role in the maintenance of environmental quality in the Province. Efforts to develop management schemes for these resources have been hampered by a lack of specific information on the values and functions of our wetlands. This is especially true in the case of freshwater wetlands (bogs, swamps and freshwater marshes). The current pressure to develop bog areas for horticulture-related uses, fuels, and industrial products, has generated a high level of interest within this department in evaluating the importance of these areas in the natural environment, and in assessing the effects of peatland development and peat utilization. Several concerns have arisen based on our present knowledge of the natural functions of bogs, the techniques employed during harvesting and the use of peat for fuel or as a feedstock for industrial products.

The drainage of bogs prior to actual peat extraction involves the release of large amounts of water over a relatively short period of time. Under natural conditions, bog waters are usually neutralized by natural buffers, such as alkalai carbonates, present in receiving waters. However, when a bog is artificially drained, large quantities of acidic water will be introduced into waters which may or may not have sufficient buffering capacity to resist pH changes.

Additionally, bog waters may contain other chemicals that could adversely affect water quality. P and N compounds may contribute to the eutrophication of nutrient-limited receiving waters. Organic compounds such as polyphenolic humic acids may form complexes with nutrient inorganic ions thereby limiting uptake by aquatic plants. The dark color of water drained from bogs may result in reduced light penetration and hence the productivity of receiving water bodies could be affected. Questions of the potential release of heavy metals in bog drainage waters have been raised.

Currently, most bogs under production in the province are drained into the ocean, and the effects of bog drainage may be mitigated by the buffering capacity of sea water. Also, the volumes discharged are probably not significant except if they are being drained into an enclosed coastal lagoon system. However, the areas having the best potential for fuel peat are inland where the receiving bodies are generally freshwater. Many aquatic systems in the Province have limited buffering capacity, and the discharge of large volumes of bog waters could result in problems such as those described above. The sport and commercial fisheries are important provincial resources and any deterioration in the water quality of lakes, streams, and rivers could have a significant impact.

In order to more clearly identify the nature and degree of impacts associated with bog drainage, a water quality monitoring program was set up in 1979 on Bull Pasture Plain, a sphagnum bog near Fredericton. A portion of this bog will be drained in preparation for peat moss harvesting and subsequent agricultural crop production.

2.0 The Program

The monitoring program involves measuring several water quality parameters (Appendix I) for three streams receiving drainage from the general area (see attached map): Niles Brook is the main outflow from Bull Pasture Plain Bog. Rising from the easterly end of the bog, it flows approximately six miles to its confluence with Little River. The biological productivity of Niles Brook is very low, presumably due to its low pH. However, Little River is a productive salmonid river. Burpee Brook originates in the southwesterly corner of the bog and flows approximately three miles to its confluence with the Burpee Millstream; Burpee Millstream flows out of Burpee Lake, two miles northwest of Bull Pasture Plain Bog. It has a resident brook trout population.

In addition, water samples from the bog itself are analyzed. Early samples were obtained by collecting surface water; presently there are three suction soil water samplers which obtain samples from a depth of 1 metre. The sampling sites are noted on the attached map.

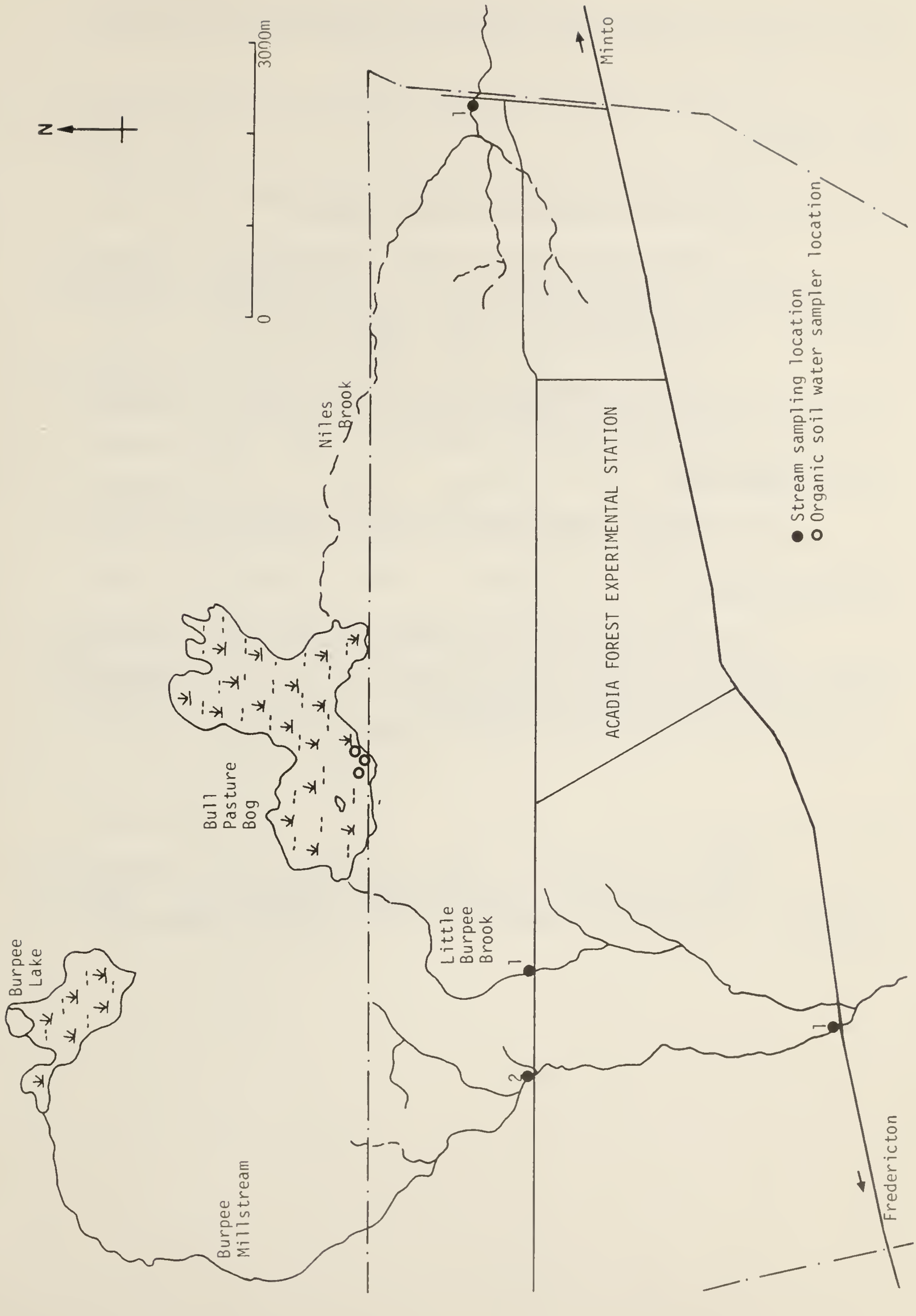
3.0 Results to date

Bog Water

Analysis of a single series of water samples taken from surface waters on the bog show the pH to be in the 3.7-4.4 range. The water is highly colored. Hardness values range from 1.2 to 4.1 mg/l; conductivity ranged from 18 to 42 microsiemens/cm., with little or no buffering capacity. Concentrations of analyzed heavy metals except mercury remained below detection limits. Mercury was detected at 4 of 7 sites on 10 July 79. However, in the absence of additional data such results cannot be considered to reflect actual conditions. Kjeldahl nitrogen levels were in the range of .7 to 1.1 mg/l. TOC levels (7.1 mg/l - 19.4 mg/l) reflect the presence of organic substances.

Niles Brook

Nineteen (19) water samples were collected between June 1979 and July 1981.


N
0
3000m
Minto
Niles Brook
Bull Pasture Bog
Burpee Lake
Little Burpee Brook
Burpee Millstream
ACADIA FOREST EXPERIMENTAL STATION
1
1
2
1
Fredericton
● Stream sampling location
○ Organic soil water sampler location

Results show Niles Brook to be acidic (pH range 4.3 to 6.3) and moderately coloured. Low conductivity (17-37 us/cm) and hardness (1.7-9.3 mg/l) values indicate very soft waters.

Nitrate-nitrite nitrogen (NO_x) concentrations were low for all sampling events, exceeding the detection limit of .01 mg/l on only two occasions.

Total Kjeldahl nitrogen concentrations ranged from .2 to 1.0 mg/l with an average concentration of .31 mg/l.

All heavy metals concentrations, except mercury, remained less than detectable. Mercury was detected in 4 of 19 samples at wide spread intervals. The inconsistent occurance of mercury indicates the four values are not representative of actual conditions.

The buffering capacity of Niles Brook is very low as reflected by total alkalinity values ranging from 0.0 to 9.3 mg/l. Sixty-eight percent of values ranged between 0 and 5.0 mg/l as Ca Co_3.

Little Burpee Brook

The waters of Little Burpee Brook are generally similar to those of Niles Brook.

Burpee Millstream

Burpee Millstream is being sampled at two points. At sampling point 2 (see map) the waters are similar to those of Little Burpee Brook. However, at Station 1, approximately 2 miles below Station 2, the waters show a marked increase in pH and alkalinity. This may be the result of groundwater contributions and water from small tributaries.

4.0 Future Work

Present plans call for sampling of streams on a quarterly basis. Sampling of bog waters will be carried out in September 1981. Sampling frequency is expected to increase with the initiation of development activities.

APPENDIX I: Sampling Parameters

ALKALINITY, total - ALKT - reported in mg/l as $CaCo_3$

ALUMINUM, extractable - AL-x - reported in mg/l

CADMIUM, extractable - CD-x - reported in mg/l

CARBON, total organic - TOC - reported in mg/l as C

COLOUR, APPARENT - CLRA - as Hazen colour units

COPPER, extractable - Cu-x - reported in mg/l

CONDUCTIVITY -COND - reported in microsiemens per cm.

HARDNESS, total - HARD - reported in mg/l as $CaCo_3$

IRON, extractable - FE-x - reported in mg/l

LEAD, extractable - Pb-x - reported in mg/l

MERCURY, extractable - Hg-x - reported in mg/l

NITROGEN, nitrate & nitrite - NO_x - reported in mg/l as N

NITROGEN, total Kjeldahl - TKN - reported in mg/l as N

pH - reported in pH units

PHOSPHATE, total - TPO_4 - reported in mg/l

SOLIDS, total dissolved - TDS - reported in mg/l

ZINC, extractable - ZN-x - reported in mg/l

APPENDIX II: Stream Sampling Data

N I L E S   B R O O K

DATE	pH	COND.	ALKT.	COLOR	HARD	TPO_4	TKN	NO_x	TOC	TDS
07 07 81	7.0	35	3.3	G70	4.2	.08	.3	L.01	18.0	40
03 06 81	4.8	29	2.9	G70	4.0	.03	.2	L.01	13.0	53
07 05 81	5.2	27	5.0	G70	4.2	.11	.3	L.01	10.8	60
15 04 81	5.0	27	4.1	60	3.4	.06	.3	L.01	7.45	14.5
13 03 81	5.5	25	6.3	60	4.3	.04	.2	L.01	7.1	35.0
12 11 80	4.8	35	1.3	G70	1.7	.03	.2	.11	816	54.0
04 10 80	5.9	30	3.5	70	1.6	.04	.3	L.01	14.5	L10.
10 09 80	5.3	18	2.6	G70	6	.05	.4	L.01	15.0	13.
07 08 80	4.9	22	5.4	150	4.9	.04	.6	L.01	19.4	-
02 07 80	5.2	23	4.3	120	7.1	.05	.6	L.01	16.0	78
18 06 80	5.8	18	4.8	70	7.1	.03	.5	L.01	12.8	50
04 06 80	5.8	21	9.2	70	5.4	.1	1.0	L.01	9.3	1.2
13 05 80	6.0	30	3.8	75	9.3	.04	.3	L.01	12.5	-
14 02 80	6.3	37	8.9	60	7.1	.03	.3	.11	--	-
15 01 80	5.5	24	3.9	60	5.7	--	--	.01	--	44.
30 10 79	5.5	27	4.6	100	5.5	--	--	L.01	--	46.
14 08 79	4.3	30	0.0	--	7.1	.11	.5	L.01	--	-
16 07 79	5.8	32	2.2	150	8.3	.13	.5	L.01	--	-
11 06 79	5.0	17	.54	130	8.7	.04	.4	L.01	15.0	-

L I T T L E   B U R P E E   B R O O K

07 07 80	4.8	20	1.9	150	5.2	.07	.7	L.01		
07 07 81	4.3	19	0	G70	2.5	.07	.6	L.01	29	

B U R P E E   M I L L S T R E A M - STATION 1 - RICHIBUCTO ROAD

07 07 80	6.5	19	7.6	100	6.6	.08	.5	L.01	-	
09 09 80	6.0	19	4.9	G70	6.4	.05	.3	L.01	-	
07 07 81	6.2	15	4.8	G70	4.1	.07	.3	L.01	11.0	

STATION 2

07 07 80	4.8	20	1.9	150	5.2	.07	.7	L.01	-	
07 09 80	4.6	23	1.6	G70	4.5	.07	.4	L.01	-	

List of Attendance

NAME	ADDRESS CODE
Anderson, Alexander	(18)
Boyd, Stephen	(15)
Carrier, Dominique	(21)
Chow, T. Lien	(1)
Coen, Gerald	(3)
Cossette, Jean-Marc	(10)
Day, John	(3)
Dinel, Henri	(3)
Doiron, Réjean	(15)
Ferguson, Don	(15)
Gautreau, Claudette	(4)
Guthrie, Ken	(16)
Hender, Frank	(5)
Henderson, Rod	(15)
Holland, Bob	(15)
Holmstrom, Delmar	(6)
Jones, R. Keith	(9)
Keys, David	(15)
Langille, Dave	(6)
Lévesque, Marcel	(3)
MacMillan, John	(13)
Mathur, Sukhdev	(3)
Michalica, Karel	(13)
Milburn, Paul	(12)
Millette, Jacques	(2)
Monti, Paul	(14)
Moon, David	(8)
Nowland, John	(3)
Rees, Herb	(4)
Schut, Larry	(19)
Shields, Jack	(3)
Sprague, Mike	(14)
Tarnocai, Charles	(3)
Thompson, Bob	(17)
Turchenek, Larry	(11)
van de Hulst, Jan	(16)
Veer, Conrad	(7)
Webb. Ken	(6)
Wilson, Floyd	(20)
Woodrow, Ed	(5)

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(15)	N.B. Dep.t of Natural Resources Mineral Resources Branch 830 Hanwell Road P.O.Box 6000 Fredericton, N.B. E3B 5H1

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